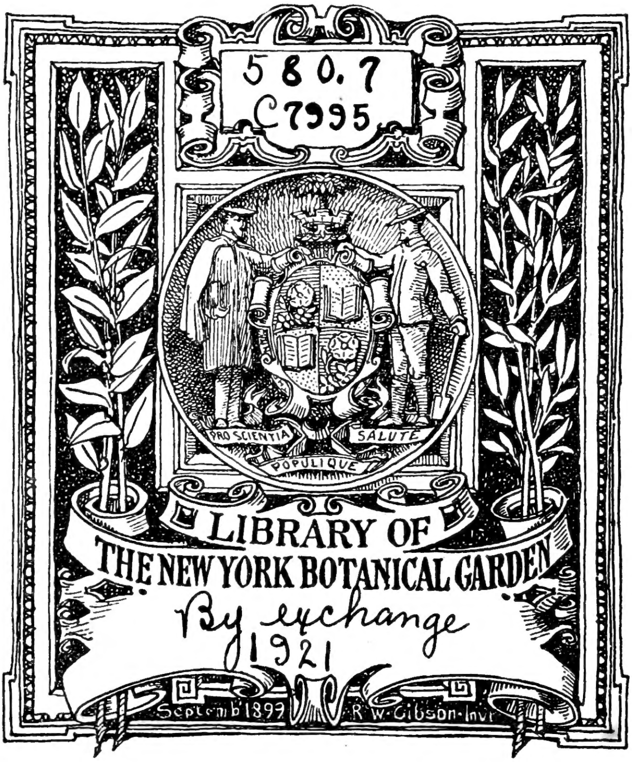
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# THE SECOND DANISH PAMIR EXPEDITION

CONDUCTED

BY

O. OLUFSEN
LIEUTENANT OF THE DANISH ARMY

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# STUDIES ON THE VEGETATION OF THE TRANSCASPIAN LOWLANDS

BY

OVE PAULSEN
MEMBER OF THE EXPEDITION

WITH 79 FIGURES AND A MAP

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PUBLISHED AT THE EXPENSE OF THE CHURCH- AND SCHOOL DEPARTMENT AND THE CARLSBERG FUND

COPENHAGEN
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# OVE PAULSEN

# STUDIES ON THE VEGETATION OF THE TRANSCASPIAN LOWLANDS

THIS paper has been published in Danish under the title «Træk af Vegetationen i Transkaspiens Lavland» (København 1911, Gyldendal), and in «Botanisk Tidsskrift«, Vol. 32. The present edition is issued with but slight alterations.

The translation has been revised and corrected by Dr. W. G. SMITH, of the College of Agriculture, Edinburgh, who has assisted also in proof-reading. I would offer Dr. SMITH my sincere thanks for his valuable assistance without which it would hardly have been possible to find correct English equivalents for Danish botanical terms.

A Russian edition is under preparation.

*The author.*

# CONTENTS.

# INTRODUCTION.

The second Danish Pamir Expedition initiated and conducted by Professor O. Olufsen, at that time lieutenant in the Danish army, left Copenhagen in March 1898. After an unavoidable delay at St. Petersburg the expedition proceeded by rail southwards through Russia, then by steamer across the Caspian and on the 23rd of April we, for the first time, set foot on Asiatic soil in Krasnowodsk.

The expedition spent a couple of months in the Transcaspian lowlands visiting Tshardshui, Buchara, Samarkand, Tashkent, Kokand, Andidshan and Osh, generally travelling by rail. In the middle of June we left Osh and went to Pamir, whence we returned in April 1899. The spring and summer of 1899 were passed in Ferghana and the Transcaspian lowlands, most of the time in Buchara and Chiwa. The journey to Chiwa was made by boat from Tshardshui down the Amu Darya (Oxus) and botanically this was one of the most interesting parts of the journey, as it afforded a good opportunity of studying the deserts of the river banks and the «Gallery forests.» The Chiwa journey lasted from the middle of June till the end of August when we returned to Tshardshui. Here I was fortunate enough to make the acquaintance of Mr. V. Palezkij, inspector of the plantations along the Transcaspian railroad, who with the greatest kindness showed me these plantations.

From Tshardshui we returned westward to the Caspian Sea. September and October were spent in Persia, whence the expedition returned, through Russia, to Copenhagen, where we arrived in November 1899.

The systematic part of the botanical results of this journey have been published from time to time as the examination of the separate families was completed.[1])

This memoir is the first part of the biological section of the botanical results of the expedition, and includes the vegetation of the lowlands.

As the expedition never remained long in one place, there was not much opportunity for thorough investigation of the desert in any locality, so that this memoir is the result of observations in many parts most of which were only examined for a short time. Physiognomy therefore occupies a prominent place in this description of a type of vegetation which in detail would constitute an extensive research. It is to be hoped that detailed investigations, such as those made at the desert laboratory in Tuczon (Arizona) or similar to FITTING's researches in the Sahara will also be made in the Transcaspian desert, so characteristic and worthy of careful examination.

[1]) These publications are located as follows: Videnskabelige Meddelelser fra den naturhistoriske Forening i Kbhvn. 1901 — Caryophyllaceae, Ranunculaceae; in the same periodical for 1903 — Cruciferae, Umbelliferae, Valerianaceae, Compositae, Gramineae, Potamogetonaceae, Chenopodiaceae; Botanisk Tidsskrift Vol. 26 — Pteridophyta, Gnetaceae, Cupressaceae, Lemnaceae, Typhaceae, Juncaginaceae, Alismaceae, Typhaceae, Juncaginaceae, Alismaceae, Liliaceae, Convallariaceae, Amaryllidaceae, Iridaceae, Juncaceae, Orchidaceae, Salicaceae, Cupuliferae, Urticaceae, Cannabaceae, Polygonaceae; in Botanisk Tidsskrift Vol. 27 — Amarantaceae, Phytolaccaceae, Berberidaceae, Ceratophyllaceae, Papaveraceae, Fumariaceae, Resedaceae, Violaceae, Frankeniaceae, Tamaricaceae, Euphorbiaceae, Oxalidaceae, Linaceae, Geraniaceae, Balsaminaceae, Malvaceae, Rutaceae, Zygophyllaceae. Polygalaceae, Ampelidaceae, Rhamnaceae, Thymelaeaceae, Elaeagnaceae, Saxifragaceae, Ribesiaceae, Hamamelidaceae, Rosaceae, Lythraceae, Oenotheraceae, Haloragidaceae, Myrtaceae, Loranthaceae, Primulaceae, Convolvulaceae, Solanaceae, Plantaginaceae, Bignoniaceae, Apocynaceae, Asclepiadaceae, Rubiaceae, Caprifoliaceae, Dipsacaceae, Scrophulariaceae, Borraginiaceae; Botanisk Tidsskrift Vol. 28 — Fungi, Cyperaceae, Labiatae; Bulletin de l'Herbier Boissier VI — Papilionaceae; Botanisk Tidsskrift Vol. 29 — Additions and Corrections.

# SECTION I. TRANSCASPIA AND ITS NATURAL CONDITIONS

## CHAPTER I

### Situation and Boundaries of the Region examined.

The great tract of lowlands, a southern extension of the West-Siberian plain, stretching from the Caspian Sea to the country round Lake Balchash, and having as its southern boundary the mountains of northern Persia, the Thianshan and Ala-tau and which is in open communication with the south of Russia, to the north-west, through the plains north of the Caspian Sea, cannot strictly be designated as belonging to those portions of the continent which are without drainage to the sea. The »Duab« or »country with two streams« traversed by the two great rivers Amu and Syr, both flowing into the Aral Sea, is of the type designated by Richthofen as a peripheral region, that is a region whose waters are carried by rivers to the sea, or to remnants of sea which are now lakes. Richthofen's Central Asia, on the contrary, includes the areas in the interior of Asia which are devoid of any drainage to the sea. Here the wind is the principal geological agent, and all the products of chemical or mechanical disintegration remain in the country; they are only moved from one place to another, filling up the hollows and thus imparting a monotonous aspect to the country. While, as Richthofen remarks, the movement in Central Asia is centripetal, it is centrifugal in the peripheral regions,

— here water is the principal agent as it continually carries away the products of erosion by the rivers.

As regards Turkestan[1]), Mushketow maintains, contrary to Richthofen, that this part is very similar to Central Asia proper. It is without drainage to the sea and the eolian or windborne deposits are the most important feature. The rivers in the lowlands have no effluence, and can therefore only be local agents in transportation. Moreover there is a very close geological affinity, deposits from the Cretaceous and Tertiary periods stretching, almost without interruption, from Hanhai into Turkestan, not only through the ravine of Dsungaria but also more to the south. Hanhai and Turkestan have been covered by the same Tertiary sea.

Mushketow therefore, for the present at any rate, rejects Richthofen's definition of Central Asia and designates as Asia-Media the regions that are without drainage to the open sea and amongst these Turkestan. (l. c. p. 11).

Turkestan or the Turkestanian Basin, called by Romanowski the Turanian Plain, is defined by Mushketow as follows: It stretches from the Mugodshar mountains and Usturt in the west to Tsungei Alatau, Thianshan and Pamir in the east, from Kopetdagh and the Chorassan mountains in the south, to Tarbagatai and Tjingistau in the north-east and in the north to the watershed between this area and the rivers running into the Irtish. (See the map appended to this memoir). The mountain range Karatau divides the area into two parts: the north-eastern Balchash Basin which is not dealt with here except as regards the distribution of plants, and the Aral Basin or the Turanian Basin proper.

This latter is the subject of the present contribution, but not to the full extent of the limits given above. In view of the botanical investigations, it is advisable to fix the northern boundary in this memoir at about 46 $^{0}$ N. Lat. This line passes through the northern part of the Aral Sea and thus cuts off the whole territory of the Kirghiz Steppe. The

[1]) Mushketow also discards East Turkestan as name of a geographical area on the ground that it belongs to the Central region of Àsia (L. c. p. 13).

northern part of this is a Stipa-steppe which I prefer to omit, as I have not seen it, and it does not occur farther south. The southern part is a desert in the sense employed in this memoir, (see chap. 5) with its northern boundary, according to TANFILJEW, (1903, pp. 386, 388) extending from the southern end of the Mugodshar Mts. to the town of Uralsk, and which, in a more or less changed form (the "Kalmyk Steppe") extends westwards to the foot of the Jergeni Mts.[1]) But this northern desert must be far less warm or less dry (perhaps both) than the deserts south of the Aral Sea. We are led to this conclusion because *Hippophaë rhamnoides, Salix repens, Koeleria glauca, Elymus arenarius, Populus tremula, Amygdalus nana, Rhamnus cathartica* and several other plants (see SAWITSH p. 224) occur here near their southern limit on the plain, although several of them *e. g. Hippophaë* and *Amygdalus* are again found in the mountains to the south (Compare BQRSZCZOW cited later p. 29, point 1,3) The list of plants given later (chap. 12) would convey a less striking picture of the character of the desert if these plants were included in it, and for this reason I have excluded the Kirghiz Steppe; moreover, as already stated, the expedition did not explore it.

What name then can be given to the territory, delineated as above, and whose vegetation is the subject of our memoir?

The area from the Caspian Sea and far into China is generally designated "Turkestan" and, even if in accordance with MUSHKETOW, we limit it to the lowlands west and north of the mountains, it will still include the Balchash Basin and the Kirghiz Steppe which we wish to exclude. The same

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[1]) According to BEKÉTOFF (1886) and PATSCHOSKIJ (1892) the Jergeni Mts. form the boundary between European and Asiatic vegetation, the former is the steppe of southern Russia, for the most part under cultivation, the latter is a desert, the «Aralocaspian steppe», as PATSCHOSKIJ terms it. According to RADDE (1899), the Jergeni forms the boundary between better humus soil (4—7 per ct.) towards the west and poor humus soil (under 2 per ct.) towards the east. Finally, according to WOEIKOFF (Hann III p. 194) the Jergeni Mts. coincide with part of the eastern limit of Russia's regular summer rains, which is evidently the cause underlying the contrast between vegetation and soils.

argument applies to the name "Turan" which covers MUSHKETOW's "Turkestan". The "Aral-Basin" would better designate our territory, but this name also includes the Kirghiz Steppe. The designation Transcaspian Plain or Lowlands or briefly Transcaspia has finally been selected as most appropriate. The same name has been used to indicate an administrative unit of the Russian empire, the government Transcaspia, which extended almost to the Amu Darya, to the borders of the vassal state of Buchara.

In thus designating my territory Transcaspia it should be emphasised that though to the east it stretches to Kara Tau, I do not use this name as defining a geographical area, but only as a name for a territory the borders of which I have determined myself, and which lies beyond the Caspian Sea.

## CHAPTER 2

### Features of the Geology of Transcaspia.

Turkestan and Central Asia are supposed to have been covered by the sea during the Cretaceous and Tertiary periods, and even on the mountains at a height of 11,000 feet, Tertiary deposits have been found (MUSHKETOW).

This sea receded from Hanhai earlier than from the plain of Turkestan, and of this country the eastern part was the first part to become dry. During the Miocene period the brackish Sarmatian inland sea connected the Aral, the Caspian and the Black Sea (KARPINSKI). At a later period, probably contemporaneous with the great Scandinavian glacial period and when there was much water from the melting ice, there existed a sea (the Aralo-Caspian Basin) which filled the depressions now occupied by the Caspian Sea and the Aral Sea, connecting them by a narrow straight (KARPINSKI, SJÖGREN).

Almost all the lowlands of Turkestan (95 per ct. according to MUSHKETOW) are thus covered with deposits from the Cretaceous and Tertiary periods. Through these, islands of older rocks emerge, for instance Tamdi-Tau, Bukan-Tau, Sultan Uis Dagh, now isolated mountainous masses consisting of various slates and crystalline rocks which as a result of greater denudation are now more cut up than the rocks of Thianshan.

The deposits from the Cretaceous and Tertiary periods are of great thickness, attaining 5000 feet in Ferghana for instance. They consist of diverse coloured strata of marl, limestone, ferruginous sandstones, gypsum, clay &c. They are not identical everywhere but change according to the nearness of the mountains: At the foot of the mountains, marginal deposits are found, such as shelly limestones, conglomerates, clay with gypsum and rock-salt, while, out on the flat land, sand and clay are found deposited in deeper water (Romanowski, Mushketow).

The Tertiary deposits, however, are rarely visible, as they are almost everywhere covered by newer deposits partly derived from them. Of these the most important are: the moving sands, the Aralo-Caspian deposits and the loess.

Deserts of moving sand cover, according to Rodsewitch, about 88 per ct. of the lowland. The sand is of varied origin. In the northern part it is derived from old Aralian sea-coast dunes and is white or grey. As this sand originates from the old Aralo-Caspian Basin, it has much the same distribution as the Aralo-Caspian deposits mentioned below.

Throughout the rest of the moving-sand territory, the dunes ("Barchans") are genuine inland deposits which owe their origin purely to the wind. The wind carries off everything available, all that mechanical disintegration provides for it. Thus the Aralian dunes, the Aralo-Caspian deposits and the older rocks contribute to the formation of the "Barchans". Illustrations of the effects of the levelling process will be found in Berg. — The Barchans are of a dirty yellow colour, they have the shape of a crescent, generally quite regular. The convex part faces the wind, the inclination of the surface is here 6—16°, while on the lee side it is 30—38° (Mushketow). The crest is a sharp and regular line, which from the highest point curves downwards and away from the wind. How the crescent shape is produced has been explained by Middendorff, Walther (p. 122) and Solger (p. 149). In contrast to the dunes of western Europe, the barchans do not owe their occurrence to the sand having at first found shelter behind some obstacle, but they take that form which offers least resistance to the wind, hence they must be regarded as gigantic wave-lines in the sand. Good pictures of barchans may be seen in Bessey.

Other forms of sand landscapes are dealt with in the chapter on the formation of the sand desert.

The Aralocaspian formations which originated in the post-pliocene Aralocaspian Basin consist of sandy clays deposited on the bottom of the basin. The area of the older sea was considerably larger than that of the present lakes; thus, its eastern part extended down both sides of the isolated mountains Bukan Tau and Sultan Uis Dagh so that these occupied a peninsula in the sea. As the sea dried up, many smaller lakes were left.

Loess, as is well known, is a calcareous loam intersected by innumerable irregular veins which often contain roots of plants. "Ein Leichenfeld von unzählbaren Generationen von Gräsern", as Richthofen puts it (I, p. 71). Loess is now generally regarded as an eolian deposit derived from dust-drift, since the finest material shifted by the wind — if not taken right away — must sooner or later come to rest either in water or on a fixed "steppe", because the wind would carry it away again from any other place (Richthofen I, p. 98). In the first case the material will go to form stratified deposits on the sea-bottom, in the latter it will form land-loess which is not stratified.

In Turkestan Loess may attain a great thickness, according to Romanowski up to 1500 feet. It occurs more especially in the south-eastern, southern and eastern parts of the territory, but also occurs in patches in other places (Mushketow).

Like all areas without drainage to the sea, the Transcaspian plains are rich in salts, since if the products of disintegration and chemical weathering cannot be taken out of the country, they must remain. Most of the Russian authors known to me are of opinion that the salts originate from the old sea as the result of evaporation. But I am rather of the opinion of ANIKIN that the salts are mainly due to the constantly continued chemical weathering.

Chlorides and sulphates occur most frequently both in the soil of the desert and in the salt-lakes. These two groups of salts are often found separate, so that some lakes have mainly sodium chloride in solution, while others have mainly compounds of sodium and magnesium sulphates. The latter are called bitter-lakes. ANIKIN explains the difference in the following way. The wind assorts the material which has been crystallized out through evaporation. The common salt crystallizes out first and as a firm mass, then the sulphates crystallize later above this in loose powdery masses which later, when left dry, are carried off by wind, the firmer masses of sodium chloride being left as a coherent deposit.

In a supplement to MIDDENDORFF's memoir on Ferghana, SCHMIDT gives a number of salt-analyses from which the following are selected:

1. Kara-Tjubé, salt-desert. Crystalline Powder with glauber-salt, gypsum, bitter-salt and clay: —

Salts soluble in water: 74,2045 per ct.

| | | | |
|---|---|---|---|
| including: | $Na_2SO_4$ | 62,4234 | per ct. |
| | $CaSo_4$ | 8,5121 | — |
| | $MgSO_4$ | 3,1500 | — |
| | $Al_2O_3$ | 6,9351 | — |

2. Mojan. Efflorescence upon limestone: —

Salts soluble in water: 21,661 per ct.

| | | | |
|---|---|---|---|
| including: | NaCl . | 2,742 | per ct. |
| | $Na_2SO_4$ | 11,287 | — |
| | $CaSO_4$ | 6,977 | — |
| | $CaCO_3$ | 47,447 | — |

3. Kokan. Jany Kurgan. Salt crust on dry plant stems: —

Salts soluble in water: 49,9787 per ct.

| | | | |
|---|---|---|---|
| including: | $Na_2SO_4$ | 44,8090 | per ct. |
| | $CaSO_4$ | 3,2232 | — |
| | $MgSO_4$ | 1,2510 | — |
| | $CaCO_3$ | 4,7170 | — |
| | NaCl | 0,2891 | — |

4. Margilan. Alty Aryk. Snow-white salt-desert: —

Salts soluble in water: 26,6792 per ct.

| | | | |
|---|---|---|---|
| including: | $Na_2SO_3$ | 9,4161 | per ct. |
| | $CaSO_4$ | 10,1121 | — |
| | $MgSO_4$ | 6,8053 | — |
| | $CaCO_3$ | 5,9624 | — |
| | NaCl | 0,1236 | — |

Radde (1899 p. 22) gives the following analysis of a "Ssor", salt-patch in the desert: —

| | | |
|---|---|---|
| $Na_2SO_4$ | 85,50 | per ct. |
| NaCl | 8 | — |
| $MgSO_4$ | 3,50 | — |
| $CaSO_4$ | 0,68 | — |

In the following the samples were collected by me and analysed by Mr. Wöhlk, chemist:

1. Salt on the earth in a desert near Buchara.

A greyish-white, amorphous, flocculent, dusty powder consisting of: —

$Na_2SO_4$
with $CaSO_4$, about 6 per ct.
and NaCl, trace.

2. Rough firm saline crust from the same place: — Salts soluble in water:

| | | | |
|---|---|---|---|
| $CaSO_4$, | ab. | 8,9 | per ct. |
| $Na_2SO_4$ | - | 5,4 | — |
| $MgSO_4$ | - | 44,7 | — |
| NaCl | - | 41,0 | — |

3. Pure white salt around the lake Jugur Kul, Chiwa. July 15th 1899: —

| | | | |
|---|---|---|---|
| $NaCl$ | | | |
| with $MgSO_4$, | ab. | 3,7 | per ct. |
| and $MgCl_2$, | - | 1,4 | — |

4. In the same place. Salt around and encrusting the base of Salicornia plants: —

| | | | |
|---|---|---|---|
| $MgSO_4$, | ab. | 21,50 | per ct. |
| $NaCl$, | - | 76,9 | — |
| $Na_2SO_4$, | - | 1,6 | — |

5. Salt from a dried-up water-hole near Chodsheli, Chiwa. July 26th 1899. A salt-cake consisting of six strata of colourless crystals lying one above another, and corresponding somewhat to the mineral Astrakanit: —

| | | | |
|---|---|---|---|
| $NaCl$, | ab. | 0,50 | per ct. |
| $MgSO_4$ | - | 36,7 | — |
| $Na_2SO_4$, | - | 41,5 | — |
| Water | - | 31,3 | — |

(including carbonate of Mg or Na).

As will be seen, gypsum, glauber-salts, magnesium sulphate, carbonate of lime and common salt are the most frequent salts. Their mode of occurence will be dealt with later, especially in the chapter on salt-deserts.

## CHAPTER 3

### General Aspects of the Climate of Transcaspia.

The climate is continental, the winter is cold and the summer very hot. Kasalinsk has an annual range of almost 90° Centig. (+ 48° C. summer-maximum, — 40° C. winter-minimum) (SCHWARZ p. 576). The precipitation is slight.

The winter is not very long, as a rule there is frost, not of long duration, but hard. In 1886 Tashkent had 89 frosty days, Petro Alexandrowsk 127 (Schwarz p. 561). January is the coldest month, and Ficker gives as the absolute minima for 10 years, — 28$^{0}$,$_{4}$ and — 28$^{0}$,$_{1}$ C. for Petro Alexandrowsk and Tashkent respectively. On the other hand, the temperature may rise to + 20$^{0}$ C. in January. — Snow is not rare, but it seldom lies long on the ground.

Spring comes quickly, commencing at the end of February, and it is comparatively warm; April is warmer than October. In May the average temperature is over 20$^{0}$ C. July is the hottest month, with absolute maxima for 10 years, according to Ficker, 43$^{0}$,$_{4}$ C. and 42$^{0}$,$_{1}$ C. for Petro Alexandrowsk and Tashkent. In Merw 44$^{0}$,$_{4}$ C. has been recorded, and in Namangan (Ferghana) as much as 47$^{0}$,$_{6}$ C. (Mushketow). The atmosphere is clear and nightly radiation strong, so that the temperature varies greatly as can be seen from the maxima and minima given in Table 1. The daily variations in temperature are also very great, but as the Russian meteorological stations do not record maximum temperatures, except the temperatures at 1 p. m., no definite figures can be given. At Tashkent in the years 1900—1902 the difference between the minima and the 1 p. m. readings varied from 11,$_{4}$ to 20,$_{0}$, but the maximum occurs later in the day than 1 p. m. Radde (1899) records from the sand-desert a variation of temperature of 36$^{0}$ in 24 hours, while Capus (p. 20) gives up to 40$^{0}$, and Obrutshew (quoted by Radde) records the following temperatures for the month of March in the sand-desert: At 6 a. m., 3$^{0}$; 9 a. m., 20$^{0}$; 1 p. m., 28$^{0}$ C.

At Tachta on the Murghab river near the northern border of Afghanistan, the following temperatures were observed on June 23$^{rd}$ (Radde 1899 p. 151):

| | | | | | |
|---|---|---|---|---|---|
| 6 a. m., | in shade | 25,$^{0}$$_{5}$, | in the sun | 34$^{0}$ | C. |
| 8 — | —»— | 29,$^{0}$$_{5}$, | —»— | | |
| 11 — | —»— | 40,$^{0}$ | —»— | 50$^{0}$ | - |
| 3 p. m. (?) | —»— | 43,$^{0}$ | —»— | 54$^{0}$ | - |

Schwarz (p. 559) gives the monthly and yearly amplitudes for a number of stations.

The amount of cloud is greatest during the winter (December—January) and least in summer (August). Buchara has 180 bright days per annum; at Petro Alexandrowsk, for instance, the average number of bright days is 17 in June, 22 in July, 25 in August, 23 in September and 18 in October (FICKER p. 554), and other places have about the same number. An overcast sky is rare during the summer; thus Petro Alexandrowsk has the low average of about 4 days during the five months June—October, and Tashkent about 8 days when the sky is overcast.

Calm days predominate, and from the records of KERSNOWSKIJ (p. 108) I have calculated that at Petro Alexandrowsk, 27 per ct. of all the observations for the year (which are made 3 times daily) showed calm. During the summer months it was 29 per ct. — The prevailing winds come from the N. and N. E., they average 37 per ct. for the whole year and 41 per ct. for the summer months. Less frequently the winds blow from the E. and N. W., while winds from the S, S. E. and S. W. together total at Petro Alexandrowsk only 5 p. ct. during the summer months. The prevailing N. and N. E. winds are moreover the strongest, yet only rarely do they attain any great strength; they are also the most constant, and blow especially during spring and summer being accompanied by bright weather, a cloudless sky and dry air. They are dry in themselves, and as they travel from colder to warmer zones they yield no precipitation, but cause evaporation (MUSHKETOW).

The precipation is slight. In contrast to southern Russia which has summer rain, the precipitation maximum occurs here during the winter or the spring (HANN III p. 192). The winter snow must be of great importance to the vegetation, and as late as April in many places rain cannot be termed rare. July and August are exceedingly dry, in Merw it has not rained at all during these months for four years. When greater quantities of rain fall it is as a few heavy downpours, not continuous rain. The number of rainy days is therefore small, which is of great importance to the plants, because extreme conditions are the result.

The relative humidity is given by Ficker, from a yearly average for all the stations, as 61 per ct. In Table 1 will be found the averages for each month at 3 different times of the day. It must be remembered, however, that these figures are taken on an oasis where the degree of saturation must be greater than in the desert. Olufsen records (1901 pp. 12—13) from various places (Merw, Buchara, Kona Urgentsh) relative humidities of 13—19 per ct.

On account of the heat and dryness in Transcaspia during summer it is natural that evaporation must be very great. According to Semenow (p. 128) evaporation is 3 times greater than precipitation in Tashkent and Samarkand, 4 times in Ferghana, 24 times in Nukus, and 270 times in Petro Alexandrowsk. Nukus and Petro Alexandrowsk lie south of the Aral Sea not far apart, and obviously local influences have to be reckoned with here.

The figures in Table 2 show the amount of evaporation and its relation to precipitation. For the daily evaporation per month we find amongst others a table in Mushketow p. 508 taken from Stelling, and another in Schwarz p. 572.

As a result of the evaporation being much greater than the precipitation, the country is becoming drier and drier. Schwarz (p. 578) proves that the Syr Darya, the Aral Sea and other lakes are continually decreasing. According to some calculations the Aral Sea sinks 7 metres, according to others 4,2 metres in the course of a century, and Schwarz is of opinion that Turkestan is in process of being irretrievably ruined on account of scarcity of water. Buchara is already on the verge of ruin because Samarkand, which lies higher up the Serafshan river, uses all the water available.

Borszczow is also of opinion that the drying up of Transcaspia is increasing, while Baer has come to the conclusion that there is now a condition of balance. As regards the Aral Sea, Berg points out (1908 p. 374), that the water-level is changing, and that at the present time it is rising after a minimum in 1880.

Comments on Table 1. This table gives meteorological data from three stations: Tashkent (comparatively cold and moist), Petro Alexandrowsk which is situated near Chiwa south of the Aral Sea (drier and colder during winter, but warmer during summer), and Askhabad to the north of the

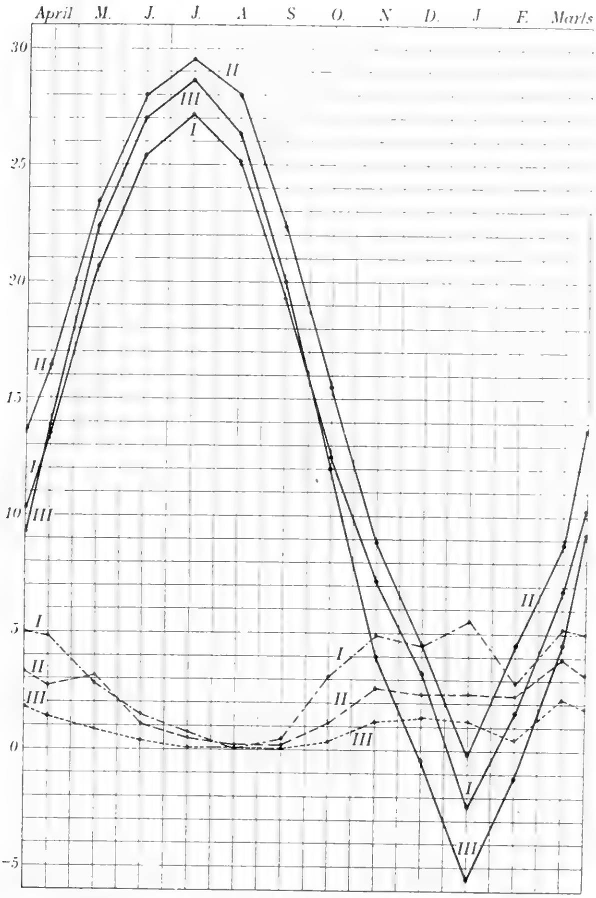


Fig. 1. Hydrothermals for three stations in Transcaspia, viz.: I. Tashkent, II Askhabad, III Petro Alexandrowsk. The ordinary lines are temperature-curves, and the figures to the left express degrees Centigrade. The dotted lines give the precipitation in centimetres. (Constructed after the method of RAUNKJÆR (1905, 1907).

mountains bordering Persia (very hot and dry). The temperature and precipitation of these stations are moreover marked out in curves in the manner indicated by RAUNKJÆR (fig. 1).

The table is prepared from the annual volumes (1897—1906) of «Annales de l'Observatoire physique central de St. Pétersbourg», especially from «Résumés mensuels et annuels». The observations were made every day at 7 a. m., 1 p. m. and 9 p. m. The maximum averages given are the mean of the highest readings at 1 p. m., and are therefore too low because that hour is not the hottest part of the day. The minimum averages on the contrary are the mean of real minima; they are not given for Petro Alexandrowsk.

The figures on the whole correspond with those given by Ficker for another decade.

Brackets round a figure indicate that it is not the mean of 10 years' observations, but only of 7—9 years' on account of gaps in the series of observations.

Within a territory of the size of Transcaspia there are of course meteorological differences, the extent of which may be seen by reference to the great «Atlas climatologique», wher ethey are charted. We need only point out here that the area south of the Aral Sea has the least precipitation and that from this centre there is an increase on all sides. As defined by Köppen this area has a true rain-less climate, the rain-probability being under $0,_{20}$. Petro-Alexandrowsk has $0,_{13}$, Askhahad $0,_{33}$, Tashkent $0,_{36}$.

Further details are unnecessary as I do not know the vegetative conditions intimately enough to be able to correlate the climatic differences with them.

The «light-climate» of Aralocaspia is characterized by the large number of cloudless days. Wiesner mentions (quoting from Hann) that in the Kirghiz Steppe there are 170 cloudless days per annum. The foliage of the plants is here aphotometric, that is it has no fixed position in relation to the light; or it is only in the lowest degree photometric, having a fixed position to the light (Wiesner p. 62). This is in the main correct, yet plants occur which turn their leaves in accordance with the light, for example *Glycyrrhiza* and *Smirnowia*.

# Table 1. 1897—1906.

| | Tashkent 41° 20′ N. Lat. 69° 18′ E. Long. 478 metres above sea-level. | | | | | | | | Askhabad 37° 57′ N. Lat. 58° 23′ E. Long. 226 m. a. s.-l. | | | | | Petro Alexandrowsk 41° 28′ N. Lat. 61° 05′ E. Long. 85 m. a. s.-l. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average temp. (Centigrade) | temp. max. average | temp. min. abs. average | total precipitation mm. average | number of days with precipitation (average) | Relative humidity. 7 a. m. | 1 p. m. | 9 p. m. | average temp. (Centig.) | temp. max. average | temp. min. abs. average | total precipitation mm. average | number of days with precipitation (average) | average temp (Centigr.) | temp. max. average | total precipitation mm. average | number of days with precipitation (average) |
| January | — 2,3 | 12,3 | — 20,5 | 57,4 | 10,5 | 82 | 62 | 84 | — 0,2 | 15,7 | — 15,0 | 25,0 | 9,1 | — 5,5 | 6,7 | (13,0) | (3,3) |
| February | 1,6 | 15,8 | — 13,7 | 28,3 | 7,3 | 80 | 58 | 82 | 4,5 | 19,5 | (— 8,2) | 23,3 | 7,6 | — 1,1 | 13,5 | (5,2) | (2,4) |
| March | 6,8 | 22,0 | — 8,7 | 51,8 | 11,8 | 78 | 55 | 77 | 8,9 | 26,5 | — 4,4 | 40.0 | 10,1 | 4,6 | 22,8 | (21,7) | (4,0) |
| April | 13,5 | 28,9 | — 0,8 | 49,2 | 9,3 | 71 | 46 | 72 | 16,3 | 33,1 | 2,9 | 28,0 | 6.2 | 13,9 | 30,7 | 14,1 | (3,2) |
| May | 20,6 | 34,5 | 6,4 | 28,2 | 6,5 | 65 | 41 | 67 | 23,4 | 38,3 | (10,5) | 32,1 | 7,4 | 22,5 | 36,4 | (8,5) | (1,7) |
| June | 25,4 | 37,4 | 9,8 | 16,3 | 4,0 | 60 | 35 | 58 | 28,0 | 40,6 | (14,1) | 11,1 | 2,6 | 27,0 | 39,6 | 5,9 | (2,0) |
| July | 27,2 | 38,4 | 12,1 | 8,3 | 1,7 | 59 | 33 | 53 | 29,7 | 41,7 | (16,8) | 4,7 | 1,5 | 28,7 | 40,3 | 0,8 | (0,4) |
| August | 25,2 | 37,1 | 9,8 | 0,5 | 0,4 | 61 | 33 | 55 | 28,0 | 40,4 | (14,4) | 1,3 | 0,7 | 26,4 | 39,5 | 0,7 | (0,3) |
| September | 19,3 | 34,5 | 4,7 | 3,8 | 1,1 | 67 | 36 | 64 | 22,3 | 37,7 | 7,2 | 1,5 | 1,0 | 20,0 | 36,0 | 0,9 | (0,4) |
| October | 12,6 | 29,7 | — 2,3 | 31,5 | 5,2 | 76 | 42 | 73 | 15,6 | 32,9 | 0,8 | 12,0 | 3,6 | 12,0 | 28,0 | 4,0 | (1,6) |
| November | 7,2 | 23,3 | — 5,6 | 48,7 | 8,6 | 81 | 57 | 82 | 8,9 | 26,9 | (— 3,0) | 25,6 | 8,3 | 4,0 | 20,0 | (12,3) | (3,4) |
| December | 3,2 | 17,5 | — 9,8 | 44,7 | 10,9 | 82 | 64 | 83 | 4,6 | 20,8 | (— 7,4) | 23,6 | 9,7 | — 0,4 | 12,1 | (14,2) | (3,0) |
| Year | 13,4 | 38,8 | — 21,0 | 368,7 | 77,8 | 72 | 47 | 71 | 15,8 | 42,4 | (— 17,1) | 227,9 | 67,8 | 12,7 | 41,1 | (91,5) | (26,3) |

**Table 2.**

Amount of evaporation and precipitation for St. Petersburg and two stations in Transcaspia. After BRITZKE Table 8.

| | January | February | March | April | May | June | July | August | September | October | November | December | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| St. Petersburg (average of 20 years' observations) | | | | | | | | | | | | | |
| evaporation, mm. | 4 | 5 | 10 | 24 | 44 | 63 | 63 | 46 | 31 | 18 | 8 | 4 | 320 |
| precipitation, mm. | 22 | 22 | 23 | 23 | 42 | 47 | 66 | 66 | 50 | 43 | 36 | 31 | 470 |
| Tashkent (average of 14 years' observations) | | | | | | | | | | | | | |
| evaporation, mm. | 29 | 39 | 87 | 97 | 146 | 198 | 215 | 201 | 139 | 88 | 57 | 43 | 1339 |
| precipitation, mm. | 41 | 40 | 66 | 55 | 17 | 4 | 1 | 2 | 4 | 21 | 22 | 56 | 328 |
| Sultan Bend S. E. of Merw (average of 2 years' observations) | | | | | | | | | | | | | |
| evaporation, mm. | 35 | 52 | 104 | 194 | 302 | 459 | 526 | 466 | 296 | 157 | 109 | 64 | 2764 |
| precipitation, mm. | 36 | 28 | 22 | 19 | 21 | 0 | 0 | 0 | 1 | 9 | 8 | 36 | 176 |

# SECTION II. THE VEGETATION OF THE TRANSCASPIAN LOWLANDS

## CHAPTER 4

### Earlier Literature.

The botanical literature on the Transcaspian lowlands is already large. During the first half of last century, Russian naturalists began to examine this country which was up till then, at least as regards natural history, an unknown land, and since then numerous memoirs have been published. Since the Russian occupation of these vast areas, they have been examined by many naturalists; but the papers containing the results of the journeys are scattered throughout different periodicals, mostly Russian and often very difficult of access. More especially during the later decades when it has become a national feature to write in Russian, it is very hard for anyone in western Europe to study Russian literature. The publications on the botanical conditions of the Transcaspian lowlands are — so far as we can ascertain — mainly taxonomic, lists of plants and descriptions of new species. There now exists a large amount of systematic material which in recent years is gradually becoming arranged into consecutive floras, mainly through the works of FEDTSCHENKO.

Very few descriptions of the vegetation exist, still less any attempts at ecological treatment. What I have had access to will be dealt with in this account, and Russian authors, inaccessible to most people, will be reported in greater detail than those who have written in the languages of western Europe.

BASINER'S journey through the Kirghiz steppe to Chiwa. This account dates from 1848. He travelled from Orenburg to Chiwa, and he gives many lists of plants as well as brief descriptions of the vegetation, and other botanical remarks. The greater part of the territory where he travelled does not belong to the areas dealt with in this work. BASINER describes the «steppe» between Orenburg and Usturt with its three regions: The grass region, the transitional region and the region of *Chenopodiaceae* of which the first is the most northern, the last the most southern region. The region of *Chenopodiaceae* is evidently closely related to the desert ot the south, such as we deal with later on. Frequently the soil is devoid of plants, yet in places a considerable number of plants were found, but these form «keine heitere Hülle, sondern höchstens ein dunkles Trauergewandt». The most common plants are: *Salsola brachiata, clavifolia, crassa, Kali, Anabasis aphylla, Brachylepis salsa* and Artemisia *(Artemisia fragrans).* The number of *Chenopodiaceae* increase towards the south and many individuals of a species were often found in masses together.

The plateau of Usturt which lies between the Aral Sea and the Caspian is divided by Basiner into four vegetation-regions: the Clay-region, the Sand-region, the Marl-region and the Salt-region. The first named embraces the greater part of the plateau, is dry and bare with a scattered vegetation. During spring many annuals are in bloom especially *Cruciferae* and bulbous plants (*Allium* and *Tulipa*); during autumn hardly anything but scattered perennial *Chenopodiaceae* are found: Saxaul, *Anabasis aphylla, Salsola glauca, Arbuscula, crassa, rigida, Brachylepis salsa* and the polygonaceous *Atraphaxis spinosa.*

The Sand-region consists of scattered sand-hills (dunes) The vegetation is richer than on the clay, as the sand retains the moisture better. The most common plant is *Pterococcus aphyllus (= Calligonum Pallasii),* next comes *Tamarix gallica,* and of annuals we find recorded *Salsola Kali, Horaninowia ulicina, Corispermum laxiflorum* and *Asperula Danilewskiana.*

The substratum of the Marl-region is looser than clay, but more compact than the sand. It occurs especially in crevices between rocks and other similar places on the eastern slope of the plateau; the vegetation is comparatively rich, Basiner gives a long list of plants which are found during autumn. This contains some annuals (*Cruciferae*), and many herbaceous perennials, undershrubs and bushes such as: *Peganum Harmala, Astragalus*-species, *Alhagi Camelorum, Tamarix, Artemisiae, Chenopodiaceae, Atraphaxis.*

The vegetation of the Salt-region is chiefly found round the coast of the Aral Sea, both on marl and on moving sands. The most important plants are: *Frankenia intermedia, Zygophyllum Fabago, Lycium ruthenicum, Saussurea crassifolia, Salsola ericoides, Schoberia (= Suæda) microphylla, Halocnemum strobilaceum, Halostachys caspica, Atriplex laciniatus,* and on sandy soil: *Clematis orientalis, Mulgedium tataricum, Cynanchum acutum, Phelipaea salsa.*

Basiner also describes thickets on the river sides with tamarisks, willows and poplars, and a wood of Saxaul, which took three hours to traverse. The height of the trees was 15 to 20 feet and the diameter of the stems 8 inches or more. The year-rings were very narrow, 200—260 being counted. The wood is brittle, for which reason providence has not furnished this tree with leaves, for if leaves were present a slight gust of wind would break the stem.

The next account from the lowlands of Transcaspia is Alexander Lehmann's "Reise nach Buchara und Samarkand". In the years 1841—1842 Lehmann, in the capacity of naturalist, accompanied a Russian envoy to the Emir of Buchara, but he died shortly after his return to Russia. The very large collections of plants made by him were examined and described by Al. Bunge, and this book is still a standard work. Lehmann's notes on the journey were published in 1852, after revision by G. v. Helmersen. The account contains occasional remarks on the scenery of the country, and short lists of plants from different localities, but one feels that the material has not been revised by one who knows the country from personal observation; it lacks those comprehensive comments, which convey a general view to the mind of the reader and make of the work a connected whole.

The next work to be dealt with is Borszczow's Russian memoir: "Contribution to the Geography of Plants in the Aralo-Caspian countries" (1861)[1]. This begins with a short topographical-geological survey of the country. In the introduction to the phytogeographical part of the work we find the following remarks:

> "The flora of the Aralo-Caspian countries is only partly the flora of the steppes; to a great extent it is a desert-flora, characterised by the prevalence of bushes and under-shrubs with herbs growing below, or by the almost exclusive occurrence of the first-named. This is the first physiognomical feature of the region we are dealing with.
>
> The second characteristic is the general poverty of the plant-covering. The vegetation develops with the greatest difficulty — one might say reluctantly — on a soil containing an abundance of salts, which is continually scorched by the merciless rays of the sun and only rarely refreshed by a light rain. It does not cover the area uni-

[1]) Borszczow's "Ueber die Natur des Aralo-Caspischen Flachlandes" (1860) contains an orographical description of the area.

formly, but appears in oases, between which stretch large tracts of quite bare soil. Even in the north-western part which has a more favourable situation and climate, and where the flora is more steppe-like in character, we look in vain for the luxuriant growth of the herbaceous plant forms which are a characteristic of the steppes of southern Russia and southern Siberia. It is not found here. The immediate neighbourhood of the vast burning deserts which occupy almost three-fourths of the whole area, and the insufficiency of the precipitation (!) have too great an influence on the climate, moreover the soil itself possesses too few of the conditions which are necessary to produce a luxuriant vegetation. The herb-covered steppe, the only refuge for the nomad and his numberless cattle, is here only a dry Stipa Steppe whose vegetation forms hardly anywhere a thick carpet; only in the river-valleys (and frequently not even there) do we find a somewhat richer development.

Here, as throughout the whole of Aralo-Caspia, it is a few specially characteristic forms which prevail, they repeat themselves continually so that the country has a very monotonous appearance. Other species are only subordinate to these. Where the character of the soil changes, these predominant species sometimes change very quickly and give place to others which in turn prevail until the soil changes again. This monotony and this repetition of certain species over vast areas is the third characteristic of the vegetation of the Aralo-Caspian countries. It is no doubt a direct consequence of the uniformity of the climate, which again is mainly dependent on the slight vertical relief of the surface.

A fourth characteristic of the flora is the unfamiliar appearance of many of the plant-forms[1]). As soon as the Ural is crossed, a different zone of vegetation is entered upon, where the plants differ greatly from those living in the same latitude, but in areas with a different geographical location, a different relief and different soil. Even

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[1]) Great poverty in Cryptogams is also a characteristic.
(B.'s remark.)

the flora of the right bank of the Ural between Uralsk and Orsk differs in many ways from the flora of the left bank. On the right bank we find for instance frequently: *Arabis pendula, Adenophora liliifolia, Tilia parvifolia, Prunus Chamaecerasus,* some *Verbascum* species, *Urtica dioica* and *U. urens, Senecio vulgaris* and many others, but they disappear totally on the left bank of the river and never appear again[1]). The unique character of the flora is still more strongly expressed in the heart of the country, south of 49° N. Lat. Plant-forms such as Saxaul (*Haloxylon Ammodendron*) Kara-Djusgjon (*Calligonum*-species), the unfamiliar poplars *Populus diversifolia* and *P. pruinosa,* Kujan-Sujok (*Ammodendron Sieversii, A. Karelini*) and the species of *Chenopodiaceae, Papilionaceae, Cruciferae* &c. are all unique in appearance and structure, and could only be developed under special conditions of climate and soil. In the Aralo-Caspian lands, the soil in particular has such a great influence on the vegetation that a change of soil — other conditions remaining the same — often alters the physiognomy totally and almost abruptly without any gradual transitions. This change is most evident in the moving sand deserts, where the depressions between the sand-hills are mainly covered by salt-swamps or by a loose clayey bottom permeated with salts. The vegetation on the sand-hills is varied and highly characteristic, but its spe-

[1]) BORZSZCOW comments on this in more detail in another place ("Ueber die Natur d. Aralo-Casp. Flachlandes", p. 272, Anm.): on approaching the steppe, the tree-vegetation disappears, poplars, elms, limes, birches, willows, *Prunus Chamaecerasus* and *P. Padus;* instead of *Salix fragilis* and *S. viminalis* so common in the Ural we have here *S. pallida* and *S. Wilhelmsiana* and "sogar die, im Ganzen, dem Grassteppen-Gebiete angehörigen Sträucher: *Caragana frutescens, Spiraea crenata* u. *hypericifolia* und *Amygdalus nana* kommen südlich von Ural nur gruppenweise und selten vor" *Stipa pennata* is replaced by *S. capillata* and *S. Lessingiana.* A great many plants disappear altogether (*Delphinium, Arabis, Trifolium, Fragaria, Scabiosa, Senecio, Urtica, Poa, Aira* &c.) The Ural is a line of demarcation between the grass and forest region on one side, and the "true steppe" on the other.

The change in the soil and vegetation south of Tshagan and the steppe-mountains was, however, previously pointed out by PALLAS (1776, p. 310).

cies suddenly disappear at the margins of the depressions and all that is left is a meagre flora, frequently reduced to two or three *Chenopodiaceae*, such as *Brachylepis salsa*, *Anabasis aphylla*, species which are uniformly distributed throughout the whole area.

These changes in the soil-conditions are mainly responsible for the variations in the general physiognomy of the vegetation. They also bring into prominence certain plant-forms which may be observed over considerable areas and which furnish the features characteristic of the areas or sub-floras into which the Aralo-Caspian countries may be divided.

There are five of these areas:

1) The Stipa-steppe
2) The Clay-deserts
3) The Salt-deserts
4) The Moving-sand-deserts
5) The river Serafshan."

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The following is a summary of Borszczow's description of these areas.

1) The area of the Stipa Steppe is the most northern, and extends from its southern boundary at the Mugodshar mountains and the rivers Tshit-Irgis and Turgai, towards the N. E. where it merges into the grass steppes of the southern part of the Tobolsk government. The Stipa Steppe thus lies outside of the area under consideration in this work. The surface of the steppe is almost everywhere undulating. Forests do not occur, but here and there are groves mainly consisting of poplars and willows. The most prevalent plant is *Stipa capillata*, then follows *Festuca ovina*. Besides these a number of species are recorded: *Amygdalus nana*, *Spiraea*-species, *Ulmus campestris*, *Caragana frutescens*, Poplars, Willows, *Betula and Alnus*, *Ranunculaceae*, *Dianthus* and *Silene*, *Eryngium*, *Trinia*, *Compositae* (*Cirsium acaule*, *Jurinea*, *Saussurea*, *Echinops*), also *Tulipa*, *Iris*, *Allium* and *Carex*. About 10 per ct. of the

total species (551) are trees and shrubs; the proportion of biennials and perennials to annuals is 1 : 0,31.

For each area Borszczow gives statistics which show for a number of families the proportion of species in the given area as compared with the whole country examined by him. After so many years of further research in these countries, his figures must be far from correct, but as they have a certain interest, the figures for a few selected families are given. In the area of the Stipa Steppe were found:

| | | | |
|---|---|---|---|
| 57 | per ct. of the | Ranunculaceae | of the whole area. |
| 47 | —»— | Cruciferae | —»— |
| 41,8 | —»— | Papilionaceae | —»— |
| 50,5 | —»— | Compositae | —»— |
| 28,7 | —»— | Salsolaceae | —»— |
| 74 | —»— | Cyperaceae | —»— |
| 58,9 | —»— | Gramineae | —»— |

The Stipa Steppe is rather monotonous in character and resembles in many ways the steppes of the adjacent western governments. It is by no means always a fertile grass-steppe, more often it is dry, clayey and poor, and the farther south one goes the more frequent do large bare patches of clay become.

Borszczow distinguishes three floras included in the Stipa Steppe: the grass-steppe, the stone-steppe (Mugodshar and its slopes) and the clay-stone-steppe. This last flora embraces, especially in its southern part, many species characteristic of the clay and salt deserts.

2) The area of the Clay Desert stretches, according to Borszczow, between the Caspian Sea and the Aral Sea (Usturt), and again to the north and east of the Aral Sea. The surface is an undulating plain, generally of higher elevation than the soil of salt-deserts and moving-sands. The soil consists of pure compact clay and loose or compact clayey or sandy marls. Almost everywhere the soil is permeated with salts, and salt-swamps are not uncommon. The resemblance to the steppes of southern Russia seen in parts of the Stipa-steppe has disappeared here. The vegetation is

characterized by few, but exceedingly characteristic plant forms, and a terrible monotony. — Of the plants (329 species) in this formation, $10{,}_{63}$ per ct. are shrubs. The proportion of perennials and biennials to annuals is $1:0{,}_7$.

Borszczow's percentages for the families already named are as follows for the area of the clay-desert:

| | | | |
|---|---|---|---|
| $29{,}_6$ | per ct. of | Ranunculaceae | of the whole area. |
| $40{,}_9$ | —»— | Cruciferae | —»— |
| $17{,}_{09}$ | —»— | Papilionaceae | —»— |
| 23 | —»— | Compositae | —»— |
| 49 | —»— | Salsolaceae | —»— |
| 26 | —»— | Cyperaceae | —»— |
| 23 | —»— | Gramineae | —»— |

The most frequent species are *Artemisia fragrans* and *A. monogyna;* these alone cover large tracts and present a most melancholy picture. They are frequently accompanied by *Salsola crassa*, *S. lanata*, *Brachylepis (Anabasis) salsa* and *Anabasis tatarica*, sometimes with Saxaul (*Haloxylon Ammodendron*), and *Ferula persica*, *Rheum caspicum* and *Calligonum Calliphysa*.

"The occurrence of these (the three last-named species) is so closely correlated with the soils of this area that it is possible with the aid of only a few specimens to determine with great certainty the character and physiognomy of the sub-flora from which they are taken."

The plants mentioned are almost the only ones to be found in the clay-deserts after the second half of April when the sun becomes very powerful. In spring the flora is richer, during the flowering season of species of *Alyssum*, *Megacarpaea*, *Tauscheria*, *Euclidium*, *Matthiola*, *Chorispora*, *Echinospermum*, *Onosma*, *Phelipaea*, *Allium (A. caspicum)*, *Tulipa patens*, and *Rhinopetalum Karelini.* These plants are the "spring decorations of the desert flora", but unfortunately they are too quickly lost again. A richer vegetation of roses with *Spiraea* and *Elaeagnus* occurs in the deep ravines on the margin of the Usturt.

3) The area of the Salt-deserts stretches over a very

large expanse at the north-east end of the Caspian Sea, but smaller stretches are found interspersed in other territories. The surface is a perfectly level plain covered with innumerable salt-lakes with here and there sand-hills. The soil is a compact clay often hard as stone, or loose marl with a mixture of chalk, permeated to a considerable depth with salts.

The vegetation is exceedingly poor and uniform. Out of 170 species, characteristic for the salt-deserts, 63 are *Chenopodiaceae*, 17 per ct. are trees or shrubs (a very high proportion); perennials and biennials are to annuals as 1 : 1,3

In spite of uniformity, the physiognomy of the evergreen salt-swamps has a much less desolate appearance than the clay-deserts.

"Here (in the salt-deserts) the vegetation tries, as it were, to make up for uniformity by its characteristic forms and by constant freshness and unusual tints. Enormous salt-swamps, pale green during the spring, turn by degrees yellowish and finally light-yellow, as the burning heat comes on, and again during the early days of autumn the colours turn to pink, scarlet and purple. Simultaneously the young green of the new branches shows forth and the four colours blend in the most charming way. It is difficult to imagine the effect of such a picture especially at sunrise or sunset, and one must see it to realize its beauty."

The salt-deserts contain: —

| | | | |
|---|---|---|---|
| 7,68 | per ct of the | Ranunculaceae | of the whole area |
| 10,84 | —»— | Cruciferae | —»— |
| 7,68 | —»— | Papilionaceae | —»— |
| 8,4 | —»— | Compositae | —»— |
| 58,3 | —»— | Salsolaceae | —»— |
| 3,7 | —»— | Cyperaceae | —»— |
| 16 | —»— | Gramineae | —»— |

It will be seen that the Salsolaceae predominate here.

Borszczow gives as the most common amongst them: *Ceratocarpus arenarius*, *Kalidium foliatum*, *K. arabicum*, *Halocnemum strobilaceum*, *Salicornia herbacea*, *Schoberia* (*Suaeda*) *baccifera, S. salsa, Salsola clavifolia, Ofaiston monandrum, Halimocnemis villosa, H. sclerosperma, H. glauca, Halogeton glomeratus, Anabasis aphylla, A. brachiata, Brachylepis* (*Anabasis*) *salsa, Halostachys caspica.* Another important species is *Zygophyllum Eichwaldii.*

4. The area of the Moving-Sands.

This stretches mainly south-east and east from the Aral Sea. The vegetation is more luxuriant than in the other areas, and is at the same time more interesting and richer in rare and strange plant-forms. In spring it looks quite like a garden. The dunes are covered with bushes of *Calligonum, Halimodendron,* Saxaul, *Tamarix, Salsola* etc. Some of these are also present in other formations, but reach here their fullest development, "so that this territory may justly be termed the forest of the desert-flora".[1])

Of the 501 species of Phanerogams characteristic for the sand-flora, 16,16 per ct. are trees and shrubs. The proportion of perennials and biennials to annuals is as 1 : 0,75. 235 species belong exclusively to the dunes. The sand-flora includes:

| | | | |
|---|---|---|---|
| 26, 9 | per ct. of | Ranunculaceae | of thew hole area. |
| 54,21 | —»— | Cruciferae | —»— |
| 63 | —»— | Papilionaceae | —»— |
| 65 | —»— | Compositae | —»— |
| 61 | —»— | Salsolaceae | —»— |
| 10 | —»— | Cyperaceae | —»— |
| 28 | —»— | Gramineae | —»— |

In addition to *Cruciferae* and *Papilionaceae, Borragineae* and *Polygonaceae* are also plentiful. Borszczow mentions amongst the Cruciferae: *Dontostemon* (several species) *Streptoloma, Spirorhynchus, Pachypterygium, Cithareloma, Lachno-*

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[1]) This simile has justly been contradicted by Korschinsky and Tanfiljew. Yet Lipsky (1911) is of the opinion that some large tracts of Saxaul — but only of this — may rightly be named forests, the trees being big and thick and giving a considerable amount of ground-litter.

*loma, Chartoloma and Octoceras;* the *Papilionaceae* include *Ammodendron, Halimodendron, Ammothamnus, Eremosparton, Alhagi* and *Astragalus.* As representatives of other families we may mention: *Heliotropium, Echinospermum, Calligonum* (17 species) various Umbelliferae (*Dorema, Ferula* etc.), and Compositae (*Artemisia, Echinops, Cousinia, Microlonchus, Scorzonera, Streptorhamphus,* etc.). The *Salsolaceae* are represented by much the same species as in the salt-deserts, but they are more luxuriantly developed; noteworthy are *Alexandra Lehmanni, Caroxylon* (*Salsola*) *hispidulum, C. subaphyllum, Eurotia Eversmanniana.* Smaller families are also represented by a number of species: *Zygophyllaceae, Rutaceae, Tamaricaceae, Gnetaceae* (*Ephedra*), and of Monocotytedons the following may be named: *Biarum, Tulipa, Merendera, Gagea, Heleocharis.*

4) The area of the Serafshan River.

Lying as this does in the mountainous regions along the upper courses of the river, it is outside of our area and need not be considered.

Following on the introductory description just summarised, Borszczow then deals with the families of plants with respect to the distribution of genera and species. This analysis occupies the greater part of his work and leads him to the following general conclusions:

"1. The majority of the commoner plants of Central Russia with a distribution west of the Caspian Sea extending to Trans-Caucasia, have as their southern limit of distribution east of the Caspian Sea in Aralo-Caspia, the parallel of $51^1/_2{}^0$ N. lat.

2. When these forms occur farther east in Siberia, the boundary limiting their area of uninterrupted distribution lies outside of Aralo-Caspia and always north of $51^1/_2{}^0$ N. lat.

3. Most of the typical steppe-plants met with in southern Russia and distributed towards the west from the Caspian to the foot of the Caucasus, attain their southern limit in Aralo-Caspia at the parallel of $49^0$ N. lat., and their eastern boundary at the meridian of the Mugodshar

range (77 $^{0}$ E. long., Ferro, ab. 60 $^{0}$ E. long., Greenw.) thus they do not overstep that part of the area of Stipa which we have termed the Grass-steppe. If these plants occur farther east, their limit of uninterrupted distribution is a line generally extending towards the north along the western slopes of the Mudgodshar Mts.; from the north end ($50^1/_2$ $^{0}$ N. lat.) of these the line strikes eastwards round the basin in which the middle and lower courses of the rivers Irgis, Ulkojak and Turgai are situated. They may of course be met with as isolated outposts south of this latitude, but never farther south than 49 $^{0}$ N. lat.

4. The more southern plant-forms, characteristic both for Persia and Aralo-Caspia, do not occur in our flora of the present time further north than 47 $^{0}$ N. lat.

5. The more eastern forms, met with in Altaian Siberia and Dsungaria, are rarely met with further west than 78 $^{0}$ E. long. F. (ab. 60 $^{0}$ W. Greenw.)

6. In the case of a great many south-eastern forms, the lower course of the Syr-Daria (45 $^{0}$—46 $^{0}$ lat.) is the northern boundary, and the meridian of the eastern shore of the Aral Sea (70 $^{0}$ E. long. F., ab. 62 $^{0}$ Greenw.) forms the western boundary.

7. The areas east of the Aral sea must be considered as the centre of distribution for tree-like forms of the families of the *Salsolaceae, Polygonaceae* (*Calligoneae*) and *Papilionaceae.*

8. The flora of the Aralo-Caspian countries as known to us at the present time is relatively new in origin, and most of its plant-forms have probably distributed themselves over these parts of Asia within very recent times; presumably they came mainly from the east and south, to a less degree from west and north, so that from these directions they have not penetrated so far. This flora is the gathering ground for forms occurring in the steppes of South Russia, the Altaian Siberia and Persia. The original plant-forms indigenous to the area are evidently limited to: *Salsolaceae*, the tree-like *Polygonaceae, Nitrariaceae, Zygophyllaceae* and some species of *Tamaricaceae, Papilionaceae* and *Cruciferae.*

9. When we take into consideration how the sheets of water and the river-systems are drying up [1]) while the dryness of the climate increases, it may almost be regarded as certain that the western and northern forms will ere long cease to reproduce themselves successfully in the Aralo-Caspian countries, and that forms already found there will begin to die out. On the other hand, it is beyond doubt that the southern and south-eastern desert-forms will continue to extend their zone towards the north and the west as a result of the environment. Saxaul, *Elaeagnus hortensis* and some others are at present migrating towards the north, whereas species such as *Populus nigra* and *P. alba* are disappearing from the southern latitudes where they occurred; this proves, that this period is already drawing near."

Borszczow's memoir ends with some brief notes on the Cryptogams which, on the whole, are not specially important. *Parmelia esculenta* occurs sporadically in the deserts along with a few *Lycoperdaceae*.

In spite of its antiquity, Borszczow's work has been dealt with at considerable length because, on the whole, it conveys an interesting picture of the Aralo-Caspian countries. The relation of the flora to that of the surrounding areas is especially well defined, hence I have included the Stipa-steppe, which otherwise does not come within the scope of this work. As far as I know, Borszczow's work is the only one that treats the flora of Aralo-Caspia from that point of view, but it may be that other important works have been overlooked on account of the inaccessibility of Russian literature.

The next work known to me in this connection is: A. A. Antonow: "On the Plant-formations of the Transcaspian territory" [1]) 1892.

[1]) According to Baer (1855), the phase of drying up is now past and a condition of stability has long ago set in. Comp. Schwarz and Berg, above page 14.

[2]) "Territory" is here given as the translation for "oblast". In Borszczow, "area" is given; this author uses it as corresponding to Antonow's "formation." Antonow himself uses the word "formation."

Antonow travelled in these parts from April 18th to June 27th in 1889, so that, as he states, he has not seen the flowering season of early spring, nor the late bloom of perennial plants.

Antonow has six formations:

1. The flora of the Clay(or loess) Desert-plains.
2. The flora of the Riverside Thickets.
3. The Loess-steppe.
4. The Sand-desert.
5. The Promontory or Stone-steppe.
6. The Mountain or Rock-flora.

1. The formation of the Clay-Deserts is the most prevalent and has the greatest extension of all. The soil has a level surface and is formed by loess which is soft and greasy in its crude form, and hard as stone when dry. When very dry it cracks into 4—5-angled polygons and the surface peels off. This soil may occur as the subsoil for other formations.

The flora is poor and monotonous, this formation being the domain of the *Chenopodiaceae.* Saxaul (*Haloxylon Ammodendron*) is the most important of these, it is here a low, twisted bush, no higher than an Arshin (about 0,7 metre); *Salsola*, *Suaeda* and *Halimocnemis* are also mentioned. The plants stand far apart from each other.—Where the moisture-conditions are more favourable, the plants are more abundant and stronger, for instance near water-holes or saline places or on the more retentive sands of the dunes.

The saline places ("Takyr" and "Ssor") are mentioned as a sub-formation, but no details are given by which they can be differentiated.

2. The Riverside Thickets. Along the rivers on the narrow strips of land which are continually moist, *Tamarix*, Poplars (*Populus euphratica, pruinosa*), Willows, *Lycium turcomanicum*, *Phragmites*, etc. grow, often accompanied by the creepers *Cynanchum acutum* and *Apocynum sibiricum* (= *A. venetum*). They form a thick and often impenetrable living fence along the banks of the river, — a luxuriant vegetation, the poplars

sometimes reaching the height of 5 Sashen (about $10^1/_2$ metres) with a stem diameter of half an Arshin (about $0,_{35}$ metre). The poplars often grow along with reeds on low islands, which are covered at high water. The tamarisks grow smaller a few fathoms away from the river and become mixed with salsolaceous plants which enjoy the moisture, but even at a distance of two to three Versts (about 1 kilom.) into the desert stunted tamarisks may still be seen.

The vegetation of the river sides contains no flora of herbaceous plants and in this respect it differs from the alluvial forests in Russia, where *Populus nigra* takes the place of *P. euphratica*. Antonow is, however, of opinion that the term forest should not be used for this formation, because it only appears in strips along the rivers and has so to speak only one dimension. In my opinion this remark is not quite correct, for in some places at least the vegetation in question has a considerable width, for instance in a deserted river-bed where the conditions of moisture are good.

Where a river bends sharply or has changed its bed, "Starizi" are often formed, enclosed backwaters where bushes and rushes grow, and "other herbaceous forms" occur around the stagnant water. In this connection, large "swamp-lakes", are also mentioned which are frequently formed in the plains by the snow-water in spring. Round these grow salsolaceous plants, but the occurrence of reeds and *Tamarix* makes it reasonable to include these places as riverside thickets. — Such thickets are often extensive, the haunts of wild boars and numerous birds, but as a rule uninhabited by man, hence Antonow calls them "biological oases."

3. The formation of the Loess-steppe is found on the same type of soil as the clay-desert, but with more abundant moisture; it occurs most frequently at the foot of mountains. It is rich both as regards species and individuals. As a type of vegetation it corresponds to the steppes of Southern Russia, but differs in its floristic composition. (Yet Antonow tells us later that no carpet of vegetation is formed, which is an important difference between this and the Russian steppe). As in southern Russia, *Caragana* and *Prunus* grow near streams, so here *Tamarix* is found, and in both countries tall herb-

aceous perennials rise above the lower, brightly coloured ground-vegetation. The following herbaceous perennials are given for the asiatic steppe: *Eremurus, Eremostachys, Astragalus, Cousinia, Centaurea* and several Umbelliferae.

4. The Sand-desert occupying about half the area of Transcaspia is the most recent geological formation. Its flora is very rich, and during the best season, April and May, it looks like a luxuriant garden. The plants include shrubs also annual and perennial herbs, but the shrubs are the most characteristic. This rich and extensive "flora or formation" has more definite limits than the others, its plants are dependent on the sand and do not migrate to other soils. The plants of the loess-deserts and the riverside thickets may intermingle or pass out on to the sand, but sand-plants are never found on loess soil. Saxaul grows both on loess and sand, nay thrives even better on the latter especially on "Ssor" covered by sand, but bushes like *Calligonum* or *Ammodendron* we look for in vain on the clay plain.

Antonow mentions as the most typical sand-bushes: *Calligonum*, *Ephedra*, *Ammodendron*, *Eremosparton*, *Salsola Arbuscula*, *Astragalus dendroides*, *Haloxylon Ammodendron*. — These bushes attain a heigth of $1^1/_2$—3 Arshin (about 1—$2,_{10}$ metres), sometimes under specially favourable conditions they may be 2 Sashen high (about $4,_2$ metres). The stems are short and bent, with a low and richly branched crown. The leafage is very poor. The root-system in several of them is strongly developed. In Saxaul and *Calligonum*, radical branches may be seen on the surface between the dunes giving rise to new shoots and creeping sometimes for a distance of 5—7 Sashen (about $10,_5$—$14,_7$ metres), so that these bushes play an important part in binding the sand. Still more important in this way are: *Aristida pungens* ($0,_7$—1 metre high) which grows as a rule on the tops of the dunes, and *Carex physodes* which frequents more sheltered places among the dunes, and there weaves the sand together with its tangled roots. These two he calls the "conqueror and regent" of the sand-desert.

The following are given as representatives of the remaining herbaceous vegetation: *Delphinium camptocarpum*, *Hypecoum pendulum*, *Roemeria refracta*, *Malcolmia africana*, *Spiro-*

*rhynchus sabulosus, Astragalus sp., Erodium oxyrrhynchum, Alhagi camelorum, Senecio coronopifolius,* less frequent are *Dorema Ammoniacum, Sphaerophysa sp., Rheum sp.*

5. The Promontory-or Stone-steppe is found on hard conglomerate soil at the foot of mountains, between these and the loess-steppe. It is an *Artemisia*-steppe, *A. nutans* being the principal plant. Amongst other species found are: *Stipa orientalis, Papaver pavoninum, Cruciferae, Caryophyllaceae, Astragalus, Umbelliferae (Zosimia, Ferula), Compositae (Centaurea ovina, pulchella, Balsamita, solstitialis, Cousinia turcomanica, dichotoma, lyrata, Achillea santolina), Labiatae, Liliaceae,* grasses and others. *Ulmus nuda* and occasionally the shrub *Zygophyllum eurypterum* occur by the streams.

6. The mountain-flora does not come within the scope of this review.

Next to be considered is the work of S. Korshinsky: "Sketches of the Vegetation of Turkestan" (1896), the first section of which deals with Transcaspia.

The "normal type" of sand-desert, the most extensive and continuous, is Korshinsky considers, "flat or undulating areas of sand" consisting of loose but not drifting sand, and covered by a meagre, yet comparatively rich and rather varied vegetation. Its most characteristic feature is that it consists chiefly of ligneous species: *Haloxylon Ammodendron, Salsola Arbuscula, Calligonum, Ephedra, Ammodendron Karelini, Eremosparton, Astragalus Ammodendron* etc. In the spring many herbaceous plants also occur, most of them growing isolated and not forming a carpet. A few species like *Carex physodes* and *Capsella elliptica*, are sometimes so luxuriant and dense that a green sward or something approaching one is formed. In the autumn the herbs have disappeared, and one finds then perennial species of *Salsola*, little bushes covered with handsome, multicoloured fruits.

The sandy parts are not so bare as one might imagine, Korshinsky says, so that there is really no reason why they should be called deserts. In spring, at least, the soil holds water at a few centimetres depth, and he adds: "I am of opinion that the sharply defined xerophytic character of the vegetation is not so much a consequence of the dryness of the soil but results rather from the dryness of the atmosphere, especially the strongly heated lower layers of the air, combined with the direct effect of the sun's rays, and the reflection of these from the hot bare yellowish-grey sandy soil."

Korshinsky regards the vegetation of ligneous plants described above as specially characteristic for the sand-desert, and he is also of opinion that this is the original vegetation which formerly covered the whole area of sand. The change from fixed to moving sands is, he thinks, due mainly, perhaps exclusively, to the action of man. As soon as roads and inhabited places are left behind, we find the sands more level and covered with the trees and shrubs just named. The nomads are mainly responsible for the extermination of trees and bushes, as they cut them down for firewood and their cattle eat and tread down the vegetation. As it is now we find perfectly lifeless areas, occupied by the high, crescent-shaped "Barchans" devoid of plants. The transition to this is seen in the stage where most of the herbaceous plants have disappeared, and isolated trees and bushes occur with *Aristida pennata* and *A. pungens* still holding their ground.

Even in the barren desert, some vegetation may still be found in places where water from melting snows or river floods has collected in the hollows and deposited finer particles of earth which bind the sand together. In addition to numerous typical sand-plants, many of the more showy herbs grow here such as *Ceratocephalus falcatus*, *Euclidium syriacum*, *Umbelliferae*, *Koelpinia linearis* and many others; Korshinsky (p. 7) gives a long list of them.

A further step in this direction in seen in the "Takyr", flats or depressions covered by water after rain. The water evaporates rapidly leaving a greasy soil, which when dry becomes very hard and cracks, salts frequently crystallising out. "Takyr" are almost always devoid of plants.

At the foot of Kopet-Dagh lies a narrow strip of cultivated land which towards the north is bordered by the desert. It is watered by streams coming from the mountains, but they are few in number and carry little water, so that large patches are left uncultivated among the fields In these uncultivated parts the desert plants are mixed with weeds of cultivation and with species originating from the neighbouring mountains. Noteworthy amongst the desert species are: *Alhagi Camelorum, Salsolaceae, Zygophyllum* and *Peganum Harmala;* the mountain plants are represented by *Leontice Leontopodium, Glaucium luteum* and *Carex stenophylla*, while the plants which frequent the neighbourhood of cultivated land are mainly *Cruciferae* and *Papaveraceae (Roemeria)*; and often *Hordeum murinum, Spinacia tetrandra, Arnebia cornuta*, etc.

From the south-eastern part of Transcaspia, on the borders of Afghanistan, KORSHINSKY describes the vegetation at the foot of the Paropamisus chain. Here the landscape is undulating ("Badchis") with a sandy, but rarely a loose surface. The lower, more gently sloping parts of the "Badchis" have a vegetation which Korshinsky calls "sand-steppe". It consists "exclusively of herbaceous plants or undershrubs which, according to the relief of the locality or to variations in dryness of the soil, stand more or less scattered, but always singly so that they do not form a green sward." This picture recalls the steppes on the black-soils in the south of Russia. Just as *Stipa pennata* is there, so *Stipa barbata* is here in Asia the characteristic plant. Moreover there are several species of *Convolvulus, Onobrychis, Ranunculaceae, Acanthophyllum, Aegilops*, etc., and in the most southern part *Dorema* and *Ferula.*

The higher parts of the "Badchis" have a different vegetation to some extent characterised by other plants, such as *Amygdalus horrida* and *Pistacia vera.* This vegetation cannot be regarded as belonging to the lowlands, and so need not to be further detailed.

KORSHINSKY also gives a short description of the river sides with their thickets of *Phragmites* and poplars, especially *P. euphratica.* The irrigation of the cultivated land is also noted, and the plants cultivated there. His interesting work will be referred to again later.

RADDE's memoir: "Transkaspien und Nord-Chorassan" (1899) also contains many valuable statements about the vegetation.

He describes the hoof-shaped "Barchans" devoid of vegetation so that the landscape looks like a stormy but frozen sea, and the more rounded sand-hills ("Hügelsand") "like a smooth sea with a swell on". On the crests grow *Halimodendron, Ammodendron,* Saxaul and Tamarisks, while the hollows between them are covered by *Capsella elliptica.* The "sand-steppe" he likens to an almost calm sea which in spring bears a rich bloom of *Capsella elliptica, Rheum caspicum, Calligonum, Atraphaxis, Lycium, Zygophyllum, Nitraria, Poa bulbosa, Bromus tectorum, Avena sterilis, Hordeum murinum, Stipa barbata.* — RADDE also describes the sand mounds in the north-western parts of the territory; here in the valleys and on the slopes of the mounds, Saxaul attains its greatest development, while *Ammodendron Sieversii* prefers the loose soil of the crests.

The leafless desert shrubs occur almost exclusively where the sand is in motion; on old-established sand-hills we find for instance *Prosopis Stephaniana, Heliotropium dasycarpum, Delphinium camptocarpum,* species of *Artemisia* and *Cousinia.* — Only plants with tubers or deep running roots keep green long, the rest are quickly scorched.

RADDE's opinion is that the relatively luxuriant "sand-steppe" is the last stage, and that the moving sand will, if left to itself, gradually become covered with vegetation and then the country will in time become level.

RADDE's long account of his travels contains many other descriptive notes on vegetation, but it is unnecessary to enter into further detail here as the work is easily accessible and other references will be made to it later.

The description of Asiatic Russia by M. P. DE SEMENOV (1900) also gives the more important features of the vegetation of Turkestan. He describes the trees of the sand-deserts, *Haloxylon, Salsola, Calligonum* etc. ("des arbres sans ombre, sans fraîcheur et sans vie") and records their importance in binding the sand. There is also an account of the vegetation of the clay-deserts of *Artemisia, Salsolaceae, Zygophyllum* and large *Umbelliferae* with their short-lived flowering period in spring, of the chenopodiaceous vegetation of the "salt-steppe" with its seasonal changes of colour and the dense thickets of poplars and reeds on the river-banks. The work also contains a number of geological, meteorological, and other observations. His classification of the sand-deserts will be referred to later.

The Petersburg Forestry Journal (1901) contains an important article by W. Palezkij on "Sand-binding on the Mid-Asiatic Railroad", and a later contribution has appeared in the Russian Forestry Journal (1908 nos. 31 and 32). The author has for many years superintended the operations for the protection of the Transcaspian railroad against sand-drift, — and in 1899 I had the pleasure of visiting parts of this undertaking under his able guidance.

The paper begins with description of the features of the different landscapes and the dune-formations, the dangers arising from sand, and the different ways in which the drift may block the railroad.

The most effective means of settling the sand-drift is to encourage vegetation; artificial means such as the planting of green turf and reeds are also resorted to. Trees are planted extensively along the railroad in belts 425 to 530 metres wide. Later on these spread naturally and have in some places reached a width of 2—3 kilometres.

The natural conditions of the sand-deserts are extraordinary, he says. It does not rain from May till November, and the precipitation during winter and spring is insignificant. Ground-water containing bitter-salt, moving sands and the broiling heat of summer are other impediments to a luxuriant vegetation. In combating the sand it is therefore necessary to select local plants acclimatised to the conditions, and sufficiently aggressive to establish themselves. Experiments with introduced plants are, however, also made. The principal species used for planting are: Saxaul *(Haloxylon Ammodendron), Salsola Arbuscula, Ammodendron Conollyi, Eremosparton aphyllum, Salsola subaphylla, Smirnowia turkestana, Astragalus paucijugus* and *A. Ammodendron, Aristida pennata, Carex physodes* and various species of *Calligonum*. Short notes on their properties are given which we shall refer to later on.

Nurseries have been established in which stocks are raised for transplanting. As the desert plants often have very long roots which would be damaged by transplanting, the nursery at Farab is located in a place where the ground-water is only about 1 metre down, and $0{,}7$ m. during summer when the water is high in the Amu Darya. The roots on an average do not exceed $0{,}7$ metre (1 Arshin) in this place. The conditions of precipitation and heat render it advisable to sow in the autumn, and before sowing the "seeds" are placed 10 or 15 days in moist sand, then into the soil loosened to a depth of about 30 centimetres. If *Calligonum* is to be sown in spring, the fruits must be kept over winter in moist sand, and the seed-beds are covered with straw as the seedlings are injured by late frosts. — After sowing all that is necessary is to weed the beds and to break up any salt-crusts which may appear, or to strew the soil with clean sand, which prevents the formation of salt-crusts. No watering is done except during abnormally dry seasons, since watering is generally harmful. The seedlings are thinned out, and in the autumn when a year old, they have grown to a height of from $0{,}35$ to $1{,}4$ metres ($^1/_2$—2 Arshin) (The author does not mention which species). The seedlings vary considerably, and this PALEZKIJ considers to be due to differences in the salinity of the soil which interferes with growth. Development is also dependent on the depth to which the soil is loosened, and where this depth is great the plants may attain a height of 2 metres. The distance between the seedlings is also important, greater space giving larger plants.

The separation of the seedlings takes place in the autumn — except Saxaul which is very susceptible to frost, — and from January to March the transplanting takes place. The seedlings are planted in rows at right angles to the prevailing direction of the wind, and it is highly important to select the right species for the different places. Thus low places with ground-water at a depth of $1$—$1{,}5$ metres are more suitable for Tamarisks, and where the subsoil is clayey *Salsola Arbuscula* thrives well. A subsoil consisting of lime and clay is specially favourable to Saxaul, while on pure shifting sand *Ammodendron* and *Aristida* and to some extent *Calligonum* grow readily. The success of the planting is dependent among other things upon the winter precipitation. During the first year, the plants are protected, and if the sand has been carried away, the roots are covered in with sand over which a layer of clay is spread. On an average about half the plants are successful, but the gaps are filled up by a second planting.

It is of the greatest importance for the natural seeding of trees and bushes that many herbaceous plants should grow on the sand; if these are absent, then many seeds of *Aristida pennata* and *Alhagi Camelorum* are sown. The herbaceous plants retain the fruits of the trees and protect the seedlings during their growth.

We have here only referred to those parts of PALEZKIJ's work which deal with the vegetation.

G. J. TANFILJEW in the second Russian edition of WARMING's "Plantesamfund" (Oecology of Plants) (translated by GENKEL, St. Petersburg 1903) gives a survey of the vegetation of Russia. The chapter dealing with deserts is of special interest to us. Desert and Steppe are closely related in the following respects: both are at the present time devoid of trees, they are not leached by running water and the soil is rich in dissolved salts, especially carbonates but also sulphates and chlorides.

In the steppe, however, carbonate of lime is dominant, and the more soluble salts do not attain the same concentration as in the desert. The steppe-vegetation is therefore richer, forming a more or less thick carpet all the year round, and the decomposing vegetable matter gives a dark colour to the upper layers of the soil (for instance in the Tjernosem). In the deserts the carpet of vegetation is either absent altogether or is present only in early spring; during summer and autumn the earth is bare or only sparsely covered with woody stems or dead shoots. No green-sward is present and no dark humus is formed, but dissolved salts are abundant and often crystallize out on the surface.

The Semi-Desert (Loess-desert) is related to both steppe and desert. It resembles the desert in that it lacks the dark surface-layer of humus and the perennial sward of plants, while it has the high salinity of the loess. On the other hand, the luxuriant spring-vegetation is like the steppe, the loess of which is identical with that of the semi-desert.

Tanfiljew gives a short description of the different parts of the Russian desert-territory which almost completely encircles the Caspian Sea.

1. The Calmuck Steppe between the rivers Manitsh and Volga and the Jergeni Mountains. The soil is here mainly clayey, and sparsely covered with species of *Artemisia*, *Achillea*, *Alyssum minimum*, *Lepidium perfoliatum*, *Triticum*, *Poa bulbosa*, *Ceratocarpus*, *Astragalus*, *Alhagi*, *Zygophyllum*, *Anabasis* etc. In sandy tracts the plants include *Elymus sabulosus*, *Calamagrostis Epigejos*, *Euphorbia Gerardiana*, *Agriophyllum* and *Calligonum Pallasii*; in salt-swamps are *Tamarix* and *Salsolaceae*.

2. The Kirghiz Steppe (Inner Horde) between the Volga and the Ural. The soil is saline clay with here and there moving-sands. The northern parts are the most fertile and include depressions with Tjernosem and true steppe-plants; here for instance are seen *Stipa capillata* and *Lessingiana*, *Koeleria cristata, Silene viscosa* and *Otites, Phlomis tuberosa* and *pungens.* etc., while the ordinary chenopodiaceous vegetation may be found on the neighbouring saline clay soil. Farther south the vegetation is poorer and in the sandy areas *Pulsatilla, Tribulus, Cytisus biflorus, Astragalus, Amygdalus nana, Thymus odoratissimus,* etc., are replaced by *Elymus sabulosus, Stipa*, *Poa bulbosa*, *Carex stenophylla* and *physodes.* Some of the latter are also found on the more northern sand areas, but are reported to be less prominent there. On the clay areas species of *Artemisia* are dominant. Low hills of gypsum have a characteristic vegetation (*Matthiola tatarica, Eremostachys tuberosa*, *Fritillaria gibbosa*, etc.).

3. East of the Ural river, Tanfiljew gives as the approximate northern limit of the desert, a line from Uralsk through Ulu Uil, the southern end of the Mugodshar mountains, the town of Irgis (Ft. Uralsk) to the southern spurs of the Ulutau mountains. North of this line lies the Stipa-steppe, which in Tanfiljew's phytogeographical map of the Russian empire is also included in the desert. South of the Stipa steppes there is a salt clay-desert which occupies the peninsula of Mangishlak, the Usturt plateau and the area

between the lower course of Syr Darya, the river Tshu, the northern shore of Lake Balchash and the upper Irtish.

The Stipa-steppe and the Clay-desert have already been referred to in our summary of Borszczow's memoir which is also followed by Tanfiljew.

4. The Sand-Deserts in Transcaspia are described as by Borszczow and Korshinsky.

In Tanfiljews treatise: "Die südrussischen Steppen" (1906), the difference between desert and steppe is again emphasized.

The Russian memoir by A. Rodsewitch: "The Tree-Vegetation of Transcaspia" (1896), is known to me only through a summary by Lipsky in "Contributions from the Botanical Garden in Tiflis", 1902.

Of about 500 species found in Transcaspia, nearly half belong to the desert-flora; of these 17 per ct. are trees and 57 per ct. perennials. The characteristics of the desert-plants are: a strongly developed root-system, sclerenchyma in the stems, the radical branches encased in a siliceous coat, and the leaves poorly developed. The most important sand-plants are: *Haloxylon Ammodendron, Tamarix gallica* (?), *Alhagi camelorum, Aeluropus repens, Salsola subaphylla, Populus diversifolia (euphratica), Ephedra, Eremosparton aphyllum, Aristida pungens var. pennata, Ammodendron Karelini, Calligonum* and *Salsola Arbuscula.*

So far as I know these are all the available memoirs which deal with the vegetation of the Transcaspian lowlands. If all have not been included, I hope that nothing of great importance is left out. Descriptions in general works on plant-geography have been omitted since they must necessarily be compiled from the original works.

## CHAPTER 5.

## Classification of Formations.

On a lovely sunny day in April 1898 the expedition saw the brown mountains of Asia rising above the Caspian Sea. The mountains near Krasnowodsk on the eastern shore of the Caspian are not beautiful, but low, round and arid-looking, they appear, as if scorched by the intense sunshine. No green was to be seen anywhere. It was delightful to get ashore and to glean our first impressions of nature in Asia. Plants were there on the mountains, although rather scattered; *Gagea*, *Tetradiclis*, *Arnebia* are here with many others, these are representative of three important forms of desert life: Geophytes, Halophytes and Annual Spring-Plants. There is scarcely time to observe more as the train soon starts eastwards and we bid the sea farewell for a long time to come. We pass through and across brown stony hills and flats with scattered bluish grey or green tufts of plants, foot-high Umbellifers and low leafless bushes. Then the sun sets. Next morning brings the finest sight we ever saw, the earth is covered with flowers, glowing poppies and tulips, green grass and Irises and many other flowers. Great flocks of birds soar in the air, and camels graze among the cupola-like "kibitkas" of the Turkomans. Towards the north the view is open, but to the south the low slaty heights of the Kopet Dagh on the Persian border, obstruct the view.

We enjoyed this beautiful scene all day. Next day all was changed, for now the train speeds through the awe-inspiring waste of the sand-desert. It is as Radde has said, a stormy sea frozen into stillness; enormous ocean-waves without motion, only the foam on the crests is active, it is the sand rising in clouds like smoke. As far as the eye can reach all is greyish-brown sand. Not a plant! Yes there is one, a grass on the top of a dune, its coarse leaves lashed by the wind. More come into view and then we look curiously at the Switch-plants. They stand in the loose sand which is whirled round them and their slender leafless branches are driven before the wind. In reality there are several species but they are all alike switches or rather small leafless birch brooms, and they are leafless, or look so at first sight.

Then the train passes the Oxus or Amu Darya whose brown water coming from the Pamirs flows below us while we slowly cross the long bridge, which extends to 3 kilometres.

The river banks are occupied by poplars and immense tufts of grass (*Erianthus*).

East of the Amu Darya we are on the desert of shifting sand again, and then the large oasis of Buchara is reached. The sun is shining on green fields, tall poplars and brown clay houses. This is our first camping place.

During these past days we have while traversing them acquired a preliminary knowledge of three of the greater plant formations of Transcaspia, namely the Clay-desert, the Sand-desert and the Riverside Thickets. The first we have seen in its luxuriant spring aspect characterized mainly by short-lived annuals; the second, seen at its worst, is distinguished by the exceptionally severe conditions under which only a few, specially equipped plants are able to live; the third is a fringing or gallery-forest ("Galleriewald") rigidly limited to the banks of the river.

It is the object of this contribution to describe these and other formations more closely. First, however, it will be necessary to consider the plant-formations of Transcaspia recognised by earlier writers and to explain our choice of names used to designate the formations in the following pages:

In the Caspian Depression-territory — extending from the southern limit of the forest in European Russia to the Caucasus and the border-mountains of Persia —, Grisebach recognises three formations, namely Grass-steppe, Sand-steppe and Salt-steppe (I p. 455). The first of these has a soil with humus and is the south Russian steppe which does not come within the scope of this work. Under Salt-steppe he records a series of other "formations" (p. 461) between which, however, he does not distinguish sharply. The following three are noteworthy: 1) Dry Clay-steppe with a few Saxauls, annual *Chenopodiaceae* or *Artemisia fragrans* or *Anabasis aphylla*, 2) More moist steppe with bushes of social *Salsolaceae* and Tamarisks, 3) Salt-swamps.

Borszczow distinguishes 3 "areas" (see p. 24), namely Salt-desert, Clay-desert and Moving-sand-desert besides two, which lie outside our area. Finally Antonow has in addition to "Mountain-Flora", five formations namely Loess-desert, Loess-steppe, Promontory or Stone-steppe, Sand-desert and the riverside thickets.

Of the authors named, Borszczow, as already stated, does not use the word formation, and Antonow, who uses it, defines it as a "natural plant-group". Grisebach's definition of formation is well known (1838): A group of plants having a definite physiognomic character, and characterised by a single social species or by several species which although differently organised, yet have some feature in common.

Though there is disagreement between the concept of formation held by these authors and the concept maintained in the following pages, it is in this case of no vital importance. In Transcaspia the natural conditions are so uniform, and the boundaries so distinct, at any rate between the more important formations (those observed on our first railroad journey), that there is very little probability of any misunderstanding.

The formations to be described by us are regarded as plant-communities, belonging to certain growth-forms — always the same within the same formation — and these are determined by and adapted to common conditions. This is the same conception as Warming has (1909 p. 140). On practical grounds the conditions of soil will be employed in the following descriptions as the principal basis of classification.

The Transcaspian formations or "areas", described by different authors are given in the following table arranged in order to show their relationship. In the column to the right will be found those formations which I regard as necessary for distinction.

| Grisebach | Borszczow "Territories" | Antonow | Paulsen |
|---|---|---|---|
| Salt-steppe | Salt-desert | Loess-desert | Salt-desert |
| | Clay-desert | Loess-steppe | Clay-desert |
| | | Stone-steppe | Stone-desert |
| Sand-Steppe | Moving-sand-desert | Sand-desert | Sand-desert |
| | | Riverside Thickets | Riverside Thickets |

It will be understood that the Salt-desert is regarded by BORSZCZOW and PAULSEN as a part of ANTONOW's Loess-desert of which another part together withe Loess-steppe is referred to Clay-desert. The salt-desert of BORSZCZOW is not however the same as that of PAULSEN.

The vegetation of the lowlands of Transcaspia is in my opinion, to be classified under the following natural formations:

1. Salt-desert corresponding to parts of ANTONOW's Loess-desert.
2. Clay-desert corresponding to ANTONOW's Loess-steppe and parts of his Loess-desert.
3. Stone-desert. Under this heading are placed not only deserts with stony soil, but also the small, scattered groups of mountains.
4. Sand-desert.
5. The Riverside Thickets.

The outstanding features of the formations are sufficiently indicated by the above titles.

The principal factor which determines the formations is the amount of water. The riversides and the salt-deserts have the moister soil, the clay-desert has the driest, in the physiological sense at least. The physical constitution of the soil also plays a great part especially all that is involved in the difference between sand and clay. Beyond these the life-conditions of the plants in the different formations are still very obscure.

To the natural formations one should add the tilled soil, the formation of cultivation, which in this work is left out of consideration. It only amounts to 2 per ct. of the total area (SCHWARTZ p. 576).

In selecting names for the formations I have avoided the word Steppe. Like SCHIMPER, KRASSNOW (1899) and TANFILJEW (1903, 1905), I prefer to recognise grass-steppe alone as Steppe (see p. 41). Carbonate of lime is here the dominant salt, the vegetation is on the whole uniform all the year round and has produced a surface layer of dark soil. The desert, on the contrary, is an open formation on soil which has not been greatly transformed by the vegetation, and which is rich in sulphates and chlorides.

The vegetation provides a further difference between the steppes of southern Russia and the Transcaspian deserts. Without entering into details on the vegetation of the steppes, we may take for instance Gruner's description (p. 106) which states that during summer and autumn a large proportion of non-xerophilous or only slightly xerophilous plants appear (*Melilotus*, *Marrubium*, *Teucrium*, *Chenopodium*, &c.). In Transcaspia the summer and autumn types of vegetation are quite distinct, as will appear from the following chapters.

The same has been pointed out by Krassnow (1899), namely that the plants of the desert have a special organisation which enables them to endure the severe drought. (He says this without any reservation although the ephemeral plants might well be taken as exceptions.) Steppes on the contrary are covered by a grassy vegetation not specially adapted to droughts, and therefore liable to be scorched. As a further disparity between desert and steppe, Krassnow points out that the former cannot produce crops except with the aid of irrigation whereas the steppe can. Both are devoid of forests.

It seems moreover to be of importance that trees are absent from the steppes (the grass-steppes), while the desert-vegetation in a considerable degree is characterised by trees and bushes. This was also pointed out by Grisebach (1872, I, p. 400). His view was, that desert is not a scientific definition but means "uninhabitable places", and, as already stated (p. 45), he included all formations under "steppe". His opinion is that the different forms of steppe are not caused by climatic conditions but originate in the soil. Where there is clay near the surface the water from precipitation does not penetrate deeply so that grasses and herbaceous perennials can live, and we find a grass-steppe. But where sand stones and rocks attract the water to greater depths, we have a desert, which is richer in ligneous plants than the grass-steppe, because their roots go down deeper. In the desert the surface consists of permeable strata.

Apart from the fact that the desert is certainly dependent upon the climate and not upon the soil, and that its surface in many places consists of impermeable clay, the reasoning of GRISEBACH has a great amount of truth. KOSTYTSCHEFF, ISMAILSKY and KRASSNOW independently point out the same circumstance in the Russian steppes, that the absence of tree-growth (among other things) is caused by the surface layer of the soil not permitting the water to penetrate into the depths. With reference to Transcaspia, ROMANOWSKI states (p. 56) that in layers of gravel under the loess, water is found and is widely diffused under the soil. This may be rain or snow absorbed through sand[1]), or it may originate from rivers which have sunk into the sand. "Consequently the sand-steppes of Turan cannot be said to be absolutely waterless."

Here then we have probably the reason — or one of the reasons — why the desert has trees, the steppe none. The presence or absence of trees taken along with the relation of the water to the soil, seem to me so important, that they, together with the climatic conditions and the conditions of the soils, must be regarded as distinguishing characters between steppe and desert.

For my own part I regard the steppe (grass-steppe) as mainly a closed plant-formation (or group of formations) occurring on soil rich in humus without excess of sulphates and chlorides, and with a comparatively moist surface-soil; the vegetation consists of herbaceous perennials, undershrubs and annuals while trees and bushes are wanting.

The soil of the desert, on the contrary, is devoid of humus or very poor in humus, and contains many sulphates and chlorides. The subsoil is (always?) better supplied with water than the surface. The formations are very open and they frequently include trees and bushes.

This attempt to explain the terms steppe and desert may not lead to any sharp distinction between the two, so much the less

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[1]) In this connection it may be pointed out that the steppes of southern Russia have their maximum precipitation in summer so that the water will evaporate quicker than in Transcaspia where maximum occurs between winter and spring. O. P.

as it is mainly based on studies in South Russia and Transcaspia. But the distinction between steppe (grass-steppe) on the one hand and desert on the other, seems easier to apply than the one maintained by most authors, for instance Warming and Vahl. Phytogeographical literature defines so many different kinds of steppe — Meadow-steppe, Grass-steppe, Vermuth-steppe, Salt-steppe, Sand-steppe, Bush-steppe and even such types as Orchard-steppe poor in grass, Tree-steppe, Steppe-forest &c. (Engler 1910) — that it is hard to see what they have in common except that all are more or less xerophilous formations.

What Schimper, Krassnow and Tanfiljew have termed steppe, is not an extreme xerophilous formation. The Sand-steppe ("die Sandpuszte", Adamovic p. 320, Woenig) belongs to the steppe type, but differs from the "Sand-steppes" described from Transcaspia which are deserts. Steppes, according to the definition given here, do not occur in Transcaspia at all.

## CHAPTER 6

## Formation of the Salt-Deserts.

Under this heading are classed localities where the plants grow on soil so saline that the salt crystallizes out as a layer covering the surface. The conditions which render this possible are: 1) the presence of salts in solution, 2) facilities for the solution reaching the surface. It is essential for this that the underground water-table is not located at too great a depth. It is usual therefore to find salt-deserts in depressions. The constant evaporation from the surface causes the salts to crystallize out, and a fresh solution diffuses constantly from below. Where the soil is loess, this upward diffusion takes place rather easily on account of the capillary structure.

"Ssor" is the name given by the natives to wet saline flats. They are often found among dunes and are said to be generally flooded during winter and spring. A "Ssor" is not a very pleasant sight (fig. 2). The ground is flat and white like snow so that in the strong sunlight it is dazzling to the eyes. Very often this is all that is to be seen, one can walk hundreds of paces without finding a plant. In some places the salt crackles under the feet, in other places the soil is soft to the tread because under the salts, it is moist or wet. One slips frequently on the greasy greenish-brown clay. In such a place the water-table may be barely 1 metre below the surface.

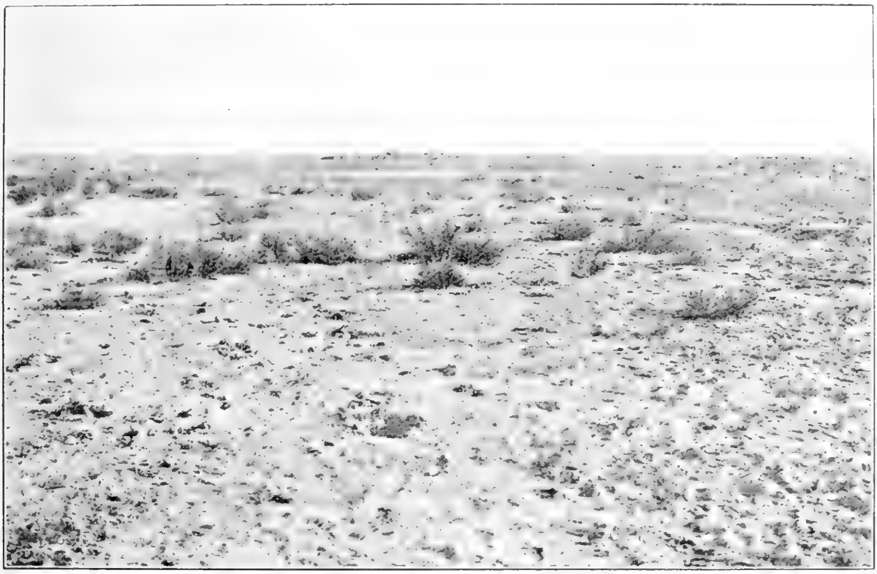

Fig. 2. "Ssor" (Salt-desert) near Buchara. The ground is white with salt and occupied by scattered *Aeluropus littoralis* and *Halostachys caspica* (the bushes). Month of May.

In small depressions the soil is brown, because here it is so wet that the salts are kept permanently in solution. Also on small elevations the soil may be brown and only coated with a thin, granular, hard incrustation. Towards summer the salt in some places becomes dry and dusty.

The salts are mainly sulphates especially of sodium and magnesium, but there is also gypsum and common salt[1]) Crystals of gypsum are sometimes found in the earth.

[1]) See above p. 9.

The vegetation is exceedingly scanty. At long intervals small stunted bushes of *Halostachys caspica* may be seen, a leafless dwarf-bush with assimilating shoots like those of *Salicornia*.

*Halocnemum strobilaceum*, a small bush, distinguished by its globular dwarf-shoots, has a similar appearance. Also *Lycium ruthenicum* is a bush with fleshy cylindrical leaves; like the other two it scarcely attains the height of one foot on this wet saline soil, but under favourable circumstances it may become many times larger. (See for instance the chapter on the riverside thickets).

A number of annual species are also characteristic for the salt-desert, or may be found there. The more important of these are: *Salicornia herbacea, Halopeplis pygmaea* (this has exceedingly succulent, thick and almost globular leaves), *Sucæda setigera, arcuata, corniculata* etc., *Bienertia cycloptera, Halogeton glomeratus, Statice leptostachya* and *spicata*, species of *Salsola*, (*S. crassa, obtusifolia* etc.) and *Halimocnemis* which, however, usually occurs more frequently on somewhat drier soil. The same holds good for *Frankenia pulverulenta* and the prostrate undershrub *Frankenia hirsuta*, also for *Anabasis*, some species of which are herbaceous perennials, some undershrubs, and all with leafless assimilating shoots. Other herbaceous perennials are *Statice otolepis* with broad leaves arranged in rosettes, and *Aeluropus littoralis*, a prostrate bluish-grey grass.

My experience is that *Aeluropus, Halostachys, Halocnemum* and *Salicornia* are the species most frequently met with on "Ssor". On one occasion near Chodsheli (in July) I found *Phragmites communis* in a locality of this kind. The soil was moist and brown at the depth of a few centimetres, but the surface was dry, white and dusty with salts. The *Phragmites* plants were small, and with surface-runners as when the species grows on wet sand in the north of Europe, but these runners did not exceed 30 cm. in length. *Tamarix* bushes, half a metre high, were growing scattered along with *Phragmites*.

The species mentioned above are all Halophytes. Most of them are Chenopodiaceae and belong to the succulent, leafless or leaf-bearing type, with the exception of *Aeluropus*, *Statice*, *Phragmites* and the salt-excreting Frankenias and Tamarisks. Their internal structure is dealt with in chapter 13.

Most of the species are annuals and all are summer-plants, none being ephemeral spring-plants. The annual Statices *(S. leptostachya* and *spicata)* are probably not very long-lived, but on this point I have no definite observations.

As regards the natural development of "Ssor", I can only say that on one occasion I observed that sand from the neighbouring sand-desert had drifted across the salt-flats, and sheltering behind plants of Salicornia had formed miniature sand-dunes. If this sand remains long enough it will become permeated by the moisture coming from below, and the salt incrustation must form over it. In this way the surface may be raised a little. This process does not seem, however, to play any great part, because I have always found clay under the salt incrustation, but further examination might perhaps reveal the presence of sand.

That the barrenness of the salt-desert is due to the want of fresh water alone, was illustrated by a striking example seen near Buchara. Here in May 1898, two parallel ditches were dug through a snow-white salt-desert, and the excavated material was made into a mound between them, so that the mound and the double ditch surrounded a square piece of of ground. The inner ditch was connected by a long straight ditch with the irrigation system of some tilled fields in the neighbourhood. The piece of ground enclosed by the mound and the ditches was perfectly green, *Aeluropus littoralis* having spread so luxuriantly that it almost formed a carpet of vegetation and so dense that it almost suppressed all the other halophytes, only a very few *Halostachys* being left.

Outside the outer ditch the ground was white with salt and covered with scattered *Halostachys caspica* and *Aeluropus* (fig. 3).

The peasants told me that the enclosed piece of ground was made into a field this year, that it had only once been irrigated (through the long straight ditch) and that in the autumn they intended to sow it with wheat. Middendorff, however, maintains (l. c. p. 123) that saline soil must be washed for two winters before it is fit to be tilled.

Batpak or Batkak, according to CHOROSHKIN (cited by MUSKETOW p. 655), must be closely related to Ssor. These are swampy depressions with efflorescent salts, and they are nearly always found by salt-lakes and may be partly covered by water. It must be areas of this kind which BORSZCZOW

Fig. 3. To the left Salt-desert with scattered *Halostachys caspica.* The soil to the right of the mound has been irrigated once and is covered with a thick growth of *Aeluropus littoralis.* Near Buchara in May.

has described as "Salt-deserts" and whose brilliancy of colour he admires so much. ANTONOW'S "Swamp-lakes" must also be of this same type.

If the above assumptions are correct, Batpak must be more swampy than Ssor. Only near Chiwa have I seen salt-swamps which can be classed in this category. These are small, shallow, stinking salt-lakes, surrounded by a snowy-white salt-steppe which is flat or slightly undulating. The salt-plain is similar to the Ssor described above, and has large tracts without any plants, but in most of the depressions are found fresh green groups of *Salicornia* or *Halimocnemis.*

Some of the depressions have been filled with water, but are now quite dried up and only contain thick incrustations of sodium and magnesium sulphates or common salt (see above p. 11). On the banks of the small lakes *Salicornia* is dominant both in and above the water. Most of the specimens on shore were red, those in the water were generally green. Round the foot of each plant, including the dead ones, there was a granular mass of salt, which reached a couple of centimetres up the stalk. This must have been formed when the water was higher than now (analysis no. 4 p. 11). The following plant-species were found on the bank of the lake. *Aeluropus littoralis,* low and withered *Phragmites* (this was in the middle of July), *Scirpus affinis.* and in the water *Ruppia maritima.* In a few places, a little way from the banks, low Tamarisk bushes, *Alghagi Camelorum* and *Halimocnemis villosa* were mixed with the Salicornias.

These few observations will indicate that the vegetation is mainly the same as on "Ssor", and that the difference between "Batpak" and the former is therefore scarcely of any oecological or phytogeographical importance, at any rate if the water-plants of the lakes are left out of consideration.

"Takyr" is the name given to flat depressions, often of great extent (several kilometres) and which in a dry condition have a hard, clayey and slightly saline surface. They are often found in depressions among the dunes. In spring they are under water and from this fine particles of material transported by water or wind are laid down. Thus, by degrees, stratified water-loess is formed and prevents the water from sinking into the ground. When "Takyr" are dry, the bottom is hard like a threshing floor and the surface cracks and peels off in crusts. These flats are, as a rule, perfectly devoid of vegetation, because, Radde suggests, they dry up late in the year and at a time when seeds cannot germinate on account of the heat of the sun. I have never seen plants on "Takyr", but Radde mentions that on certain low sandhills which rise above the water during spring, a few *Chenopodiaceae* may be found. Along the margins, that is where the water first subsides, a poor "Wermuth-flora" (*Artemisiae*), is also said to exist, and the stiff-leaved grass *Crypsis aculeata* is said to grow here. These latter species indicate that "Takyr" is also closely related to the Clay-desert.

From what has been said about the Salt-deserts, we can deduce the following characteristics of the formation: it consists of annual or perennial Halophytes of which a few are dwarf-bushes, very few are bushes (*Tamarix*) and none are trees. The plants grow scattered on a very saline soil. There is no spring flowering period but all the plants vegetate throughout the summer or, at least, far into it. This last feature I regard as the chief distinguishing characteristic between this formation and the Clay-desert.

The formation does not fall in with GRISEBACH's Salt-steppe or BORSZCZOW's Salt-desert both of which occur to some extent in the Clay-desert. This is indicated by the fact that both authors mention trees and bushes as constituents of the vegetation.

## CHAPTER 7

### The formation of the Clay-Deserts.

Clay-deserts are distinguished here as areas which have a clay substratum, and which do not contain salts to the extent that they to a greater amount come to view on the surface. This concept is to some extent identical with "The area of the Clay-deserts" in BORSZCZOW, but parts of his Salt-desert also belong here. ANTONOW's formation of the "Loess-steppe" belongs here, likewise "the Clay-desert" with the exception of the saline places, which are here classed under the preceding formation.

According to many authors, Clay-deserts are very extensive in the lowland of Transcaspia (comp. BORSZCZOW above p. 25, and ANTONOW p. 32), and RICHTHOFEN regards them as "the true normal steppes of Central-Asia".

The soil of the Clay-deserts differs from that of the Salt-deserts by its greater dryness. When these two formations are found together, the Salt-desert always occupies the deeper parts. The saline ground-water cannot diffuse up to the surface of the Clay-desert, therefore no salt, or only a little, crystallises out there. It must be kept in mind that the ground-water in the desert is almost always saline, and that fresh water is only found in the underground streams which have washed out the salts from the water-bearing layers (Baer 1856 p. 47).

The clay forming the surface of the desert is mostly loess in the southern parts. Pure compact clays (Aralo-Caspian formations?) are also said to occur in the Clay-desert (Borszczow, see p. 25), but I have not seen any.

The Loess includes a proportion of fine sand, sometimes quite as much sand as clay or even more, and it frequently contains mica. (Obrutshew, cited by Radde 1899 p. 19). It is moreover unstratified, rich in lime, very porous and totally devoid of stones. When water is present, loess is a very fertile soil for vegetation. Below it, at a depth of 7—10 metres, layers of sand are generally found alternating with thin layers of clay containing gypsum.

Because of its porous structure loess absorbs water easily, but as the surface-soil is generally compact, that only absorbs water to a slight degree. The result is that the water from precipitation easily runs off, or remains on the top and evaporates. As loess has in addition a high water-capacity ($59,_5$ per ct. of dry weight, Clements), the upper layers retain the water absorbed, so that it does not penetrate deeply and is therefore exposed to rapid evaporation[1]). According to Wysotzki (cited by Ramann p. 402) there is found under the “live” layer, which contains the water of precipitation, a “dead” layer with its water-content unchanged, below this follows the layer containing ground-water (if there is any). Accordingly loess is not favourable to tree-growth as it prevents water from sinking down to where the tree-roots can get it (comp. above p. 48).

It is likewise of importance that loess being a rather fine-grained soil retains the water, so that the roots of plants can only absorb a proportionately small percentage. The percentage available to the plants Clements calls Chresard, as

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[1]) Kostytscheff p. 113, Ismailsky p. 24, Ramann 1905 p. 415.

opposed to Echard, the percentage retained by the soil and which the roots cannot absorb even if the plant wilts. According to CLEMENTS (p. 31) loess can absorb 59,3 per ct. (of its dry weight), and of these 49,2 per ct. are Chresard, 10,1 per ct. Echard.

In the case of clay CLEMENTS gives 9,3 per ct. Echard, SACHS has 8 per ct. (Vorlesungen, 2. Aufl. p. 239). Sand can absorb much less water, but on the other hand, almost all the water is available for the plants: the Echard is very small (Comp. E. GAIN 1895).

The capillarity of loess is considerable, so that where ground-water occurs it is able to raise this higher than sand, although the rate of movement is slower. On the one hand this process brings the deeper-lying water within reach of shorter roots, but on the other hand it promotes the evaporation of ground-water in loess as compared with that in sand.

Since the surface of loess is even and fine-grained, more water will evaporate from it than from a sand-surface (RAMANN p. 262). Another factor which promotes this is that loess has a dark colour and is therefore strongly heated by the sun. MIDDENDORFF records the following surface-temperatures on a sunny day in May. On loess 62° C., on a white salt-incrustation 45° C. The lower temperature of the salt-incrustation is due to combined evaporation and reflection.

Thus it will be seen that loess under dry conditions is as unfavourable to vegetation as it is favourable when water is present.

The maximum of precipitation (p. 17) for the areas we are considering occurs during winter or spring, whereas the summer is practically rainless, but very hot. The plants of the clay-desert which live through the summer in a vegetative condition cannot be adequately supplied by the small proportion of the comparatively limited spring rain which remains in the clay-soil. These plants, the Summer-Plants, must therefore supplement their water-supply from the saline ground-water. Thus one finds that in the true dry Clay-deserts where neighbouring mountains do not make the conditions specially favourable, the plants are almost all Halophytes. Conspicuous amongst them are many *Chenopo-*

*diaceae* both annuals and perennials. These plants do not die or go to rest till the autumn. SCHIMPER calls such plants "Ground-Water Plants".

Another group of plants satisfy their water-requirements from the precipitation of the winter and spring, the melting snow and rain-water which is stored in the upper layers of the soil. When the dry hot time comes (in May—June) most of the available water (Chresard) from these strata evaporates, and they become very dry. What water remains becomes more concentrated and saline through evaporation (BERNATSKY p. 209), and as the plants dependent on the water in the upper layers — the Spring-Plants — are not xerophilous or only slightly so, the increasing heat soon makes them wither. Before this takes place, however, their development is finished, and they have dispersed their seeds. Most of the spring-plants are annuals or ephemerals, as VOLKENS terms them, but there are also some bulbous plants and other perennials, especially in the more favourable localities. These perennials go to rest when summer comes, and assimilate and bloom only in spring.

This distinction between a spring-vegetation and a summer-vegetation has long been known for many deserts and steppes. (It is also present, though perhaps less pronounced, in the whole region of temperate winter-rains). GRISEBACH (1872 I p. 449) has already recorded *Artemisia* as one of the few perennials ("Stauden") which vegetate through the summer, and he also states that most annual plants die quickly during the spring, whereas some annual *Chenopodiaceae* live through the summer, blossom in the autumn, and do not die till the frost sets in. — The spring-flora of the South-Russian steppe has been described among others by GRUNER and TANFILJEW, that of Egypt by VOLKENS, and that of the desert-territory of western North-America by MAC DOUGAL, THORNBER and others. Here we find two maxima of ephemeral plants corresponding to the two rainy seasons of winter and summer.

We shall first describe the Transcaspian Clay-desert in its Spring aspect, and afterwards attempt to present a picture of the more sombre aspects of Summer and Autumn.

Certain forms of the sand-desert also have these two aspects, and one finds here in places a quickly fading Spring-vegetation; this is referred to in chap. 9.

The spring-flowering period of the Clay-desert attains its richest and finest development at the foot of the mountains, for instance at the Persian Kopet Dagh and the western Thian-Shan. In such places the amount of water is greater than on the plains, and this causes in itself a richer vegetation of spring-plants. Moreover there is often cultivated land at the foot of the mountains, and weeds from there along with plants from the neighbouring mountain slopes mix with the plants of the desert (Korshinsky see p. 36). Such deserts, rich in vegetation, Tanfiljew calls Loess-Desert-Steppe (the exact term used is not easily translated from Russian!). "Semi-Desert" will be used to indicate them in the following account.

A sketch of such an area has already been given (p. 44). In spring it certainly does not resemble a desert. Looking at the mass of flowers one obtains an overpowering impression of richness, vigour and luxuriance. A closer examination, however, reveals traces of the desert nature.

The plants do not form a close carpet or they do so only in patches, whereas in other places the soil is quite naked especially where salts crystallise out as a light dusty covering which gives the soil a greyish colour. Here and there among the fresh-green flowering plants one finds a grey *Artemisia* or an almost leafless low chenopodiaceous bush; they are still very backward in their development and one can see that their season is still to come. In a few places there are small stretches of moving-sands in the midst of the flower-decked area; these are bare or scantily covered with scattered coarse tufts of grass or low grey bushes.

The following is a list of the plants which bloom during the spring in the Semi-desert, together with a short summary of the characters they have in common.

Grasses are the principal constituents of the vegetation, and of these *Poa bulbosa* is by far the most dominant, that and the less important *Hordeum secalinum* are the only perennial grasses. The shoots of *Poa bulbosa* have, as is well known, a bulbous swelling at the base, and the resting buds on this are well protected both against drought and cold. I have always found the ears viviparous. Other grasses of importance are: *Apera interrupta, Trisetum Gaudinianum, Festuca ciliata, Nardurus tenuifolius, Koeleria phleoides, Triticum Aegilops* and *orientale, Agropyrum squarrosum, Schismus minutus, Bromus tectorum, oxyodon* and *Danthoniae, Hordeum*

Fig. 4. Semi-desert at Chawast N. E. of Samarkand. In the foreground half-withered leaf-rosettes of *Ferula Asa foetida. Artemisia sp.* dominant, with *Poa bulbosa, Haplopyllum lasianthum, Carum turkestanicum, Eremostachys labiosa.* Month of May.

*crinitum* and *secalinum, Boissiera bromoides.* All these grasses are annuals, rather low-growing, scarcely a foot high, and with flat leaves.

The "flowering herbs" include a number of annuals. The poppies first attract the eye: *Roemeria rhoeadiflora, Papaver arenarium* and *pavoninum.* Then one sees a great number of *Cruciferae* (*Malcolmia africana* and *Bungei, Alyssum marginatum* and *linifolium, Sisymbrium*-species, *Goldbachia laevigata, Leptaleum filifolium, Cryptospora falcata, Euclidium syriacum, Chorispora tenella*); also *Boragineae* (*Anchusa hispida, Arnebia* *linearifolia, Asperugo procumbens, Lappula*-species, *Heliotropium europaeum, Onosma hispidum, Nonnea picta*), *Umbelliferae* (*Aphanoplema capillifolia, Carum confusum* and *turkestanicum,*


Fig. 5. Representative ephemeral plants from Clay-desert: a, *Goldbachia laevigata*. b, *Lallemantia Royleana*. c, *Matricaria lamellata*. d, *Koelpinia linearis*. e, *Caucalis leptophylla*. f, *Ceratocephalus orthoceras*. g, *Malcolmia Bungei*. h, *Hypecoum pendulum*. i, *Acanthopleura capillifolia*. j, *Lappula spinocarpos*.

*Caucalis leptophylla*), and *Labiatae* (*Hypogomphia turkestana*, *Lallemantia Royleana*, *Ziziphora tenuior*). The following will illustrate various other common families of annuals: *Spinacia*


Fig. 6. Ephemeral and perennial Spring-plants from Clay-desert. a, *Delphinium persicum*. b, *Valerianella turkestanica*. c, *Spinacia tetrandra*. d, *Gentiana Olivieri*. e, *Andrachne telephiodes*. f, *Plantago lachnanta* g, *Geranium tuberosum*.

*tetranda, Koelpinia linearis, Matricaria lamellata, Ceratocephalus falcatus, Hypecoum pendulum* and *trilobum, Trigonella*

Fig. 7. *Eremostachys labiosa.* May.

*monantha* and *longiflora, Euphorbia pygmaea, Galium tricorne, Delphinium rugulosum* and *persicum, Nigella integrifolia, Astra-*

*galus filicaulis* and *camphylotrichus, Plantago lachnantha, Tribulus terrestris.*

Here and there in patches are found the stiff-haired Chenopod *Halocharis hispida*, or *Bassia sedoides*, and often on saline spots there is the very small succulent *Tetradiclis tenella.*

Noteworthy amongst the perennials which bloom in the spring are a fine red *Tulipa sp., Ixilirion Pallasii*, with blue blossoms, *Allium Tschulpias* and other species, *Gagea reticulata*, the tuberous geophytes *Geranium tuberosum* and *Leontice incerta*, besides *Iris caucasica, falcifolia*, etc.

*Eremostachys labiosa* (fig. 7), a foot-high Labiate with handsome Acanthus-like foliage and large light flowers is so plentiful in places that the green grass is dotted over; it has tubers and is a hemicryptophyte like *Ferula Asa foetida.* This latter also dominates large areas in some places with its large yellowish-white compound umbels rising a metre or more above the ground, in other places it is represented only by rosettes of large dissected leaves which are already turning yellow at the end of May; the plant has tubers and thick rhizomes.

*Rheum tataricum* occurs locally spreading its large bossed leaves, a metre wide over the ground. I have not seen it in bloom, but to judge from an illustration published by Tanfiljew (1903 p. 390) the inflorescence is strongly branched and rather low. In the middle of May the leaves are already turning yellow.

Other hemicryptophytes found during spring in the semi-desert are: *Astragalus Alopecias* with vigorous prostrate shoots which have multipinnate silver-white leaves and dense yellow flower-heads, *A. sogdianus, A. macronyx* with its yellow blossoms on short stalks at the base of the long leaves, *A. mucidus, flexus, orbiculatus, Petunnikowi* and other species, *Solenanthus petiolaris, Gentiana Olivieri*, several species of *Scorzonera* with tubers, *Taraxacum sp. Dianthus crinitus* and *angulatus, Ranunculus Sewerzowi, oxyspermus* and other species, *Haplophyllum lasianthum, Lepidium Draba, Andrachne telephioides, Onosma hispidum, Achillea micrantha, Cachrys didyma, Carex stenophylla var. desertorum*, species of *Carum, Peucedanum,* *Tragopogon*, etc. Here and there may be seen the erect blue inflorescences of the parasitic *Orobanche amoena.*

The plants just mentioned belong to the Spring-plants. Both annuals and perennials are represented, the former being predominant. The perennials are either bulbs, tuberous geophytes or hemicryptophytes. Rhizome-geophytes seem to be absent, with the exception of *Garex stenophylla* which is generally a sand-plant; nor is the stiff clayey soil favourable to them.

The spring-plants, with the exception of *Ferula Asa foetida*, are low, ranging from a few centimetres up to about 30 cm, and they are as a rule soft pliant erect herbs with no pronounced xerophytic structure (see figures 5, 6, 7). A frequent character is that the leaves or the leaf segments are narrow, linear or sometimes filiform (*Leptaleum, Euphorbia pygmaea, Valerianella, Koelpinia, Caucalis, Aphanopleura, Carum confusum, Peucedanum* &c,), and generally hairy. The *Astragalus* species have multipinnate leaves, *A. mucidus* with about 20 pairs of leaflets, *A. macronyx* about 30 pairs.

Plants with broader, elliptical or ovate leaves are less common, for instance *Euclidium syriacum, Malcolmia africana, Goldbachia laevigata.* The leaf-blade in most of them is downy or setaceous, while *Alyssum marginatum* and several *Cruciferae* have stellate hairs. *Cousinia* and *Galium tricorne* are thorny. A good many plants occur which are glabrous or nearly so, for instance: *Koelpinia, Trigonella, Valerianella, Aphanopleura, Peucedanum, Goldbachia, Spinacia, Hypecoum.*

Erect and short stems are the most common. The occurrence of a number of plants with prostrate stems (e. g. *Arnebia decumbens, Trigonella, Galium, Leptaleum filifolium, Andrachne telephioides*) is a natural feature of a vegetation which is not dense; between the plants there is enough space and light for prostrate stems. These do not apparently give off roots; there are neither above-ground runners nor subterranean ones.

A few rosette-plants occur, both annuals and perennials. Annual rosette-plants are represented by *Hypecoum, Plantago lachnantha, Ceratocephalus*, perennials by *Taraxacum, Gentiana Olivieri.* There are several semi-rosette-plants (Raunkjær 1905

p. 390) i. e. plants with the greatest number and the most vigorous leaves placed at the base of the stalk: *Ranunculus oxyspermus* and *Sewerzowi*, *Eremostachys*, *Astragalus macronyx* and *sogdianus*, *Cachrys didyma*, and to these may be added a number of ephemerals e. g. *Malcolmia Bungei* and *africanum*, *Sisymbrium pumilum*, *Goldbachia laevigata*.

The presence of rosette and semi-rosette plants is also in accord with an open plant covering, since a dense vegetation will favour plants with elongated shoots and high-placed leaves.

As regards the floral features, small flowers seem to be more abundant than large ones, and white and yellow flowers are more frequent than blue or red although the red species, such as the poppies and tulips, are often prominent when they occur in masses.

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Some idea of the diversity of the spring vegetation of the Semi-desert may be obtained from the following representative lists of plants made in various localities.

1. At Bami west of Askhabad; April 24th: *Poa bulbosa*, *Roemeria rhoeadiflora*, and a red species of *Tulipa* are dominant. Other species: *Asperugo procumbens*, *Euclidium syriacum*, *Malcolmia africana*, *Myosotis sp.*, *Hypecoum trilobum*, *Spinacia tetrandra*, *Ixilirion tataricum*, *Iris caucasica*, *Lepidium Draba* and *perfoliatum*, *Trigonella monantha*, *Sisymbrium Sophia* and *pannonicum*, *Koelpinia linearis*, *Matricaria lamellata*, *Papaver arenarium*, *Anagallis* sp. and a few grey Artemisias. Beside a house were some willow-bushes with catkins, but no leaves.

2. North of Dshisak at the foot of West-Thianshan; May 7th: *Poa bulbosa* and a grey strongly aromatic *Artemisia* in places form the whole vegetation.

3. Other places (near Balan Hur) are much richer, and in addition to *Poa*, poppies and tulips, one finds *Ixilirion Pallasii*, *Carex stenophylla*, *Malcolmia Bungei*, *Cryptospora falcata*, *Euphorbia pygmaea*, *Leptaleum filifolium*, *Astragalus sogdianus*, *macronyx*, *mucidus*, *Solenanthus petiolaris*, *Gentiana Olivieri*, *Eremostachys labiosa*, *Ranunculus Sewerzowi*.

In the true clay-desert, which is drier than the semi-desert, I had no opportunity of seeing the spring-vegetation. That ephemeral species also occur here is known from Basiner, Borszczow (see above p. 26) and Radde. From the last named author (1899, p. 26) is taken the following description of an area near the eastern shore of the Caspian Sea, visited on April 28th:

> "Ist diese Sandzone passiert, so kommt man, direkt nach N. wendend, auf festerem Lehm, zum Teil mit Salzgründen und in die elendeste Salsola- und Artemisien-Steppe oder besser gesagt: Wüste."

And later on he says:

> "Die arme Flora bietet immer dasselbe, im Ganzen kann man hier kaum 15 Arten finden. Gagea reticulata steht in Samen, Hordeum murinum, Boissiera bromoides, dieselbe Kamille, dieselbe Allium wie bei Tschikisljar, Ceratocephalus falcatus, Geranium oxyrhynchum, Plantago arenaria W. K. und die gelbbraune langbehaarte Kochia scoparia im Jugendzustande, sowie der schöne Astragalus macrotropis wurden hier gesammelt. Alles das miserabel, nur ein Paar Zoll hoch, eine Statice, die jetzt schon blüht, Salsolen und Artemisien nur strichweise häufig. Man vergesse nicht dass diese Zeit für die hiesige Flora die Glanzperiode ist, Ende Mai ist alles mit Ausnahme von Salsola und Artemisien todt. Es gibt zwar an einigen wenigen Stellen Vertiefungen grösseren Umfangs, die infolge geringer Feuchtigkeit etwas besser bewachsen sind, aber nirgens sieht man den Versuch einen schwächlichen Rasen zu bilden, es fehlen sogar die Sand-Carices. In solchen Vertiefunger konnten Lepidium Draba und hier und da als Seltenheit Lep. perfoliatum existieren."

On comparing this with the accounts given by Basiner and Borszczow, it will be seen that the difference between the Semi-desert and the true Clay-desert lies in the varying degree of dryness, correlated with a less or greater abundance of the spring-vegetation. Ephemeral species and spring-perennials occur in both places. Since the summer and autumn vegetation is similar in the two forms of desert there is no reason for distinguishing between "Clay-desert" and "Loess-steppe", as has been done by Antonow.

In the middle of May the Semi-desert is already beginning to turn yellow, and many of the spring-plants have even dispersed their seeds in April. Towards the end of May almost all the plants of non-xerophytic structure have withered or are withering rapidly, and the summer-plants make their appearance. Our illustration (fig. 4) shows the rolled-up withered yellow leaf-rosettes of *Ferula Asa foetida*, while many grey *Artemisia* bushes are not yet in bloom. The surface soil in this place was cracked by drying, but at a depth of 7 centimetres the loess was still dark with moisture. Thus it seems to be the dryness of the air rather than that of the soil which kills the spring-vegetation.

As June advances, any spring-plants left become so dry and brittle that they fall to pieces when touched. They soon disappear entirely and then the semi-desert becomes a true desert similar to the clay-desert proper. The two desert forms will therefore in what follows be treated together under the latter designation.

The surface in places is perfectly bare, but as a rule it is spotted over by scattered summer-plants. Generally only a single species or very few species occur together in each locality, different ones in the different places. The number of summer-plants is extremely limited, and a review of them is soon made.

*Artemisiae* often constitute the whole of the summer-vegetation; Borszczow records *A. fragrans* and *monogyna*, but specimens I brought home were identified as *A. herba alba*. In any case the species are closely related to *A. maritima:* silver-white, aromatic undershrubs, strongly branched at the base. This mode of growth (a "Wermuth-Steppe") is seen in the illustration (fig. 4), and it may be uniform over large areas.

In other places *Salsola rigida* is the principal species. Its growth-form is between a shrub and an undershrub, half a metre high, dry and twiggy in appearance, and generally with many dead branches; its leaves are rigid and cylindrical. This is also the type of growth-form of *Haloxylon Ammodendron, Salsola Arbuscula* (figures 12 and 38), *subaphylla* and *verrucosa,* when these species grow in the clay-desert, but they have quite a different appearance when growing in the sand-desert. Low shrubs of leafless *Ephedra alata*, species of *Calligonum* and the succulent, salt-excreting *Reaumuria oxiana* are similar in type. *Smirnowia turkestana* and various species of *Astragalus (A. Ammodendron, paucijugus, unifoliatus)* are shrubs, sometimes a metre high, with inflated pods and poorly developed foliage. *Smirnowia* has small entire circular leaves, while the *Astragalus* species have leaflets which fall off quickly, leaving a persistent leaf-rachis.

In places where the ground-water is not too deep (e. g. near oases or rivers) the following are characteristic shrubs: Fresh green or greyish Tamarisks; the narrow-leaved *Nitraria Schoberi* comparatively rich in foliage; *Halimodendron argenteum,* a silver-leaved thorny leguminous bush with large inflated pods; *Halostachys caspica* and *Halocnemum strobilaceum* both bushes with Salicornia-like shoots; *Prosopis Stephanianum* a low mimosa-bush with pinnate leaves (probably occurs also in very dry places); *Lycium ruthenicum;* the broad-leaved *Capparis spinosa*, and the spiny rosaceous *Hulthemia berberifolia* (I am not quite certain whether the last two vegetate during summer). There are also *Frankenia hirsuta, Heliotropium dasycarpum, Statice suffruticosa, Alhagi Camelorum,* all regarded as undershrubs and mostly found in the more favorable localities along with the perennials *Peganum Harmala, Zygophyllum Eichwaldii, Pluchea caspica, Inula caspica, Dodartia orientalis* (leafless) and *Cressa cretica* one of the *Convolvulaceae* well covered with a foliage of grey salt-excreting leaves.

As summer-plants of the dry clay-desert we should include the Chamaephytes[1]) *Anabasis aphylla* and *salsa*, *Arthrophytum subulifolium, Nanophytum erinaceum* and *Noaea spinosissima,* all leafless or thorny-leaved stunted undershrubs; also *Anabasis eriopoda,* a leafless Hemicryptophyte[1]), and finally a number of annuals.

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[1]) See chapter 12.

These last include *Frankenia pulverulenta, Crozophora gracilis* one of the low *Euphorbiaceae* with flat leaves densely coated with hairs, *Carduus tenuiflorus*, the fragrant *Lachnophyllum gossypinum* a Composite semi-rosette plant, and a few other species.

By far the greater majority of the annual summer plants belong to the *Chenopodiaceae*. They are almost all succulents and amongst them one can distinguish between various types. The first type is the Thorny Leaf-Succulents whose representatives (*Salsola Kali, sogdiana, aperta, Androssowii*) have spiny pointed leaves with water-storing tissue in the middle. The second type is the Thornless Leaf-Succulents (*Salsola crassa, lanata*, species of *Halanthium, Halimocnemis macranthera, pilosa* and *villosa, Piptoptera turkestana, Suæda* &c.); these have succulent, often hairy cylindrical thornless leaves which still retain their function as the most important organs of assimilation. The third type, which I propose to call Bracteole-Succulents, are characterised by a distinct water-translocation (BURGERSTEIN, MESCHAYEFF) i. e. the plants sacrifice certain of their own organs to support the others, and in this case the foliage-leaves are drained of water and wither, while the plants concentrate their vigour on the inflorescence. Each floret of this is surrounded by three spoon-shaped bracteoles, namely the subtending leaf and two prophylls. These three organs are very succulent with their outer layers developed as green tissue, and they, with some assistance from the green stems, take the place of foliage leaves in assimilation. At the same time they protect the florets which sit squeezed in between them (see fig. 8 and 78).

The Bracteole-Succulents include *Salsola incanescens, spissa* and *sclerantha, Halimocnemis Karelini.*

These species are good examples of the type, and later in the summer they show scarcely a single foliage-leaf. The whole plant is beset with small globular bodies (the florets and their bracteoles), so that they have a characteristic appearance (fig. 8). Fleshy bracteoles around the flower are also frequent in the other types, but the appearance of the plants is very different when the foliage-leaves are present. Along with the Bracteole-Succulents may be mentioned *Ceratocarpus are-*

Fig. 8. *Salsola spissa*, an annual bracteole-succulent. June.

*narius* a plant of frequent occurrence many places in the clay-desert. Its flat, spiny non fleshy leaves lose all their parenchyma during the summer and become reduced to thorns, assimilation being taken over by the two connate spiny prophylls. The whole plant forms a spiny ball sometimes as large as 30 centimetres in diameter and of a grey colour. (See fig. 66).

Under the Summer-plants should also be grouped a red Lichen, *Lecidea decipiens* which in some places is common on the surface of the loess.

The structure of the Summer-phanerogams will be dealt with later (chap. 13), when the different types of desert-plants are described. Here it is only necessary to give some of the more important features. The species which grow in the most favourable localities, where the ground-water is not too deep, are generally these with relatively the richest foliage: *Tamarix, Halimodendron, Prosopis, Peganum, Zygophyllum, Pluchea, Inula, Alhagi* have all distinctly green leaves and flat, with the exception of those of the *Tamarix*. None of them however have much foliage, nor does it cover the stems. In *Alhagi* only the oldest leaves persist, so that the upper shoots look like leafless spiny branches.

The plants of the dry desert may be grouped as follows: Succulents, Bracteole-Succulents or Leaf-Succulents, the last including *Salsola Arbuscula, subaphylla, rigida* and *verrucosa, Reaumuria*; leafless Stem-Succulents such as *Haloxylon, Anabasis* and *Calligonum;* deciduous shrubs like the species of *Astragalus* where other organs take over the work of assimilation; and finally plants with narrow leaf segments coated with hairs (*Artemisia*). All the species from the dry clay-desert belong to very xerophytic types, many have in addition a halophilous stamp (cylindrical assimilation-organs with aqueous tissue in the middle). In a case such as we are now considering it may be difficult, perhaps impossible, to distinguish between the xerophytic and the halophytic; which structural adaptations are due to desiccation and which to salinity of the ground-water can only be positively determined by experiments.

The usual aspect of the clay-desert in summer is a flat or slightly undulating surface, brown and dry, here and there with slight incrustations of salt, bare or scantily covered with scattered xerophilous plants which are herbs or small shrubs rarely higher than half a metre. The following are the most common: Saxaul, *Salsola rigida, Artemisia, Halostachys* and *Halimodendron.* — In depressions salt-deserts are found which are white with salt and produce their own particular vegetation closely related to that of the clay-deserts.

The Growth-Forms of the Clay-desert in Spring are Mesophytes, including Ephemeral plants and Perennials with short-lived aerial shoots; while in Summer (and of course also in spring) we have Xerophytes, some small shrubs and undershrubs, others perennials and long-lived annuals.

As emphasized above, the chief difference between Clay-desert and Salt-desert is that the latter lacks the spring-aspect.

## CHAPTER 8

### The Formation of the Stone-Deserts.

ANTONOW has recorded (see above p. 35) a formation which he calls "Promontory or Stone-Steppe", said to be characterised by a special flora. This formation, according to the nomenclature employed here, cannot be termed steppe but must be called desert. Whether it is different from the clay-desert as regards its growth-forms I cannot determine with certainty because I have seen so little of the stone-desert. But it must be more correct to keep apart that which cannot with certainty be united, and therefore the stone-deserts will be considered here as a special formation.

The soil of the Stone-deserts is either rock, or gravel with stones, or a conglomerate. The layer of conglomerate, which is mentioned by ANTONOW, is probably the ordinary tertiary conglomerate of stones cemented together by a loess-like clay. Conglomerates of this kind are very common in Turkestan (WALTHER) at the foot of the mountains and higher up in the mountain-valleys.

Where the cement is loess, what was stated about loess as a soil (p. 57) holds good here. But the presence of numerous stones makes the soil still more unfavourable to vegetation because the stones retard the absorption of water, reduce the capillarity and promote the conduction of heat in the soil. On the other hand they act favourably by reducing the evaporation from the surface (RAMANN).

The vegetation will only be described for the more important localities I have seen (all with one exception in summer).

At the base of Sultan Uis Dagh, an isolated group of mountains near Chiwa (see map), I examined a desert strewn with loose pieces of slate, and dotted here and there with rocks *in situ*. This desert evidently corresponds to what VOLKENS calls "Kieselwüste" WALTHER and MIDDENDORFF call "Kieswüste". As in Egypt, so the desert here was almost devoid of plants. Only in depressions and where the number of stones seemed to be less, did various low undershrubs and dwarf-bushes occur: *Salsola rigida, Artemisia herba alba, Capparis spinosa, Atraphaxis compacta* and *Haloxylon Ammodendron,* the latter being low shrubs about half a metre high. Less conspicuous were *Stellera Lessertii*, *Convolvulus fruticosus,* along with *Halimocnemis macranthera* and *Anabasis eriopoda,* two pronounced halophytes. In Ferghana, MIDDENDORFF found about one plant per square foot (l. c. p. 21) on the stone-desert.

The mountain itself, Sultan Uis Dagh (Sultan Baba-ne Dagh-e) consists of nearly vertical strata of a greenish clay-mica-slate, often impregnated with quartz. The surface in many places is covered by disintegrated matter, fine yellow clay and pieces of slate with a shiny tawny weathered surface. Everywhere was very dry, even the deserted beds of several streams, which were no richer in vegetation than the rest. The following plants were found scattered widely about: *Atraphaxis compacta, Salsola Arbuscula, Salsola rigida, Capparis spinosa, Artemisia* sp., all dwarf or undershrubs, also two withered annuals, a Composite and *Lepidium persicum* (?) and low trees of Saxaul less than a metre high.

At Kis-Kalá, a mountain with a ruined castle, on the right bank of the Amu Darya more to the south, I saw a desert where the soil consisted of very stony gravel and sand.

On this soil *Reaumuria fruticosa* was characteristic, a low bush with closely set minute leaves covered with salt-crystals. Some other species occurred on some small dunes, but these only appeared one at a time on the stony soil. (See chap. 11). The following Lichens were found on stones: *Sarcogyne perileuca, Placodium Paulsenii, Acarospora interrupta.* At Dana Sher Kalá not far from this place, there was a stony gravel plain with very scattered small bushes of *Salsola rigida* behind which hillocks of sand had drifted; this was the only species.

At Ak-Yar (also on the Amu Darya) there is an undulating plain of loess with splintered pieces of clay-slate and knolls of the same rock *in situ.* The following plants were scattered about, approximately 3 paces apart: *Salsola rigida* and *Arbuscula, Reaumuria oxiana*, Saxaul and rarely *Lycium ruthenicum;* all were stunted shrubs less than half a metre high. The herbaceous species included *Salsola carinata, Suaeda sp.* and *Lepidium obtusum.* Depressions with a stiff fissured clay were devoid of plants or bore only a few halophytes (*Halocnemum, Halimocnemis*).

At Pitnjak there was a gravel plain with *Peganum Harmala, Convolvulus eremophilus* and *Anabasis salsa,* very scattered.

At Kisel-Yi also situated south of Chiwa, we found hard clay hills with many white stones, quite bare except in the depressions where there were scattered plants of *Halimocnemis macranthera* (an annual summer-plant with thick leaves) *Salsola rigida,* low Saxaul bushes, *Artemisia, Alhagi Camelorum.* The last alone crept up the hillside here and there.

Near Andidshan (Ferghana), very stony loess about a foot thick formed a layer over stones and gravel. Here grew (May 27th) Tamarisks not more than a metre high, *Alhagi Camelorum, Crambe orientalis* (?), the thorny and silverhaired undershrub *Convolvulus fruticosus, Echinops sp., Astragalus sp.,* etc.; the visit to this locality was a very brief one.

Other localities were observed where the soil was rock *in situ* or stone, but as these were covered by sand, partly shifting, and as it seemed to me that there the sand was mainly responsible for the character of the vegetation, they are not included here.

These observations indicate that the vegetation of the Stone-deserts is mainly characterised by xerophytic stunted shrubs and undershrubs. Whether spring-plants occur there, I cannot say.

The following are species found only in the Stone-desert: *Convolvulus fruticosus*, *Stellera Lessertii*, *Reaumuria fruticosa* and *Atraphaxis compacta*, all dwarf-bushes or undershrubs with small and flat leaves. The following seem to be common in the Stone-desert, though they also occur in other formations: *Reaumuria oxiana*, *Salsola rigida*, (one of the most frequent) *Arthrophytum subulifolium*, *Artemisia sp.*, *Convolvulus eremophilus*, *Capparis spinosa*.

## CHAPTER 9

### The Formation of the Sand-Deserts.

The soil of this formation is sand, at least on the surface. The sand varies in origin and age as stated in chap. 2 [1]), but these differences do not seem to play any essential part with respect to the vegetation (Korshinsky p. 8). The different aspects presented by the sand are of greater interest to the botanist. These have been described by Mushketow, Radde and Semenow, and the following survey of the various sand-landscapes is based on the observations of these authors.

1. Barchans, crescent-shaped, dirty yellowish or fawn-coloured dunes of inland sand. Musketow states that they are generally 30—40 feet (ab. 9—12 metres) high, and may attain a height of a hundred feet (ab. 30 metres); Semenow gives 40 metres but I have rarely seen any higher than 10 metres and Radde gives 30—35 feet (ab. 9—10 metres) as the maximum. The sand-grains are rather small. Radde (1899, p. 16) gives 0.2—0.3 m. m. as the average size for Barchan-sand and Sand-steppe sand from Amu Darya and Kara

[1]) See moreover Romanowski p. 52.

Kum, and at Dshideli MUSHKETOW found Barchan-sand with grains not exceeding 0,1 millimetre.

The sand always, in the Barchans and elsewhere, consists of quartz. A little mica is found in it, also varying quantities of clay (up to 30—40 per ct. on barchans in dry river-valleys), and frequently iron, small quantities of gypsum, calcite, etc. (RADDE 1899 p. 16).

The form of the Barchans has already been described (p. 7). RADDE's comparison of a barchan-landscape to a frozen stormy sea is a good simile except that waves are not regularly crescent-shaped. Standing on one of the summits and looking towards the north so that the concave sides of the barchans are turned towards one, this imposing waste is most awe-inspiring. As far as the eye can reach vawe rises behind wave, crest behind crest. The barchans arise irregularly, often several in a group, their flanks blending so that the sharp crest-lines undulate up and down, in and out. Even a gentle breeze raises the fine sand from every crest, and the brownish sand-smoke from the bare dune-summits adds an additional weirdness to the waste landscape.

As the prevailing winds are northern or north-easterly the sand migrates towards the south and west and crosses the Amu Darya. This will be further dealt with in chap. 11.

2. Hummock-Desert, Hummock-Sand (in RADDE "Hügelsand", in SEMENOW "désert de sable mamelonnée"). Rounded hills, quite low or fairly high, up to about 10 metres, with basin-shaped hollows between them, and with no windward and lee side. They are stationary dunes with a comparatively rich vegetation.

3. Desert of the sand-plains ("Sand-steppe", "steppes sablonneuses"), flat or somewhat undulating areas of sedentary sand.

4. Dune-chain sands ("Ketten-, Reihen-, Wall-, oder Streifensand" of RADDE, "déserts dẹ sables en sillons" of SEMENOW). Parallel sand-hills formed by the grey or white sand of present or past times. Between the chains are valleys, ab. 45—200 metres (150—700 feet) wide, the soil of which is bare clay (Takyr). The valleys are crossed by lower dunes which run transversely to the main dune-chains. Dune-chain sands

are mostly found in the northwestern part of the lowland. They are comparatively well covered with switch-like desert-shrubs, *Carex physodes*, etc., and the sand-drift is of no great importance.

5. "Dunes", or recent accumulations of shifting greyish or white sea-sand occurring mostly along the coast of the Caspian, and generally arranged in chains which follow the direction of the wind.

Dune-chain sands and recent dunes, both formed by white or grey sea-sand, I have not seen, hence they are here left out of consideration, and only the different forms of inland-sand are dealt with.

The first point to be considered is sand as a soil for plants in comparison with clay.

In dry countries sand is, in some respects, more favourable to vegetation than clay.[1]) Water is quickly absorbed so that it has no time to evaporate. Less water will evaporate from a rough, coarse-grained surface of sand than from an even, fine-grained surface of clay. Because of the slight water-holding capacity of sand, the water is carried to greater depths, whence it does not rise easily to the surface owing to the poor capillarity of sand. The evaporation-surface of the water will therefore be situated down in the earth where it is protected by the overlying drier layers of soil (comp. LIVINGSTON 1906). Deep sand is a soil which suits plants with very long roots. The switch-shaped trees and shrubs generally occur here.

Though sand can absorb much less water than clay (14,3 per ct. of dry weight, loess 59,3 per ct. according to CLEMENTS, p. 34), almost all the water absorbed is available for the plants: "Echard" is only 0,3 per ct., "Chresard" 14 per ct. (comp. above p. 58). The figures vary of course somewhat according to the properties of the sand, especially the size of the grains (LIVINGSTON 1905), but I am not aware

[1]) *Fitting* (p. 251) also finds that the sand-plants of the Sahara have a lower osmotic pressure than the plants of the stone-deserts even when they belong to the same species.

that investigations on these conditions have been made in Transcaspia.

Where the sand forms a stratum over the loess it becomes of special importance. The water from precipitation will be let down through the sand into the upper layers of loess, whence it cannot evaporate because protected by sand, and yet it is still available for the roots of plants, if the sand is not too deep. The natural conditions are here specially favourable, and it is on sand over loess that the most luxuriant desert-vegetation is found during summer (see chap. 11). These conditions are now successfully imitated by man. In the dry parts of North America "dry farming" is conducted, the principle being that the subsoil, by the aid of special implements, is always kept solid, so that it can raise the water, while the surface-soil is kept loose so that it can protect the subsoil and itself lose the least possible amount of water through evaporation (see MATENAERS).

Though sand is more easily leached than clay, the under ground water in the sand-desert is almost always salt, and gypsum crystals frequently occur in quantity at a depth of $^1/_2$—1 metre (PALEZKIJ p. 36). Many of the sand-plants are also halophytic in structure.

Where no water is present the desert-sand is an exceedingly hot soil, all the more as it is not white but brown. The expedition recorded 53 ° C. on a summer's day just below the surface, but even higher temperatures might certainly be found.

Sand is more unfavourable to vegetation than clay, in this respect, that the sand is moveable. Sometimes the roots of the plants are laid bare, sometimes aerial shoots are buried, either of which conditions may kill the plant. The drifting sand-grains may also bruise young or unprotected plant-tissues and in this way cause injury. This has already received attention in the literature on European dunes, e. g. WARMING 1909.

The following description of the vegetation of the Sand-desert deals first with the more shifting deserts, afterwards with the stationary types. The desert is described in its summer-aspect; then in its spring-aspect, which greatly reminds one of that of the clay-desert.

In the more shifting deserts there are areas with nothing of interest to the botanist. Hills and valleys of sand, not even a stone, nothing but sand. This is sorted out by the wind, the coarser and darker sand covers the gentle slopes of the windward side and the crests of the wind-billows, while the finer and lighter sand is found on the steeper lee side and in the valleys. These variations in shade increase the relief of the surface.

The first pioneer of the vegetation is "Selin", *Aristida pennata* Trin.[1]), so aptly called by ANTONOW the Conqueror of the Sand-desert.

*Aristida pennata* takes first place as a sand fighter. It grows quickly, and gives off many roots, many leaves, many branches, while its internal structure enables it to endure drought and sand-drift. It is more fully described later (chap. 13), but features of its biology may be indicated now.

After germination it forms a number of basal scale-leaves through whose sheaths the fibrous roots break out. The foliage leaves follow on short internodes so that their sheaths form a "Tunic" (HACKEL), the one sheath lies over the other, with only a short apex free, so that the expanded leaf-blades are close-set one over another. In the axils of the scale-leaves lateral shoots quickly appear covered by their "tunics". The young plant thus forms a close tuft with the oldest shoots in the middle (fig. 9), and as the tufts grow older they become coarse leafy tussocks half a metre or more in diameter. When the sand drifts over, the plant pushes upwards with longer internodes, and new lateral shoots with basal roots are continually being formed. so that the plant is fixed in the sand almost right up to the surface. The lateral shoots

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[1]) This plant has been named at different times *A. pungens* Desf., *A. pungens var. pennata*, *A. pennata* and sometimes it has been regarded as two species *A. pennata* and *A. pungens.* It is certainly closely related to the Sahara form *A, pungens*, being distinguished from it mainly by its more slender growth and by longer branches of the panicle. I do not think there is any reason for calling specimens with shorter panicle-branches *A. pungens.* The Transcaspian specimens are certainly all the same species

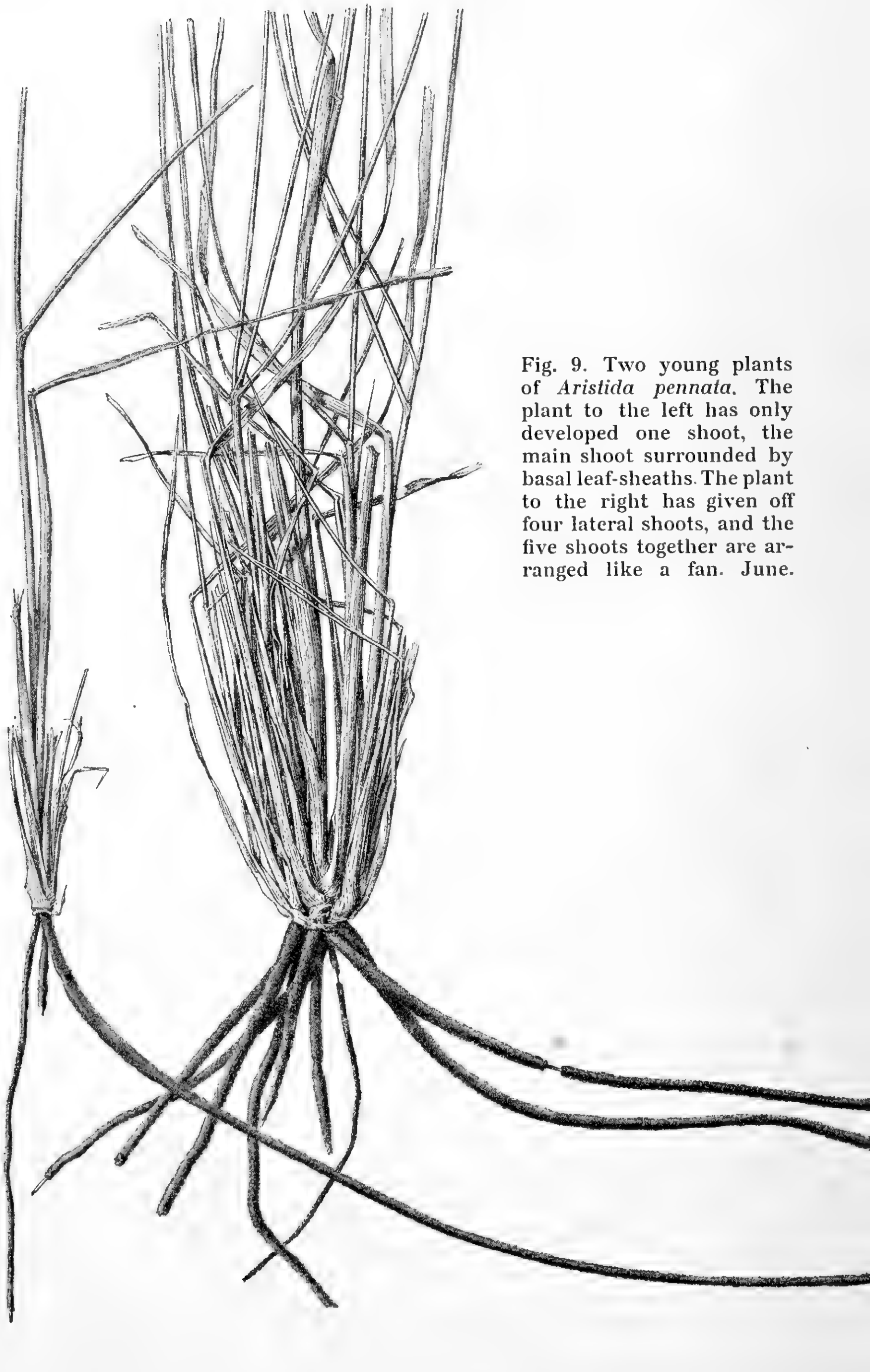

Fig. 9. Two young plants of *Aristida pennata*. The plant to the left has only developed one shoot, the main shoot surrounded by basal leaf-sheaths. The plant to the right has given off four lateral shoots, and the five shoots together are arranged like a fan. June.

continue to grow and to struggle against the sand after the older main shoots have flowered. Horizontal runners are not formed, so far as I know. According to Palezkij, *Aristida* forms two kinds of roots, long horizontal anchoring roots, and shorter perpendicular absorbing roots. The roots are protected by a "sand-stocking" or cover in which the other root-tissues are loosely enclosed. The leaves are able to roll up like those of *Psamma*, and have green tissue on the protected upper surface.

In the shifting sand-desert, all other vegetation is dependent on the presence of *Aristida pennata*.

This plant is not merely a sand-binder, but plays an even more important part because its dense tufts are practically the only place, where seeds of other plants can secure a roothold. Palezkij has drawn attention to this fact, and I have frequently observed, that the fruits of the switch-bushes find a resting place in the *Aristida* tufts where they are retained amongst the leaves and shoots and are frequently covered by sand. These fruits easily roll about in the wind so that they would hardly ever germinate in the shifting desert if it were not for the tufts. In more stable parts, the conditions are more favourable and there is generally sufficient vegetation for the fruits to establish themselves.

The plants which come next after *Aristida*, and perhaps some of the annuals, are the switch-bushes, a very characteristic type. In the sand-desert the most hardy is the Sand Acacia (*Ammodendron Conollyi* (fig. 10) and *Karelini*). It occurs as slender trees or low shrubs standing hundreds of metres apart. Grey in colour, it has small narrow leaves thickly coated with silky hairs, and light passes through the crown so that only a slight shade is cast (see Lipsky 1911 tab. 1). In the valleys between the barchans it may form a tree with a trunk and elegant hanging branches, but sometimes where the barchan has swept over the trees only the tops of the crowns are seen protruding above the sand. The strength of the Sand Acacia lies in its height, its long roots (19 metres, Palezkij) and its small leaves.

If this plant can hold its own and produce seeds from the butter-coloured one-seeded samaras which ripen in May,

Fig. 10. *Ammodendron Conollyi.* A flowering branch (on the left) and a fruiting branch (June). The dead axes of the inflorescence complete the year-growth of this shoot.

Fig. 11. *Calligonum Caput Medusae.* Fruit-bearing branch, which has lost some of the fruits. End of May.

and if these are allowed to germinate, then the vegetation (if such a word can be employed) becomes by degrees somewhat denser and other species appear. First and foremost come other switch-bushes: *Calligonum*, *Salsola Arbuscula* and *subaphylla*, *Eremosparton*, Saxaul and sometimes *Ephedra alata*. A desert covered with these shrubs is a most characteristic sight; to describe it the following lines by KORSHINSKY l. c. p. 4) may be cited:

> "They are bushes or small trees, from 1 to 4 or 5 Arshins high (0,7 — 2,8 — 3,5 metres[1]), very characteristic both in their appearance and in their mode of growth. Their stems as a rule are short, bent and often very irregularly shaped on account of deep and long furrows. The branches are generally white or greyish, the leaves narrow and greenish-grey. Frequently there are no leaves at all, and they are replaced by the young branches which contain chlorophyll. Most of these ligneous plants grow very slowly and have an exceedingly hard but brittle wood, this is especially the case with Saxaul. These low trees stand widely apart, they do not cast the least shade, so that the soil under them is almost as dry and unfertile, almost as scorched by the rays of the sun as if there were no trees at all.
>
> No comparison is possible between this bushland and forest or scrub in temperate areas, and on the whole none of the expressions used in literature or science are adequate to describe them. They form a special type of vegetation, so unique and characteristic that I cannot believe it will ever fade from the memory af any one who has had a single opportunity of seeing it."

Only two of the switch-like trees and bushes have a luxuriant green appearance. They are *Salsola Arbuscula* and *S. subaphylla* (figures 12 and 13), especially the former. This plant has already been described (chap. 6) as frequent in dry clay-deserts, where it is a dry, stiff, prickly bush about half a metre high with short hard shoots and stiff plump leaves.

[1]) This description deals with vegetation on more stable soil where the trees and bushes are lower. O. P.

Fig. 12. *Salsola Arbuscula var. longifolia* (The Sand-desert form). Part of a year's shoot with flowering branches. September.

But when it grows in the moving-sand desert, it becomes a small tree, more than 4 metres high, and with long, pliant shoots and leaves (comp. fig. 12 and fig. 38). The foliage is comparatively rich; it is a green tree sufficiently dense to cast a shade.

The plant is very hardy and can endure being covered by sand, a process which only hastens its already precocious growth, and (according to PALEZKIJ) roots are formed from the buried parts of the stem. He also states that he has measured roots 15 metres in length, many of them horizontal. Whether suckers are formed from them I do not know. I have seen a tree from which the sand had been blown away, so that it had fallen and lay on the slope of a dune with some of the branches buried. The plant, however, was perfectly fresh, still fixed by its roots and it had given off new roots from the buried branches.

*Salsola subaphylla* is somewhat similar in appearance, but has coarser and less dense foliage and neither in height nor age does it come up the other species. Somewhat saline soil is the most favourable for this plant.

Both species blossom freely in the late summer and in September they bear large clusters of broad-winged perianths carrying the fruits.

These two species, particularly the former, play an important part in the operations for binding the sand along the railways.

*Calligonum* (figures 11, 27, 28) and *Eremosparton aphyllum* (figures 23, 24) are both leafless i. e. the leaves are reduced to quite small scales, and both are shrubs or small trees attaining a height of about 4 metres. They have long roots (PALEZKIJ measured roots of 4,25 metres in a year-old specimen of *Calligonum Caput Medusae*) and both plants can form root-suckers.

They are both sand-plants — *Calligonum*, however, not exclusively — and they endure the sand-drift very well. Of the many species of *Calligonum* (see list in chap. 12), *C. Caput Medusae* is the most important. It flowers in May or June and already in June one finds the curious globular reddish fruits set along the slender twigs. The fruits are achenes twisted like a screw and with several rows of long many-pronged bristles spread out in every direction and quite stiff when ripe. The fruit thus appears as a kernel set in the midst of a globular transparent meshwork, the diameter of the whole being 2—3 cm. (See fig. 28). These fruits are exceedingly mobile and roll away at the slightest breath of wind.

The fruit of *Eremosparton* is a one-seeded woolly-haired pod, one centimetre long. The red blossoms open in May or June and form small racemes, but only the earlier blossoms set fruit as the later ones are shrivelled up by the heat.

Saxaul or Sasák (*Haloxylon Ammodendron*) (fig. 14) only thrives well where the sand has a subsoil of clay or limestone. Under favourable conditions it may become a tree of 7 metres. Often, however, it is a much-branched shrub. As the growth is slow, this species does not stand sand-drift very well, and the young, soft, leafless shoots are also bruised and damaged by the sand-grains[1]).

These switch trees and bushes have the following characters in common (other details of morphology and internal structure are given in chap. 13). They are small trees or bushes; the Sand-Acacia and Saxaul occasionally become larger trees (8 metres).

All of them have their leaves much reduced. *Ammodendron* has flat leaves, but they are small and thickly coated with silky hairs. The *Salsola* species have cylindrical chenopodiaceous leaves with central water-tissue. In *Calligonum*, *Eremosparton* and *Haloxylon* the leaves are reduced to small scales, and the assimilatory functions are performed by the stems alone.

The first-year shoots are frequently branched, sometimes

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[1]) Saxaul is said to form vast bushlands ("forest", comp. Lipsky above p. 28) east of Lake Aral (Wladimirskaja). The trees here are said to attain a height of 16—18 feet and have a thick tap-root. Saxaul often occurs here together with rushes and is supposed to stand in a certain relation to the Syr Darya (Jaxartes) inundation area. "The Saxaul forests everywhere begin as a low thorny scrub along with Tamarisks, then they become bushlands and finally forests." (Middendorff p. 308). — Lipsky (1911 p. 14) denies that the growth of Saxaul is necessarily slow.

Fig. 13. *Salsola subaphylla.* Part of a year's shoot with branches. The fruits are ripening. September.

Fig. 14. *Haloxylon Ammodendron.* Fruit-bearing branch and flowering branch. November and April. (Afghanistan).

bearing several series of branches. The vegetative branches are annual like the floral ones, and may therefore biologically be regarded as leaves which fall off at the end of the vegetative period.

The perennial as well as the annual branches are often closely bunched together owing to the formation of new branches year after year at the same place. The younger branch-tips are often pendant and wave in the wind (*Ammodendron*, *Haloxylon*, *Salsola Arbuscula*).

They have all long roots. The fruits in every case contain one or at most a few seeds, and are so formed that they fly or roll easily before the wind, hence one finds them massed together in sheltered places.

To the bushes and trees given above for the Sand-desert, the following may be added which like Saxaul are rather plants of clay soils and do not thrive so well on pure deep sand: *Smirnowia turkestana*, *Astragalus Ammodendron*, *paucijugus*, *unifoliatus*, *Ephedra alata*, Tamarisks and probably others.

The switch-shaped trees and bushes (and *Aristida*) are however rarely the only living plants in the Sand-desert. Between the dunes where there is a certain amount of shelter, the soil in many places is sufficiently stabilised for the growth of hardy herbaceous plants. These are not places where there is clay soil between the dunes — such belong to the formation of the clay-desert, -- but where there is sandy soil somewhat sheltered and therefore not shifting. Here grow a number of annual and perennial herbs which are more xerophytic and less halophytic in type than the clay-plants. They occur scattered about, and frequently they have a hard struggle for existence where the sand blows away or drifts over them.

One of the most frequent is *Heliotropium Radula*. This like *H. sogdianum* which also occurs, has a thin horizontal rhizome, sometimes of considerable length (2,5 metres and more), and lying close under the sand-surface; it puts forth numerous aerial shoots, which generally form hairy leaf-rosettes arranged in a row, similar to the rosettes of our *Carex arenaria*. (Fig. 63). Long-jointed shoots bearing inflorescences may also be found. The rhizomes are sometimes laid bare, one I saw being 132 centimetres long and only attached at one end, but still living. When the plant is buried by sand, a new aerial shoot is formed from an axillary bud of one of the higher leaves and terminates in a rosette on the sand. (Fig. 22). But these shoots do not endure the sand-drift very well, and I have seen specimens buried again which were dead. The long rhizomes may be regarded as a means of defence; with the aerial shoots widely distributed there is always a possibility that some of them may escape destruction by the sand-drift. The hairs on the leaves also probably give some protection against bruising by sand.

Living in the Sand-deserts are also a number of plants of the type of *Salsola Kali*, i. e. spiny hard plants with a limited amount of assimilation tissue. These include both annuals and perennials, mostly the former. The following are the most noteworthy amongst those I have seen.

*Horaninowia ulicina* (fig. 70) is an annual. From the summit of the long straight lignified root, there arise a number of stems 20—30 centimetres in length, which lie on the surface of the ground. The leaves are opposite, acicular and spiny, and bear in their axils dwarf-shoots or long-shoots. The dwarf-shoots appear as bunches of thorns (see figure 70) and when long-shoots are formed they bear the groups of thorns. Should this plant be covered by sand, the dwarf-shoots elongate and become long-shoots, which struggle to reach the light, while the main-shoots may be seen to change their direction and to grow obliquely upwards, until they again emerge above the surface.

In more favourable places the species has longer leaves and is more erect (*var. longifolia*). The leaves and young stems are coated with stiff, viscous hairs amongst which sand-grains are often retained; these hairs must limit the mechanical effects of the sand-drift.

*Agriophyllum minus* (fig. 72) is also an annual. Large specimens become strongly branched. The leaves are grass-like flat, dry, multicostate, stellate-haired and thorny-pointed; all bear dwarf-shoots like bunches of thorns, or long-shoots which carry the thorny shoots. The leaves more especially the lower ones die early, but the axillary shoots remain active (Translocation of water).

Closely related to the last is *Agriophyllum latifolium* (fig. 74). The chief difference is that this plant has broad, opposite ovate or almost circular leaves with long stalks, and the primary vein terminates in a thorn. The upper leaves all show transitions towards the narrow, grass-like leaf of the preceding species. All the leaves support long-lived bunches of thorns as in the former species.

*Salsola Kali* also belongs to this type together with the allied species, *S. sogdiana* (fig. 76) and *aperta*, also *Cornulaca Korschinskyi* (fig. 68) and *Arthrophytum subulifolium,* all thorny-leaved, stiff, branched plants, and annuals except the last which is an undershrub. *Acanthophyllum elatius*, an undershrub with prostrate branches and stiff, thorny leaves, should also be included here. *Ceratocarpus arenarius* (fig. 66), frequently a clay-plant, may also be found on sand; it is exceedingly branched and thorny and is generally globular in shape. The parenchyma dies away, but the midrib remains as a long, pointed thorn (comp. above p. 72 and chapt. 13).

*Convolvulus erinaceus*, an undershrub very abundant locally in the Sand-desert, also assumes the globular form. In spring it has true narrow foliage leaves at the base, but later on only scales are present and the work of assimilation is entirely carried on by the branches. The first-year shoots are strongly branched and geniculate at the nodes, and their branches of the later (1—2—3) sequences are thorns which bear a single flower. The plant forms a leafless thorny ball, it can attain a height of 40 centimetres and has very long roots. I have seen pieces several metres long, laid bare above the sand, and although only fixed at one end they were giving off fresh shoots. If the plant is buried the upper branches grow upwards through the sand.

*Convolvulus eremophilus* has a similar structure, but it is less strongly branched and less thorny.

*Euphorbia cheirolepis* an annual plant with small, bright green and glossy, spathulate and spiny toothed leaves belongs to another type. The same green colour distinguishes the vigorous, broad-leaved and very thorny *Cousinia annua* which attracts attention by its glossy snow-white stems. This plant I found in a deep valley amongst the dunes on a shifting sand-desert almost devoid of vegetation; there were only a few specimens and only in this particular valley. This illustrates the very scattered occurrence of the various species; one must examine a great number of localities before a thorough knowledge of the flora of the desert is acquired. Each locality presents only a few species of trees, shrubs or herbs. Other examples of this will be referred to in chap. 11.

It will be seen from the above description that the flora of the shifting Sand-desert is extremely poor. Looking over the desert from the top of a barchan, the eye is attracted by the scattered rough tussocks of *Aristida* and the switch or brush-like dwarf trees and shrubs, standing widely apart, particularly *Ammodendron* and *Calligonum* the most frequent and most enduring.

Only on closer examination does one find the herbaceous plants which hide in the valleys. These plants, already referred to, are ill-adapted to withstand sand-covering and are often smothered. But they endure desiccation, heat and the tear and wear of the drifting sand. This tear and wear is perhaps the reason why the plants of the more stable sand-desert are very rarely seen in the true shifting desert.

From the shifting sand-desert where the barchans hold their sway, we turn to a more stable type of sand-desert, the Hummock-desert (see p. 78), which Radde compared to a dead sea with a swell on, and which he regards as a transitional form between the barchans and the flat deserts. The sand hills are round and generally rather low, Radde states from a few feet up to 4—5 fathoms, i. e. about 10 metres at the most, which is, however, a considerable height. Where the hills are grouped closely together, the valleys between them are basin-shaped. Smaller crescent-shaped barchans may be present so that the sand-drift is not everywhere perfectly stabilised. The movement must however be slight in many parts, as indicated by Radde finding on the hill-tops a lichen (*Urceolaria indurata* Wain.), a thin black and white coating over the surface of the sand.

The vegetation consists partly of the same species as on the barchans, but they are differently developed, the trees and shrubs being weaker while the herbs are stronger. Another part of the vegetation consists of more exacting species including halophytes which grow in the valleys.

I look on the vegetation of the Hummock-desert as a sub-formation of the formation of the Sand-desert.

The vegetation is richer than on the barchans. The desert switch-plants are closer together than on the barchans, but they are smaller and generally take the form of shrubs, not trees. In such a Hummock-desert I found the average height of the bushes to be 2 metres and the distance between them from 7 to 20 metres. The conditions for germination are better, hence the greater density; on the other hand that acceleration of growth brought about by drifting sand is lacking, hence the smaller size.

The Sand Acacia (*Ammodendron*) is rarer here, while of general occurrence are *Salsola Arbuscula* and several species of *Calligonum* (these are difficult to determine without fruits). Amongst other plants present are Saxaul, *Eremosparton, Smirnowia*, bushes of *Astragalus*, and *Nitraria Schoberi* (which sometimes causes the formation of small dunes); *Lycium sp.* and *Reaumuria oxiana* are both halophytic bushes, generally occurring on clay, but also found in the lower parts of the sand-desert. Tamarisks occur on peculiar knolls of stratified sand which originate as follows: every year the Tamarisks cast numerous small twigs and flower-stalks over which a layer of sand drifts next summer; then comes another layer of branches and so on. The layers are generally exposed all the way round, and the slopes of the hill are more or less perpendicular. These low hills are generally circular, or the larger ones are elongated in the direction of the prevailing wind; their height is 2—4 metres. The bushes on them vary from half a metre to 2 metres high, and frequently have old and thick roots, which are exposed where the wind has destroyed the hill. On the other hand, hills of this kind may be buried in blown sand.

These Tamarisk-knolls are presumably remains of a former continuous tract of sandy soil now blown away except where the roots and shoots of the Tamarisks have kept the sand at the old level. MAC DOUGAL (1908 pl. 2) gives a picture of a sand-hill formed in the same way by a species of *Rhus*.

All the herbaceous plants given for the shifting desert occur in the Hummock-desert, where they live under more favourable conditions, because less exposed to burial by the sand or to exposure by denudation. Amongst other herbs occurring in the Hummock-dessert the most important is *Carex physodes* which, though mainly a spring-plant, yet plays a considerable part throughout the summer. It is a hemi-cryptophyte with sympodial, horizontal rhizomes, which together with the branched roots form a network in the surface-soil (fig. 15). The growth is so dense that during spring *Carex physodes* forms a green-sward in places. In June the leaves have already withered, and the resting summer-buds are hidden in a tunic of dead leaf-sheaths. The plant plays a prominent part in binding the sand, but it cannot contend against a severe sand-drift. This plant and *Aristida pennata* do not thrive together because the latter is only luxuriant in shifting sand, *Carex* where it is stable.

*Alhagi Camelorum* is very common in many parts of the stable desert. It spreads vegetatively by aerial shoots produced from long, horizontal roots. The part above ground is annual, poorly provided with leaves, thorny and often globular. It is very hardy, and when buried it forms new aerial shoots from the leaf-axils of the old shoot, while if the sand is blown away, new aerial shoots arise from the subterranean parts. *Alhagi* may occur as a plant of the dunes under apparently unfavourable conditions, but it seems to depend on tbe ground-water not lying too deep. Like many other plants in the neighbourhood of oases, it is used for fuel.

Other plants in the Hummock-desert are: *Tournefortia sibirica*, similar in habit to a *Lithospermum*, rather strongly hairy, with white blossoms and light fruits which the wind gathers together in sheltered places; *Convolvulus divaricatus* is woolly-haired with small cordate leaves; *Pluchea caspica* and *Jurinea derderioides* are thin-leaved knap-weeds; *Goebelia pachycarpa* is one of the *Papilionaceae* with pinnate hairy leaves; *Haplophyllum obtusifolium* is a bright green glabrous

Fig. 15. *Carex physodes.* April (nat. size).

undershrub with an offensive smell; *Artemisia*, an undershrub, and *Peganum Harmala* one of the *Zygophyllaceae* with a thick tap-root and prostrate branches. These species are all xerophytic in structure, but at the same time somewhat mesophytic since they are all comparatively leafy. The following species occurring in the lower sandy basins are halophytic in structure. *Cressa cretica*, a geophyte with salt-excreting leaves, *Zygophyllum*-species with thick leaves, *Tetradiclis tenella*, *Halimocnemis*-species, *Halanthium gamocarpum* and *Lipskii*, *Salsola crassa*, *spissa*, *sclerantha*, *Halostachys caspica* and *Euphorbia Turczaninowii*, the latter with thick glabrous foliage. Most of these are annuals (summer-annuals); *Cressa*, *Zygophyllum* and *Halostachys* are perennials. All except *Cressa* are stem-succulents, leaf-succulents or bracteole-succulents. Some are the same species met with in the clay-desert, and they all belong to the same types seen there. The lower saline parts of the Hummock-desert are thus very closely related to the clay-desert, as regards their vegetation; the two are scarcely distinguishable except by the soil.

In this connection we may quote a description by Radde (l. c. p. 154) of the sand-areas near the border of Afghanistan (July $8^{th}$):

> "Diese alten festen Sandberge ernähren keine Straucht art welche auf dem jüngeren zumteil noch wogenden Sande die ersten Bedingungen zum Haften desselben darbieten. Nur wo entblösster, beweglicher Sand lagert, finde ich wenige, schwächliche Exemplare von Calligonum polygonoides Pall[1]). Auf der ganzen Strecke sahen wir meistens eine Unterlage von jetzt vollständig vergilbter Poa bulbosa, welche die Pferde dennoch gerne fressen. Alhagi Camelorum, typisch und in einer niederliegenden Varietät in graugrünen Kolorit wechselt mit Peganum Harmala ab. Beide bevorzugen den mehr lockeren Sandboden, auf dem alten festen werden sie schwächer und seltener, diesen liebt Prosopis Stephaniana, weite Strecken sind von ihm bestanden, dazwischen etwas Heliotropium dasycarpum und überall gelbes Delphinium camptocarpum, welches von der Sonne

[1]) *C. Pallasia* l'Hér. O. P.

zur Blütezeit getrocknet wurde, so dass die Blumen beim Berühren alle abbrachen und keine Samen gebildet wurden. Andere Gebiete sind mit einer lebhaft gelbgrünen, ausdauernden Artemisia (Art. campestris L.?) bestanden. Rasch durchlaufendes Feuer, welches die spärlichen Poa-Grasflächen vernichtete, beschädigte diesen Wermut mehr, als die sengenden Sonnenstrahlen, er treibt nun oben, wo das Feuer ihn verschonte. Eine hohe Composite (Cousinia Raddeana C. Wnk.) ist schon ganz abgetrocknet, sie wählt die Gehänge zum Standorte, der Wind verwehte weithin die abgebrochenen untenher weisfilzigen Blätter und Blütenstengel. In Löchern und Windstillen bilden diese sammt Alhagi grosse Haufen von totem Burian. Das duftende, wollig bedeckte Lachnophyllum gossypinum Bg. blüht noch nicht, erreichte bis 1 Fuss Höhe und brach aus dem abgesengten Boden überall aufs neue hervor. Eine hohe Malva (Alcea sulphurea Bois.) besteht in gedrängter Anordnung die östlich gekehrten Gehänge des Kuschk-Ufers, sie könnte prachtvolle Malwengarten bilden, wenn nicht auch an ihr die Sonnenstrahlen ihre vernichtende Macht geübt hätten, Blumen und Knospen sind vertrocknet. Als sechster Florentypus ist noch die stinkenden Psoralea drupacea Bg. zu erwähnen, welche namentlich in den Thalmündungen ausschliesslich bedeutende Strecken besteht."

From a botanical point of view the Hummock-desert is closely related to the Desert of the Sand-plains, the one which Radde and Semenow call Sand-steppe and which the former author compares with "an almost calm sea". The type of landscape, as expressed by the name, is flat or slightly undulating expanses of sand. In places they are interrupted by bare "Takyr"-depressions or by moving-sands. The switch-shrubs are locally the dominant vegetation as in the hummock-desert; the same species, but here of still smaller stature, seldom higher than a metre. In other places there are no shrubs, except perhaps isolated bushes of *Salsola subaphylla*, and the vegetation consists then mainly or exclusively of herbaceous plants interspersed with a few dwarf-bushes such as *Prosopis Stephaniana* and *Lycium turcomanicum*. Most of the herbs take part in the spring-aspect described later. The summer-vegetation on the whole has the same character as that of the hummock-desert, yet my impression, without having seen many localities of this kind, is that the annual *Chenopodiaceae*, more especially the succulent ones play here a minor part; this would be natural, since low and therefore saline places will rarely occur in an area which is almost level.

The minor place taken by annual succulent Summer-

Fig. 16. A sandy and uncultivated area called "Reksar", near Buchara. *Alhagi Camelorum*, *Zygophyllum Eichwaldii*, *Peganum Harmala*, *Goebelia alopecuroides*, fewer *Suaeda pterantha*, *Salsola sclerantha*, *Atriplex dimorphostegium*, *Ceratocarpus arenarius*. May.

Chenopodiaceae in the level Sand-desert indicates some difference between this and the Clay-desert. As to growth-forms the two resemble each other, in having low shrubs, perennials, and ephemeral and other spring-plants.

The most common plants in the Sand-plain desert are *Alhagi Camelorum*, *Goebelia alopecuroides*, *Zygophyllum Eichwaldii* and *Peganum Harmala*. Fig. 16 shows a vegetation where these four species take the principal part, especially *Goebelia* with its multipinnate, white-haired leaves.

Other Summer-plants are *Kochia prostrata* and *stellaris*, *Bassia sedifolia, Heliotropium Radula, Elymus sabulosus, Suæda dendroides, Salsola sclerantha* and other species of *Salsola, Ceratocarpus arenarius, Cressa cretica, Haplophyllum* sp., *Artemisia,* perennial *Astragalus spp.,* and the species of *Convolvulus* already mentioned. What was said about *Carex physodes* under hummock-desert also holds good here, namely that, although a spring-flowering plant, it plays a part during summer in binding the sand by its rhizomes and roots.

The vegetation of the desert of the sand-plains may be comparatively dense (see fig. 16), but in other places, the plants are much more scattered; the plain may indeed be so bare that one must search for the plants. In spring, however, there is always a richer vegetation.

The majority of the species are the same as in the other forms of Sand-desert (sub-formations) and so are the growth-forms. In addition to small shrubs, the following types of herbs are found: thorny species (*Alhagi,* some species of *Salsola, Ceratocarpus*), hairy species *(Goebelia, Kochia, Bassia, Heliotropium, Salsola sclerantha, Artemisia, Convolvulus),* the succulent species are of minor importance (*Suæda, Salsola*). Most of the species are perennials or undershrubs; the latter include *Kochia prostrata, Suæda dendroides* (?), *Artemisia* and some species of *Convolvulus. Kochia stellaris, Bassia,* species of *Salsola* and *Ceratocarpus* are annual summer-plants.

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If a survey is made of the distribution of the growth-forms, more especially that of the annual summer-plants of the Sand-desert, it will be found that the annuals constitute the majority of the plants in the Shifting-desert, and a much smaller proportion in the Desert-plains. Of the herbaceous plant-species given above for each sub-formation, 62 per ct. in the shifting Sand-desert, 44 per ct. in the Hummock-desert and 25 per ct. in the Desert-plains are annuals. Though no very great importance can be attached to these figures owing to incompleteness of the plant-lists, yet they have a certain value because they confirm the results of direct observation. The latter has taught me, that in the shifting desert such herbaceous plants as are present are generally annuals, whereas on the more stabilised sands these give place to perennials and undershrubs. This is only natural, for if the perennials have not, like *Aristida*, unusual powers of resisting sand-drift, they will sooner or later be smothered by a shifting barchan and very few, if any, will produce seeds during the first year; on the other hand, the annual plants with a shorter growth-period will have a greater chance of surviving and ripening seeds.

The difference in the numbers of annuals in Hummock-deserts and Desert-plains appears to be due to the annual halophytic *Chenopodiaceae* which occur in the depressions of the Hummock-desert, but seem to be of less importance in the Desert-plains.

Finally, attention is directed to the trees of the desert (the switch trees and shrubs) which as emphasised in the preceding pages, play the most promiment part and attain the richest development in the shifting desert, while they deteriorate where the sand is stable. Sand-drift seems to be a condition essential for vigorous growth in their case and also with *Aristida pennata*.

Making a mental comparison between the sub-formations of the sand-desert described, we see that they have many features in common both floral and biological, but that the differences between them are not altogether to be neglected. The most important common feature which unites them and which causes them to be regarded as sub-formations and not as formations is first the general occurrence of the desert-trees, though under a somewhat different form; secondly that the soil is sand, which is saline only in the depressions so that the true halophytes play a comparatively minor part except in these places.

The different forms of sand-desert are evidently historically related in that the one must have originated from the other. What has been the course of development? It has been already pointed out that Radde (1899 p. 16) following Obrutschew regards the Desert-plains" the covered Sand-steppe" as the last stage in the metamorphosis of the sand; that the sand-hills, while being covered by vegetation, are gradually being levelled down through the agency of water, wind and burrowing rodents. In the terms used by Cowles this metamophosis is a topographic succession, due to topographical changes of the surface. Korshinsky regards the matter from a different point of view. His opinion (1896 pp. 6, 8) is that the "normal type" of sand-desert is the Desert-plain "level or undulating areas of sand" covered with *Haloxylon, Salsola Arbuscula, Calligonum, Ephedra, Ammodendron* and *Eremosparton*, and during spring with a number of herbaceous spring-plants; this desert-tree vegetation Korshinsky regards not only as the most characteristic, but also as the original type (comp. above p. 36). He is of opinion that in former times a similar vegetation covered the whole area of sand, and that man is the agent of destruction to whose devastations the naked and shifting sand-desert is due. "As soon as we get away from roads and human habitations and reach more solitary places, we always find that the sand-surface becomes more closely covered with vegetation of trees or shrubs. These trees arrest the sand, not through their sand-binding roots, but through their size which modifies the force of the wind and screens the soil from its attacks. Under their protection a richer herbaceous vegetation is also developed." This development from stable to unstable desert through the agency of man must be termed a biotic succession (Cowles). This and the topographic succession mentioned above do not exclude each other.

Even if we allow that Korshinsky is correct, that man through felling trees for firewood and through his herds of cattle roaming about, has in many places laid bare the arrested sand and thus brought about the appearance of the naked desert, — it is still probable that the Desert-plains and the Hummock-desert have originated from the shifting-desert. In what other way could the hilly or undulating sand-desert originate? With Obrutschew and Radde I consider it most natural to assume that the normal and natural development (the regional succession, (Cowles) not the topographic or biotic one) has taken place from Barchans to Hummock-desert and from the latter to Desert-plains. It is not correct as Korshinsky states that the stable desert is always found far from human habitations, for in such places I have seen wild sand-desert almost devoid of vegetation.

In this connection attention is drawn to the Taklamakan-desert where S. HEDIN travelled for days through a desert perfectly devoid of vegetation, and far away from any human habitations.

If it has been thus established that the development of the Sand-desert has in all probability been from Barchans to Hummock-desert and Desert-plains, that it has proceeded from the most shifting condition to the more stable, then we have at the same time traced the process of development of the vegetation. This process is expressed by the order in which the various sand-desert vegetations were described in the preceding pages, and it may be shortly summed up:

1. *Aristida pennata.*

2. *Ammodendron*, *Calligonum* and other desert trees. A few herbs, mostly annuals.

3. Desert-trees, smaller, but growing more closely. Several herbs, among which perennials are dominant. Annual halophytes in the valleys. (Hummock-desert).

4. Small desert-trees (or none). No halophytes (or few). (Desert of the Sand-plains).

To this process of development the definition of formation by Moss might be applied. What this author (1907 p. 12) terms a formation is:

"The series of plant associations which begins its history as an open or unstable association, and eventually becomes a closed or stable association."

Even if the Desert-plain be not closed, it is in itself stable, a terminal sub-formation, and the definition of formation given by Moss thus seems to be applicable to the Sand-desert as a whole. The definition of formation by Moss applied in this way, is employed here as a means of illustrating the unity of the sand-desert and to elucidate its metamorphosis. It must be emphasised, however, that I have grouped the different types of sandy desert in the same formation not because they constitute what might be called a historical series derived from each other in a definite sequence, but because at the present time they agree on general lines as regards soil and growth-forms. More thorough knowledge of the vegetation would perhaps lead one to designate the different types of sandy desert as formations, or even to create more, e. g. a special formation for the vegetation of the valleys between the sand-hills. If one followed the concepts of CRAMPTON in a recent paper — published subsequent to the Danish edition of our memoir —, then the different types would be regarded as formations: the Barchan desert would be a migratory (or neogeic) formation whose substratum "owes its features to recent geological processes", whereas the Desert of the Sand Plains would be termed a stable (or palaeogeic) formation; presumably the Hummock desert would also be a stable formation.

Though brought into existence in a different way, the development of the Sand-desert is similar to that of the dune-territories of northern Europe.

The Spring-aspect of the Sand-desert I hardly know from personal observation, hence the following account is mainly based on plant-lists and descriptions borrowed from KORSHINSKY and RADDE (1899). The Spring-plants are mostly found in the stable sand-desert, but they may also occur in the more shifting desert, especially in depressions where the moisture is greater, the clay-content larger, and the surface therefore firmer. Wherever the seeds are carried, there they must germinate when spring comes, and even on loose sand and under unfavourable conditions the ephemeral plants may still succeed in maturing their seeds; their precocious development comes here to their aid and is indeed their only means of preservation.

On stationary sand the spring-vegetation may be comparatively rich, yet nowhere does it form a carpet.

The only species which locally attempt to form a greensward are *Carex physodes* and *Capsella procumbens.* The former has been frequently referred to already (see p. 97) as it plays a great part in binding the sand. It is already in flower in March and bears fruit in April, the fruiting ear is large and inflated so that it is easily rolled along by the wind. *Cap-*

*sella procumbens* is a small, delicate annual plant which disappears very quickly.

The remainder of the plants of the spring-aspect in the Sand-desert can be classed, like those of the Clay-desert under the groups: Ephemerals, Hemicryptophytes and Geophytes. The following species belong to the ephemerals which are the most abundant group: *Triticum squarrosum* and *desertorum, Danthonia Forskalei, Schismus calycinus, Bromus tectorum, Boissiera bromoides, Avena sterilis, Hordeum murinum, Papaver pavoninum, Hypecoum parviflorum, Capsella procumbens, Isatis minima* and *emarginata, Tetracme quadricornis* and *recurvata, Lachnoloma Lehmanni, Malcolmia circinnata, grandiflora* and *Bungei, Streptoloma desertorum, Euclidium syriacum, Octoceras Lehmannianum, Goldbachia laevigata, Chamaesphacos ilicifolium, Lallemantia Royleana, Anchusa hispida, Nonnea picta, Echinospermum semiglabrum, Plantago lachnantha, Statice spicata, Valerianella Dufresnia, V. Szovitsiana, Crucianella filifolia, Erodium bryoniaefolium, E. oxyrrhynchum, Astragalus arpilobus, Ceratocephalus falcatus, Delphinium persicum, D. camptocarpum, Matricaria lamellata, Scorzonera glabra, S. hemilasia, Senecio subdentatus, Koelpinia linearis, Lactuca undulata, Heteroderis pusilla, Heteracia Szovitsii, Cousinia alata, tenella* and *minuta, Dipterocoma pusilla, Centaurea moschata, pulchella* and *phyllocephala, Silene nana, Psammogeton setifolium, Eremodaucus Lehmanni, Aphanopleura capillifolia, Diarthron vesiculosum, Atriplex dimorphostegium.*

Many species in this list occur also amongst the ephemeral plants of the Clay-desert. Those which I have not already remarked on in the Clay-desert are of the same type: low, mesophytic or slightly xerophytic plants, sappy and without much mechanical tissue, and almost all with small leaves or leaflets which are often more or less hairy. A few have glabrous leaves (*Senecio, Diarthron*). Thorns are found on *Cousinia alata* and *minuta, Centaurea phyllocephala, Centaurea Moschata;* a few others have rather broad leaves. *Heteroderis pusilla, Hypecoum* and some *Cruciferae* have rosettes.

A comparison between figure 17 and figures 5 and 6 will show that the ephemerals of the Sand-desert are of the same type as those of the Clay-desert.

Fig. 17. Annual Spring-plants from Sand-desert: a. *Lachnoloma Lehmanni.* b. *Tetracme recurvata.* c. *Fumaria Vaillantii.* d. *Streptoloma desertorum.* e. *Senecio subdentatus.* f. *Boissiera bromoides.*

If we now consider the perennial Spring-plants, they will also be found to be the same species or species of a similar type as the ones of the Clay-desert. There *Poa bulbosa* was the most important species, and in the Sand-desert it occurs locally in great quantities on stationary soil, but *Carex physodes* (and *C. stenophylla*) are here the chief species; the horizontal rhizomes of these species are well adapted for growth on a stationary sandy soil.

Other hemicryptophytes in the Spring-aspect of the Sand-desert are *Rheum tataricum* (see p. 56), *Eremostachys*-species, *Scorzonera pusilla*, *Astragalus ammotrophus*, *chiwensis*, *orbiculatus*. The species of *Astragalus* have multipinnate leaves as in the Clay-desert, the leaflets are hairy and elliptical or ovate.

A number of geophytes are recorded for the Sand-desert in spring: *Tulipa biflora* and *Androssowii*, *Allium caspicum* and *sabulosum*, *Rhinopetalum Karelini* (all *Liliaceae*), *Eminium Ledebouri* (*Araceae*), *Iris falcifolia*, *Linaria odora*, and the parasites *Phelipaea flava* and *trivalvis*, the former with an inflorescence which almost attains the height of a metre [1]).

By comparing the plants mentioned, it will be seen that the spring-perennials of the Sand-desert are formed after the same type as those of the Clay-desert. It is possible that at any rate all the ephemeral species are common to both.

## CHAPTER 10

### The Riverside Thickets (Bushland).

My own observations on the Riverside Thickets only extend to those on the lower part of the Amu Darya, but thickets also occur along the rivers Tedshén and Murghab, etc. (Antonow, Korshinsky).

My knowledge of the Amu Darya was acquired during a boat-journey made by the expedition from Tshardshui to Chiwa and Kunja Urgentsh, a trip described by O. Olufsen in "Geografisk Tidsskrift" vol. 15.

[1]) Figured by O. Fedtschenko in Bull. Jard. Bot. de St. Pétersbourg VI 1906.

Though the Amu Darya from Kelif to the Sea of Aral, a distance of about 1000 kilometres, has not a single affluent, it is in its lower course an imposing river. Where it is wide (3 kilometres or more) its brownish waters glide calmly along laying down banks, on which the boat is continually stranding, or removing them again. But where the river has forced its way through firmer rocks, for instance the limestones occurring in its lower course, there it becomes narrower, runs with greater speed and forms no strand.

From the river one sees the desert on both sides. Though it extends down to the river in a few places only, yet the desert gives the character to the landscape. Beyond the green fringe along the banks lie brown drifts of sand, bare slopes of loess, limestone or sandstone, or low, dry, terraced mountains on whose flat tops old ruined castles are often visible. Where the river-bed is much wider than the river, one enjoys the characteristic sight of green oases on the background of the brown desert. Thus the oasis Eldjik appears like a green plot with verdant fields, light slender poplars and dark domelike *Ulmus campestris*, surrounded by the naked sand. In other places thickets of shrubs, sometimes of considerable width, clothe the banks from the river to the desert; here one may see the cupola-shaped tents of the Kirghiz, and their cattle roaming about. In less fertile places one may scare the wild pheasants or see the ground torn up by the wild boar. The royal tiger is also said to visit these places occasionally.

On the eastern side of the river the desert sand in some places extends right down to the water, and the bank is then a high glissade, the lee side of an advancing barchan. (Comp. above p. 78). In such a case there is of course no vegetation on the bank.

In other places, where the river has eaten into the margin and then retreated a little, a narrow green streak will be seen mainly formed by Tamarisks, *Phragmites* and perhaps *Erianthus Ravennae* or *Glycyrrhiza glabra*. A firm moist soil will carry also *Equisetum ramosissimum, Polygonum Bellardi, Mulgedium tataricum, Plantago major, Aeluropus littoralis, Juncus compressus, Scirpus hamulosus* — all small, herbaceous, mesophytic or somewhat hydrophytic species.

The larger plants given above reappear almost everywhere. In many places the thickets are formed by Tamarisks alone. Thus flat banks of clay left by the river may be covered uniformly by small plants of Tamarisks about 0,5—0,7 metres high. These uniform thickets are partly artificial as they are cut down close to the ground every third or fourth year and taken away for firewood.

In the true thicket the Tamarisks attain a height of about 3 metres. There are two species (perhaps more, as LITWINOW has in recent years described a number of species): *Tamarix*

Fig. 18. Growth of *Erianthus Ravennae* in the river-valley of Amu Darya at Chasarasp. In the foreground, scrub of *Lycium* and Tamarisks. August.

*hispida* with its somewhat bluish green foliage and *T. laxa* a glabrous species. *T. elongata* is also met with here.

*Erianthus Ravennae* is a huge tussock-grass, with grey hairy tops rising 4—5 metres above the ground, and long narrow leaves bent outwards in all directions. This plant sometimes forms pure or almost pure thickets (fig. 18), open forests of high grass-shoots, but dense enough below amongst the huge tussocks with their long leaves. On the ground below we have *Glycyrrhiza glabra Aeluropus littoralis* and (according to LITWINOW) the Orchid *Limodorum turkestanicum*. Interspersed among the *Erianthus* other tall plants may be found: *Phragmites*, *Elæagnus* bushes, *Calamagrostis pseudophragmites*, *Tamarix hispida*. *Erianthus* more frequently, however, occurs here and there amongst other plants, the tussocks standing singly or in groups among these.

*Glycyrrhiza glabra* may here and there form pure or al-

Figur 19. "Shar Togai", thicket on the left bank of the Amu Daria. In the background *Tamarix* and a tuft of *Erianthus Ravennae*, in the foreground *Alhagi Camelorum*, *Lycium ruthenicum*, *Halostachys caspica*.

most pure thickets. The stems attain the height of a metre (up to $1{,}_5$ metres), and stand close together borne on subterranean horizontal runners, often several together as a "radix multiceps." The species has pinnate leaves which at night assume the sleep position, all the leaflets moving vertically downwards, so that their lower surfaces touch.

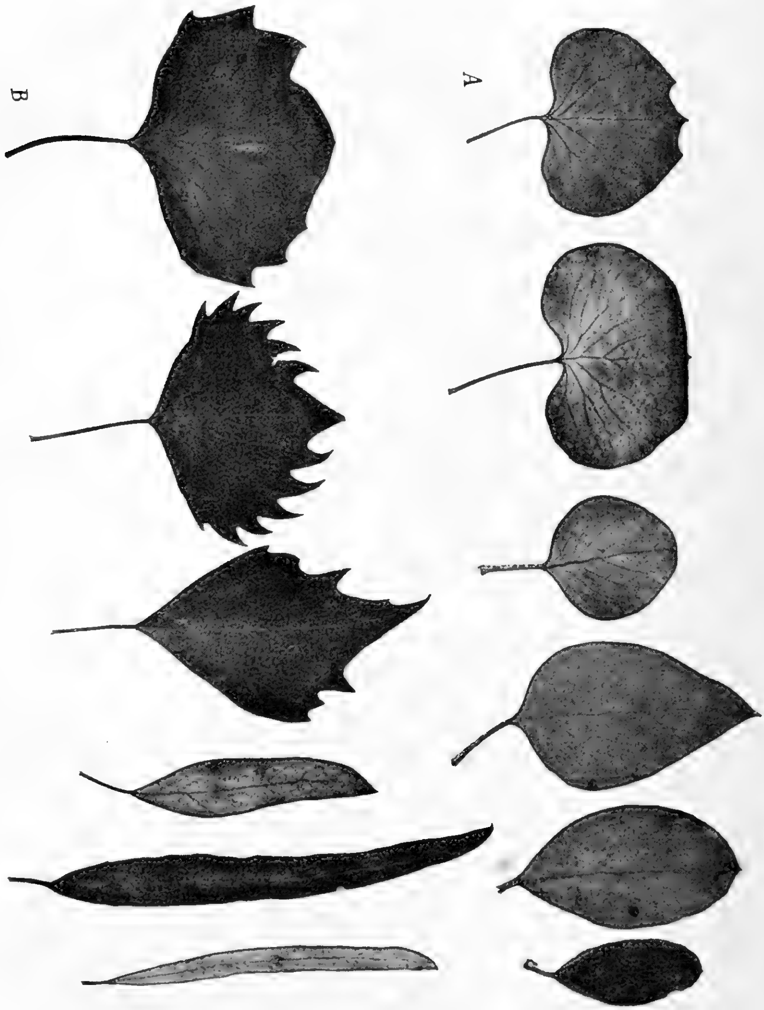
Besides *Tamarix*, *Erianthus* and *Glychyrrhiza*, the following species occur on moist, but not wet or muddy soil: *Saccharum spontaneum*, very striking in appearance with its shiny, snow-white top at a height of about 2 metres from the ground; *Halimodendron argenteum*, a thorny leguminous bush which rarely exceeds a height of 2 (2,5) metres; *Alhagi Camelorum* and *Lycium turcomanicum,* shrubs attaining a height of up to 2 metres; *Halostachys caspica* a migrant from the desert, which on the river-banks is exceedingly luxuriant in growth, and amongst *Tamarix* bushes it may attain a height of 3 metres; also *Equisetum ramosissimum, Zygophyllum Eichwaldii,* and several casual visitors, e. g. *Launaea nudicaulis, Mulgedium tataricum, Plantago major. Phragmites,* although strictly belonging to moister places, may also be found here; so also with *Calamagrostis pseudophragmites* a metre-high grass with thin subterranean runners, and *Typha Laxmanni.*

These plants form low thickets as represented in fig. 19. They present a particularly curly or rufled appearance, because the bushes appear devoid of leaves; nothing is seen but twigs forming a confused mass, and where (as in the picture) *Lycium* and *Alhagi* are prominent the thicket is almost impenetrable on account of thorns. — The scattered *Erianthus*-tussocks with their orderly ranks of flowering shoots and long leaves are an agreeable relief in this otherwise confused picture.

In other places the thorny species disappear and the vegetation is formed by Tamarisks, *Glycyrrhiza* and grasses. Sometimes these also occur: *Elæagnus hortensis var. continentalis,* bush-willows and poplars. (*Salix angustifolia var carmanica, S. Wilhelmsiana, Populus pruinosa, P. euphratica*).

These, especially the poplars, generally attain their full development at higher elevations. *Populus pruinosa* is the one I have seen most frequently but *P. euphratica* is also widespread. I saw it frequently in the country round Chiwa. Both occur either as shrubs or as trees up to a height of 6—8 metres, and are noteworthy because of the wide variations in shape presented by their leaves as illustrated in fig. 20. The narrow leaves are mostly found on bushes which may be entirely narrow-leaved or somewhat broader leaves may occur higher up the branches. Larger trees, during the flowering period or after it, generally have broader leaves. Through a twisting of the petiole, the leaves assume a vertical edgewise position and they have a light greyish colour.

These species of poplar may occur as shrubs interspersed amongst Tamarisks, *Halimodendron, Erianthus,* etc., but they attain a greater height than the others. At higher levels where the surface is perfectly dry during summer except that it may at times be flooded by the river, but where a water-supply




Figur 20. Leaves of: a. *Populus pruinosa*, b. *Populus euphratica*. (Botanisk Tidsskrift 26).

derived from the river is available at a slight depth, the poplars often become large trees sometimes interspersed in the thickets, sometimes forming forests.

Antonow describes (l. c. p. 188) how in spring when the rivers carry most water, the poplars (*P. euphratica*) stand with their bases submerged, and he says that the soil round them is only dry at midsummer. I have only seen the riverside thickets from June till August, and my observations confirm that at this time of the year the poplars stand on dry land. On the area I examined the taller trees grew in more elevated localities than the low shrubs.

The poplars can attain a height of up to 10 metres. The type of vegetation they form must be characterised as forest, and ANTONOW's argument against this, that they only form a

Figur 21. Forest ("Togai") at Kavaklé on the left bank of the Amu Daria. *Populus pruinosa*. At the left side of the man is *Elaeagnus hortensis var. continentalis*. In the foreground, *Erianthus Ravennae*. End of June.

narrow strip and "so to speak have only one dimension" does not hold good; they have a considerable width in many places, especially where the river curves and the flood-plain is much wider than the river.

From Tshardshui to Chiwa *Populus pruinosa* forms the forests (fig. 21) and only one other tree occurs, namely *Elaeagnus hortensis* var. *continentalis Serw.* This tree scarcely equals the poplar in height and many shrub-like specimens may be seen. Its foliage is still whiter than that of the poplar, so that this forest is not at all like the northern bright-green forests.

The poplar forest may be quite dense, but not hard to traverse except where the undergrowth is dense, and this only occurs where light penetrates the tree-canopy. The principal species of the undergrowth are: the thorny bush *Halimodendron argenteum*, *Erianthus Ravennae* and *Tamarix*, these species, more especially *Tamarix*, cannot grow in deep shade. The other species present, *Glycyrrhiza glabra*, *Aeluropus littoralis* and *Alhagi Camelorum*, can endure shade, but it is very noticeable how much wider apart they stand here than in the light. When they form undergrowth they are so scattered that one may walk about without treading on them, whereas in the light they usually form a close mat. — Open glades in the forest where *Halimodendron* and *Erianthus* occur, seem in many cases to be due to human agency. Trees are cut down for building purposes and for fuel.

In the *Populus pruinosa* forest, lianes are represented: *Cynanchum acutum*, *Asparagus verticillatus*, *Clematis orientalis* (*f. oblonga*). These may be seen climbing high into the trees, but neither so frequent nor so luxuriant as to allow it to be said that they give the forest a special character. This may, however, be said of *Cuscuta Lehmanniana*, the growth of which in many parts is so luxuriant that it kills large branches and even whole trees.

Along the river-banks in the Chiwa country *Populus euphratica* sometimes forms forest. It has the same grey leaves as *P. pruinosa*, but their shape is still more variable (see fig. 20), the leaves of the bushes being linear while those of the trees are as broad as the broad leaves of *P. pruinosa*. *P. euphratica* attains about the same height as *P. pruinosa*. It may perhaps only be accidental, but where I have found it as the chief species in the thicket it was more a shrub than a tree with a trunk, and it seemed to be less inclined to form a close canopy than *P. pruinosa*. One result of this is that the *P. euphratica* association is less forest-like and has more the character of a thicket. These thickets may be very dense, sometimes they are almost impenetrable because of the thorns of *Halimodendron argenteum*. In addition to this species there are bushes of *Tamarix* and *Salix angustifolia* with narrow-leaved *Populus euphratica*, while masses of *Glycyrrhiza glabra* hide the ground. The dominant plant after the poplars is *Apocynum venetum*, which attains the height of 2—3 metres and has thin stems, the growth being that of a semi-liane supporting itself on other bushes by the aid of its outspreading branches. These extend horizontally and through their own weight become pendulous, the extremities bearing inflorescences of handsome red blossoms.[1]) When *Apocynum venetum* grows on treeless ground, the branches lie prostrate along the surface.

Also *Clematis orientalis* and *Cuscuta Lehmanniana* I have recorded as being of frequent occurrence in thickets of the above type.

The thickets described above must be regarded as true riverside or gallery forest, an edaphic formation whose differentiation from the surrounding formations depends solely upon the presence of the river; in the first place the thickets are only found along the river, and secondly one can see that further from the river they become thinner and lower. Such is for instance the case at Kogertlé on the right bank of the Amu Darya. Here the river-bed is much wider than the river and is evidently subject to periodical flooding. The plain is covered with thick luxuriant forests of poplars interspersed with *Phragmiteta* and glades with *Erianthus* and Tamarisk. Gradually as one goes farther away from the river, the forest thins out and the poplars become lower and less vigorous. The clumps of trees become separated more and more by open spaces occupied only by isolated plants of *Glycyrrhiza glabra*, *Halimodendron argenteum*, *Zygophyllum Eichwaldii*, *Tamarix* or low poplar-bushes. The Tamarisks become more frequent until as almost pure communities they form the outposts against the brown bare hills of the desert. As will be shown later (chap. 11), the Tamarisks may even invade the desert, where by means of their very long roots they can always secure water from deeper layers.

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[1]) A fibre obtained from *Apocynum venetum* is used by the natives for cordage under the name "red hemp" (Kisil Kandir).

Another illustration may be given from Ak-jar on the left river-bank, where the thickets attain a width of about 70 metres. Nearest the river the thicket consists of *Erianthus Ravennae*, interspersed with *Halimodendron argenteum*. The latter extends farther inland than *Erianthus*, and towards the desert it becomes intermingled with *Tamarix laxa;* this plant is absent from the outer part of the thicket nearest the river but forms the whole of the inland half, growing as scattered bushes about 2 metres high and interspersed with *Alhagi Camelorum*. *Alhagi* also extends into the desert, or one might say that it passes from the desert into the thickets, for, although never seen in the most barren desert, it must be regarded as a true desert plant. This is also the case with *Halostachys caspica*, it may be strongly developed in the thickets, but it is especially widespread in the salt-desert (see p. 113). *Zygophyllum Eichwaldii, Lycium turcomannicum* and *Halimodendron argenteum* are occasionally desert plants confined to clay soils, but in my opinion they are more exacting in their demands and belong to more favourable habitats such as the riverside thickets.

The plants which are more definitely restricted to the river banks are: *Erianthus*, *Saccharum*, *Calamagrostis*, the poplars, the willows and *Elaeagnus*, with the addition of the marsh-plants. A few of these, however, occasionally migrate from the river-banks, thus I have seen a weakly form of *Phragmites* with short aerial runners, along with *Calamagrostis pseudophragmites* on a slightly saline plain near Chodsheli; the occurrence of *Populus pruinosa* in the desert is described in chapter 11.

In conclusion we give a translation of ANTONOW's description of the transition from the thickets towards the deserts (l. c. p. 189):

> "These thickets quickly become more stunted and poorer at each step we take from the river towards the loess-plain. Only a few Sashen[1]) from the river, the bush-forms of *Chenopodiaceae* put in an appearance comparatively well-

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[1]) 1 Sachén (fathom) = about 2,13 metres = 3 Arshin. 1 Verst = about 1067 metres = 500 Sashén.

developed because near water. *Tamarix* alone forms a dense fringe round the riverside thickets and stretches away from the river, far into the desert as low bushes bearing a scanty foliage. Scattered bushes may still be found 2—3 Verst[1]) from the river-bank, but what a difference between these poor stunted bushes no higher than 2 Arshin[1]) and the vigorous little trees of 2—3 Sashén[1])! The occurrence of this bush in the loess-desert (or plain) is the sign that there is probably a river in the neighbourhood, so constant are the conditions of distribution of this species."

In connection with the riverside thickets, a brief reference ought to be made to the aquatic and marsh-vegetation along the Amu Darya.

Beyond the thickets, in the water or on the very wet muddy soil, there are dense reed-swamps, up to 3 metres high, of *Phragmites*, (Phragmiteta) or of *Typha* (Typheta) including *T. angustifolia*, *T. Laxmanni*, *T. stenophylla*. The two last are small and narrow-leaved forms. *T. Laxmanni* seems to occur most frequently of the three; as already stated, it may also invade some parts of the land which is dry during summer and mingle with the plants of the thickets, but in relation to these it always plays a subordinate rôle. *Calamagrostis pseūdophragmites* which is also a wet-soil plant with horizontal subterranean runners, prefers a somewhat drier soil than *Typha*, and when it occurs along with the latter it is subordinate; so also in the thickets, it is generally subordinate to the plants of the thickets. *Calamagrostis* however, may form a pure association on submerged soil.

In the irrigation-canals and ditches, the following plants were observed: *Scirpus Tabernaemontani* and *S. maritimus*, *Zanichellia pedicellata*, *Potamogeton perfoliatus var. Mülleri*.

At Giaur Kalá, I saw a deserted branch of a river ("Stariza," see p. 33) now a lake, and in this the following plants were growing: *Phragmites communis*, *Polygonum amphibium*, *Potamogeton perfoliatus* and *lucens*.

These are the only notes taken on the aquatic and marsh vegetation of the Amu Darya, but they can be supplemented

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[1]) See note page 118.

by plants which I saw in the Turkestan herbarium in the Imperial Botanical Gardens at St. Petersburg; according to the labels they were all collected on the Amu Darya near Chiwa.

*Najas major* Roth., N. *minor* All., *Ruppia maritima*, L., *Zanichellia pedicellata* Fr., *Butomus umbellatus* L., *Vallisneria spiralis* L., *Salvinia natans* Hoffm.

The following species which I collected in various small Chiwensian lakes may perhaps be of interest in this connection.

In salt-lakes where *Salicornia* not only fringed the border but also entered the water: *Phragmites* (withered), *Scirpus affinis, Ruppia maritima.* (Comp. above p. 55).

In fresh or slightly saline lakes, *Phragmites* is often dominant; the growth is here very dense and strong, and single reeds may attain a height of more than 4 metres.

In other small lakes, *Typha angustifolia* and *T. latifolia* are dominant, interspersed with *Scirpus littoralis* or *Calamagrostis pseudophragmites,* and in lakes of this kind the following submerged plants were found: *Potamogeton crispus* and *fluitans, Myriophyllum, Ceratophyllum demersum*, and *Polygonum amphibium* with floating leaves.

## CHAPTER 11

### Descriptions of Vegetation from selected Localities.

In the previous description of the various desert-formations, the distinction between them is based mainly on the soil in which the plants grow, but it has also been attempted to characterize them by means of their growth-forms. Taken as a whole it seems to be the case that a different soil produces different growth-forms. One thus refers to the switch-trees and the dry and thorny herbs of the Sand-desert, to the dwarf-bushes and halophytes of the Clay-desert, and to the richly leaved trees and lianes of the Riverside Thickets.

But the formations pass over one to the other, and there are species common to several formations. A description of the individual formations such as has been given in the preceeding pages can therefore only present a schematic view of the vegetation. It may bring the physiognomy of the vegetation more clearly before the reader if I reproduce here a series of descriptions from selected localities in the desert of Transcaspia.

1. Sand-desert at Tasha-Kirr on the right bank of the Amu Darya. June 22nd 1899:

The Sand-desert in this place stretches right down to the river with a high glissade slope, and that this condition has probably existed for a long time may be confirmed a little farther north where there is a long high cliff of sandstone 8 to 10 metres high. This cliff consists of strata of conglomerate with much sand (the stones attain the size of a bean). Peculiar forms of erosion are shown, low columns and pillars of sandstone crowned with larger masses, probably the remains of more resistent strata which have protected the lower parts.

The brown desert behind is very rugged, dune behind dune each with crescent-shaped concavities turned towards SE. Tamarisks grow on the dunes nearest the river-valley, sometimes up to the summits, the bushes being about 2 metres high. Where the river has eroded the foot of the glissade so that the sand has fallen down, one sees the stems and long roots of the Tamarisks hanging on the slope.

Farther into the desert, the fresh green colour of the Tamarisks is lacking, but many dead remains of old stems and branches were seen, probably *Tamarix*. This is a sombre, naked desert formed of large, crescent-shaped dunes. The larger plants stand hundreds of metres apart. The most common is *Aristida pennata*. None of this plant was seen in the most exposed places, the tops of the dunes. *Calligonum* and *Ammodendron* on the contrary defy the most unfavourable conditions and thrive well. *Calligonum*-bushes were seen on the very tops of the downs, a height of about 2 metres, and there was also a small tree with a stem. Now and again a bush of *Smirnowia turkestana* was found, its large, vesicular fruits gone, but they were seen hanging in the grass-tussocks.

In depressions where the soil is more gravelly, flat and without loose sand, there grows a considerable abundance of *Horaninowia ulicina* an annual saltwort with acicular leaves, and *Heliotropium (Radula?)*, together with a few *Cousina annua*. The pale yellow blossoms of this plant protrude from the heads which do not open but remain closed together as if to protect the gynoecia.

This desert locality has a deep sandy soil and the plants are dry sand-plants. There are no halophytes, neither annuals nor perennials. Saxaul is also absent.

2. Sand-desert outside the town of Petro-Alexandrowsk (Chiwa) Juli 1th 1899.

A dune area where *Alhagi Camelorum* is dominant, with a sparse admixture of *Halimocnemis* in the depressions and on the dunes, and *Aristida pennata* on the dunes only. It is noteworthy that the *Alhagi* association here suddenly ceases without any apparent reason, the dunes beyond are naked but otherwise quite similar to the ones covered with *Alhagi*. There seems to be no other reason for this, than that *Alhagi* in its subterranean migration aided by its horizontal roots had not yet extended its range any further. A few plants occur on the bare dunes; *Aristida pennata* and *Calligonum;* and in depressions *Agriophyllum latifolium* and *minus, Halocnemum strobilaceum* and *Heliotropium sp.*

The vegetation is thus chiefly made up of sand-plants, but a few succulent halophytes occur *(Halocnemum, Halimocnemis)*.

3. Sand-desert south of the town of Chiwa. July 11th 1899.

Here the sand is very distinctly sorted out by the wind, the coarser sand being darker in colour than the finer. The coarser sand lies in great quantities on the crests of the wave-like drifts and on the windward side of the dunes, while the fine sand is found between the wave drifts and forms the greater part of the sliding mass on the lee side of the dunes. The smaller dunes formed in the shelter of plants or other obstacles also consist of the fine sand, and so assume a lighter colour than the surrounding surface. Over 99 per ct.

of the fine sand has grains less than 0,5 mm and some of this is smaller than 0,25 mm. The greater mass of the coarse sand is between 1 and 0,5 mm in diameter.

The larger dunes here are very long, but comparatively low (2 about to 3 metres) narrow, and crescent-shaped. Their direction is about NNE—SSW, with their lee sides towards ESE; they must consequently have been formed by winds from WNW. The soil between the dunes is sandy also, no clay is visible.

No vegetation is found as a rule on the dunes themselves. *Aristida pennata* is rather common, but it does not grow, or only rarely, on the most shifting, crested dunes. *Alhagi Camelorum* and the other herbaceous plants prefer still calmer places. Nor do the switch-shrubs occur frequently on the shifting sand; of these *Eremosparton aphyllum*, *Ammodendron sp.*, *Smirnowia turkestana*, are found as low bushes which may attain a height of about a metre. *Ammodendron* is here very thorny (*A. Siewersii?*). The shrubs are very broad, some measuring about 1 metre in diameter. One had become tree-like through the lower branches on the stem having been killed by some previous sand-drift.

The most common plant in the desert here is *Convolvulus erinaceus* (see p. 94), which at this season shows numerous small pink blossoms. It is plentiful everywhere except in the deeper valleys and on the tops of the dunes. Its form is a leafless, thorny ball. The roots are white and very long. The sand has been blown away from many of the plants so that they look like small trees with stems which are in reality the upper rootstocks. If still more sand is blown away, the plant falls prostrate on the ground. Thus roots over a metre long can be found lying on the surface of the sand fixed at one end only, and still having small green shoots.

Uncovered vertical stems of *Alhagi* are also seen, dead at the end and with new aerial shoots springing from the lower, previously buried parts; also buried specimens which have formed new aerial shoots from the axillary buds of the upper leaves.

*Heliotropium Radula* (?) is also common, growing in the way already described (see figs. 22, 63). There are rhizomes


Fig. 22. A buried shoot of *Heliotropium* (*Radula*?) with a rejuvenating shoot. A, the former surface-level; B, the present surface.

bearing dwarf-shoots others bearing long-shoots; the deeper rhizomes appear more disposed to form flowering long-shoots, while those nearer the surface of the sand (warmer and drier) mostly form dwarf-shoots. Several rhizomes laid quite bare still carry living aerial shoots, both short-shoots and long-shoots. Fig. 22 shows a buried long-shoot on which one of the upper axillary buds has formed a new aerial shoot which forms a rosette on the surface of the ground.

*Horaninowia ulicina* and *Agriophyllum minus*, dry annual plants with thorn-tipped leaves, are also common. Both have been already referred to. There are also the annuals *Crozophora gracilis* and *Euphorbia cheirolepis*, one woolly-haired, the other with glossy leaves.

These plants form here an unusually rich desert-vegetation, the average distance between the plants is about one metre.

In moist depressions the vegetation is still denser, and includes *Lycium ruthenicum*, *Halostachys caspica*, *Peganum Harmala*, *Pluchea caspica*, *Alhagi* and especially *Aeluropus repens*.

This locality forms a transition stage between the shifting desert and the hummock desert. Succulent halophytes occur only in the depressions; but here also the soil is sand. On the higher sand, dry plants only are present.

4. Sand-desert north of Mailé Togai on the right bank of the Amu Daria. June 22. 1899.

The soil, formed of sand, is fairly level with low dunes. *Aristida pennata* grows sparsely and not luxuriantly, *Carex physodes* on the contrary is rather frequent; *Heliotropium sp.* (*Radula* or *sogdianum*), *Agriophyllum latifolium* and dead stems of *Cistanche* also present. The switch bushes grow comparatively close together but are stunted: *Haloxylon*, *Ammodendron*, *Salsola Arbuscula*, *Calligonum Caput Medusae* are metre-high bushes; some small single-stemmed trees of *Ammodendron* attain a height of 1—2 metres.

A dark-spotted lizard, *Scaptira grammica*, was captured here, also a long slender greyish-green snake, very active in its movements, and which climbed up the bushes and hid itself among the branches.

This is a Hummock-desert. Earlier in the year there were probably numerous spring plants, but they have disappeared now.

5. At the railway-station Chodsha Dawlet between Buchara and Tshardshui. June 10. 1899.

The boundary of the oasis lies a short distance to the east of Chodsha Dawlet, but still far into the desert one sees well-preserved ruins of houses apparently not very old. The country has formerly been cultivated, but has been abandoned on account of scarcity of water; it is uncertain whether this is because the Serafshan river carries less water than formerly or whether more water is now utilised in its upper course.

The soil here at Chodsha Dawlet is loose, fine, slightly drifting sand. The ground is flat, with some knolls or level surfaces of loess the original soil; sometimes with small white patches of powdery salt. In other places there are small dunes barely a metre high. Near the railway is a small wood, no doubt planted, of Saxaul, (*Haloxylon Ammodendron*). Here it is a shrub rather more than 3 metres high, with several stems, the outer ones bending obliquely outwards. Round the foot of each bush there is a hillock of slightly cohesive sand which partly owes its existence to the shelter of the plant, partly perhaps to mice whose holes are not hard to find in many of the hillocks. — The average distance between the Saxaul bushes is about 3—4 metres. On the level clay-flats, the bushes do not thrive well, they are sparser and any present are half dead. On the contrary *Lycium ruthenicum* is quite at home here, bushes of this species attain a height of over a metre. They are even more dreary looking than the Saxaul shrubs, dry, grey and stick-like. *Smirnowia turkestana* occurs in a few places as low shrubs together with the thick-leaved hemicryptophyte *Zygophyllum Eichwaldii.* In other places I found *Salsola inermis* a grey herb, *S. Kali* and another grey annual *Chenopodiacea* with fleshy, hairy leaves (*Halimocnemis sp.?*); also a few green *Alhagi Camelorum.* These were the only plants found here, and they occurred very scattered.

Walking towards the north one soon arrives at the end of the small wood. Here in the sand there were several

*Alhagi* and *Aristida pennata*, occasionally *Peganum Harmala*. No others were seen, *Halimocnemis* (?) and *Salsola inermis* have totally disappeared.

The desert-lizards seen here were very amusing; three species were found at this place. The little *Phrynocephalus interscapularis* is brown like the sand: when resting it rolls its tail upwards like the spring of a watch and shows the underside of the tail with black and white stripes. The animal in this state soon catches the eye, but if one tries to capture it rushes off, stops suddenly, buries itself in the sand and lies as if dead. It is almost impossible to secure specimens. There is also a larger species (*Phrynocephalus auritus*). A third one, which I could not capture, is somewhat larger than *P. interscapularis* and has a long tail; it generally climbs the *Alhagi*-bushes. There are many flies and I also saw grasshoppers. Turtle-doves and *Coracias* and sparrows flew about the ruins.

The above-named plants soon disappear as one continues to go north, and then the naked dunes appear. They are not very high here, about 3 metres, crescent-shaped with the concavity directed almost SW. Between them the loess-soil is seen. All is bare, not a plant for long distances. In some places, however, the coarse tufts of *Aristida pennata* are seen. It is silent as death here, the sand on the crests of the dunes lifts slightly and looks like thin streaks of smoke. Out here there are no lizards.

If one now turns and crosses the railway walking southwards, one sees in the other direction first a more covered (planted) country and then the bare loose sand forming on the horizon immense brown dunes. The dunes of the covered belt are also in many places perfectly devoid of plants, but there are parts where *Aristida pennata* grows very luxuriantly forming tussocks about 1,5 metres in height and more than 0,5 metre in diameter. A few bushes of *Smirnowia* and Saxaul are also seen here. There are a good many depressions the soil of which is sand, they are rather well covered: flowering *Alhagi Camelorum*, a large-leaved form of *Aeluropus repens*, *Pluchea caspica* a metre high, small *Phragmites* and especially *Tamarix* shrubs, attaining a height of 2 metres or more. An advancing dune of about the same height is in process of burying some of them, the bushes impede the progress of the sand but where there is a break in the *Tamarix* the dune presses forward curving in a south-westerly direction.

6. Desert south of the town of Kunja Urgentsh (Chiwa) and south of a branch of the Amu Darya running towards the west. August 4. 1899.

Along the river as a green belt runs a rugged tract of sand thickly covered with Tamarisk-bushes. These are some of the *Tamarix* dunes already described (p. 96) which are stationary and stratified, but the bushes also grow in great numbers on the loose shifting sand. Interspersed among the Tamarisks are thousands of *Alhagi Camelorum* often extending right up to the top of the dunes; on lower places *Pluchea caspica*, *Lycium ruthenicum* and *Phragmites communis.* The boundary between this green band and the desert is sharply defined. The latter is a naked plain with loess as a soil; it is stable and flat and bordered in the far distance by the green trees and fields of an oasis. In some places, however, the soil is torn up, possibly through wind-erosion, and here the loess shows a well-known characteristic in that it forms perpendicular shelves, the largest a couple of metres high.

To the west lie some large and almost naked sand-dunes which show by their shape that north-easterly winds prevail; here and there smaller dunes appear on the loess-plain, and in their neighbourhood the clay-soil is covered by a level layer of sand.

Isolated tufts of *Aristida pennata* grow on the larger dunes. In a sandy valley between two dunes one notices even from a distance fresh green patches which are groups of large, vigorous *Alhagi.* The glissade of the most easterly dune has commenced to pour its masses of sand over them, and some show now only the outmost shoot-apices projecting above the sand, their days being numbered. On the other side of the dune, *Alhagi* suffers in the opposite way, for here the sand is blown away from it and strong vigorous bushes of aerial shoots are overthrown and lie on the sand, anchored by stems metres in length. Previously while these were covered by soil, they were vertical. One could see that they had been laid bare quite recently and that there had not yet been time to form new aerial shoots from their lower parts.

Yet another plant-species is seen on the larger dunes, some bushes of *Populus euphratica*, attaining the height of a man. This plant is a migrant from the river valley. Only a little group occurs at a single place where sheltered by one of the larger dunes.

The deepest valleys among the dunes extend down to the loess-soil which is here perfectly naked. If any vegetation previously existed, it has been smothered by the sand which has only recently been blown off such valleys.

Seen from the tops of the dunes, the loess-plain is not green, but is closely studded with green patches. On account of the neighbourhood of the river it is unusually thickly covered with vegetation. The following plants occur: low shrubs of *Salsola subaphylla* and *S. Arbuscula*, *Alhagi* and three annual species *Ceratocarpus arenarius* (thorny), *Halanthium Lipskii* and *Salsola sogdiana* (leaf-succulents).

Places where there is sand are distinctly richer in vegetation than the parts with pure clay. The first reason for this it that where the vegetation is more plentiful, the sand drifting along the plain becomes fixed. Thus hillocks of sand are drifted together here and there under the Salsola bushes, and the occurrence of e. g. *Heliotropium* is conditional on the presence of sand.

Another and doubtless a more important reason is that the sandy soil affords more favourable conditions for vegetation than the clay-soil. Some species are only found on these sandy soils, the most important being *Tamarix* which grows both on stationary stratified dunes and on loose sand. There is a tendency for the sand in dunes of this kind to form incrustations on the surface. *Calligonum sp.* (not frequent) and *Heliotropium Radula* are also present.

Some of the species of the loess-plain are more frequent in occurrence and more strongly developed on sandy soil than on clay. With *Alhagi* this is mainly manifested by its bushes on the pure loess soil occurring as a rule singly, while on the sandy soil many were grouped together. This is doubtless due to the fact that the long horizontal roots which produce aerial shoots penetrate the sand easily, but the clay only with difficulty. *Salsola Arbuscula* was also more vigorous, its branches and leaves being less stiff when it grew amongst the dunes.

7. Desert at Kis Kalá on the right bank of the Amu Darya. June 23. 1899. This locality has previously been referred to (p. 75).

Kis Kalá is one of the many ruined castles along the Amu Darya; it stands on the summit of a table-topped mountain. (The rock, a kind of limestone, cannot unfortunately be determined, as the sample I collected has disappeared). Round the mountain itself lie great accumulations of detached gravel and stones. The soil of the desert is partly sand forming small dunes, partly gravel with coarse sand and many stones. Of these two soils the sand carries the richer growth, and low shrubs of the following species occur: *Haloxylon Ammodendron* (thick-stemmed 1—2 metres high) *Salsola Arbuscula*, *Calligonum sp.*, *Ephedra alata*, *Ammodendron sp.* and *Reaumuria oxiana* (very scattered), *Tamarix hispida*, stunted specimens of *Salsola subaphylla*. Near the river, and only there, *Lycium ruthenicum* is abundant and aids in the formation of dunes 1—2 metres high. Along with it are other plants restricted to the river-banks such as *Phragmites communis* and *Erianthus Ravennae*. On the loosest sand in the desert *Aristida pennata* grows, but only a few occur and these are small and poorly developed; the sand-drift in this locality is very slight and the soil is not loose enough for it. *Alhagi Camelorum*, on the contrary, is found in great numbers, besides withered stems of *Phelipaea*. The following species were also collected: *Agriophyllum latifolium*, *Heliotropium sogdianum*, *Salsola sogdiana* and *aperta*, dry or thorny plants, true sand-desert plants; in addition we found *Euphorbia Turczaninowii*, *Halimocnemis macranthera* and *villosa*, *Aeluropus littoralis*. These last species are characteristic for this locality as they are halophytic in type; the three first named are succulent-leaved plants, the species of *Halimocnemis* being very grey on account of their hairs, the grass *Aeluropus* is a characteristic plant of the salt-desert (p. 52). These plants indicate that the soil is shallow and the ground-water not deep, and with this is correlated the smallness of the bushes and the poor development of *Aristida*. The occurence of an *Allium sp.* (with ripe fruits) is likewise indicative of such a soil.

In a depression with the soil hard and crackling with salt and the subsoil moist, we have a Salt-desert flora consisting of *Halocnemum strobilaceum* and *Aeluropus littoralis*, — here the ground-water is still nearer the surface. The stony soil is more sterile than either the sand or the salt; the plant characteristic for this soil is *Reaumuria fruticosa*, a shrub half a metre high, with thick stiff branches densely clothed with very small thick leaves crusted with grains of salt. A few *Tamarix hispida* and *Salsola Arbuscula* occur here as stunted bushes with wide bare spaces between them. On loose stones I gathered the following lichens: *Sarcogyne perileuca* Wain., *Placodium Paulsenii* Wain., *Acarospora interrupta* (Ehbg.).

8. Desert at Kara Aigir on the left bank of the Amu Darya. June 26. 1899.

The desert, which lies beyond the riverside thickets of Tamarisks and *Phragmites*, is limited towards the thicket by a low round hill. The soil is firm, consisting of a kind of loess, but slightly pervious under the surface. The desert is undulating, the soil always the same, but as one proceeds away from the river it becomes more and more covered by gravel or sand. It is noteworthy that this desert poor in sand lies to the west of the Amu Darya: the prevailing northerly and northeasterly winds drift the sand into the river which carries it along towards the north. This is why the western bank is regularly poorer in sand than the eastern one.

On the clay-soil there is scattered vegetation of stumpy, shrubby plants about 1—3 metres apart on the average. *Salsola rigida* occurs most frequently as a small bush about 30 centimetres high, densely coated with hairs and dry like a stick. The leaves are cylindrical with central water-storing tissue. Other shrubs present include *Lycium ruthenicum* and *Calligonum sp.* about a foot high.

The sand occurs in patches which are really low dunes, lowest near the river and becoming higher away from it. The layer of sand very seldom attains the thickness of 1 metre. This sand is more closely covered with vegetation than the clay, and two species are specially characteristic: *Carex physodes* (the aerial parts withered, but fresh buds present far down in the dense mat of old sheaths) and *Artemisia herba alba* (a form of A. *maritima* s. lat.); the *Carex* is restricted to the sand-patches, the *Artemisia* occurs now and then on the bare clay. The following species likewise follow the sand: *Haloxylon Ammodendron*, small shrubs about 0,5—1 metre high, *Salsola sogdiana*, *Halimocnemis villosa*, *Halanthium gamocarpum*, *Cousinia dichotoma*. *Halimocnemis* and *Halanthium* are grey annual Chenopodiaceae (leaf-succulents) never found on deep dry sand; they are typical clay-plants, and along with the other plants mentioned, they occur here chiefly on the sand because it only formed a thin layer and thus created more favourable conditions by protecting the firm subsoil from desiccation (see above p. 80).

There is a relation between the presence of the sand in this place and *Carex physodes*. It is very improbable that this sedge could originally have grown on the clay-surface and thus have caused the sand to become fixed. I never found it on clay, nor has any one else so far as I know, and it would not be in accordance with its mode of growth. The sand must have been present first, perhaps retained by stems of clay-plants, and then *Carex physodes* appeared — its vesicular spathes are easily transported — the stability of the sand being assured by its presence. More extensive investigations may perhaps decide this question, but my observations in this locality were very limited.

9. Desert at Dana Shér Kalá ("the castle of the wide-awake tiger") on the left bank of the Amu Darya. June 27. 1899. This locality (see also p. 76) lies west of the river, like Kara Aigir (No. 8) and the locality described next (No. 10), so that there is very little sand. The desert is a stony, gravelly plain (coarse sand and small stones) with an exceedingly poor vegetation. The only species is *Salsola rigida* as small scattered shrubs with little heaps of sand round the base — a sign of sand-drift, but the sand does not remain lying. In one small valley, sand had accumulated and the

vegetation was richer: *Salsola Arbuscula, Calligonum sp., Artemisia,* Saxaul, *Salsola sclerantha.*

10. Desert at Ak Jar and northwards, on the left bank of the Amu Darya. June 28. 1898.

An undulating plain of argillaceous slate and loess covered with a layer of sand or gravel. The slate appears on the surface here and there, forming small knolls. There is a slight sand-drift and small hillocks of sand lie round the base of the shrubs. The vegetation in places is uncommonly rich, the distance between the shrubs being on an average about 2 metres. The most common plants are: *Salsola rigida* and *Arbuscula* (the clay-form, in flower) and *Reaumuria oxiana.* This plant is more conspicuous than the others because its foliage is darker and not so grey; it has fruits and flower-buds, but no flowers open (2 p. m.). *Lycium ruthenicum* rarely occurs (any specimens seen are over a metre high), Saxaul is more frequent but thrives badly here rarely attaining a height of 0,5 metre, many specimens are quite red or reddish. The herbaceous plants are *Salsola sclerantha, Lepidium obtusum,* and in other places: *Halimocnemis villosa* and *Suæda sp.* The latter sometimes scrambles over *Lycium* and other shrubs somewhat like a liane; it may attain a height of half a metre.

The depressions are small "Takyr" (p. 55), the light-coloured soil is stiff, regularly cracked by desiccation and often lacks vegetation. In some places, however, *Halimocnemis villosa* occurred abundantly; in one depression *Halocnemum strobilaceum* grew luxuriantly, I measured a circular tuft 140 centimetres in diameter.

A similar gravel-plain at Pitnjak, not far from Ak Jar, was sparsely covered with *Peganum Harmala, Convolvulus eremophilus* and *Anabasis salsa.* No switch-bushes were found here.

11. A low mountain north of the fortress Ustyk (Buchara) on the right bank of the Amu Darya. June 19. 1899.

The mountain is terraced with low crags about 1—4 metres high. It consists of a soft stratified sandstone with diverging layers mostly red in colour. Behind it stretches the bare sand-desert. On the mountain the soil mainly consists of coarse, stony sand which becomes covered by fine desert-sand, as proved by numerous small dunes on the lee-side of plants and in depressions. The wind bearing the sand is burning hot as if from a fire. The temperature of the air was 40° C., that of the surface of the sand 53° C. At a distance the only plants discernible are large tufts of *Aristida pennata,* widely scattered about 2—3 metres apart. Coming nearer, the following plants are observed: *Astragalus unifoliatus,* a shrub less than a metre high with bunches of crooked branches and small leaves; *Reaumuria oxiana* a shrub up to 1 foot high with small white-spotted leaves (salt-glands); the perfectly leafless shrubs of *Ephedra alata* attain the height of 1 foot; *Salsola subaphylla* as shrubs of about the same height looking very dry like sticks, and with stiff hard leaves. *Arthrophytum subulifolium* is a transitional form between a shrub and a perennial herb, its short green branches with opposite acicular leaves occupy a short green stem not 30 centimetres high, so that the plants resemble miniature trees, the plant apparently striving to lift its assimilation-shoots off the ground. The hairy leaf-rosettes of *Heliotropium sogdianum* appear above the sand while its rhizomes are subterranean. A few dwarfed specimens of the perennial *Zygophyllum sp.* are seen here. *Agriophyllum latifolium* and *minus* and *Cornulaca Korschinskyi* are dry, thorny annual Chenopodiaceae already described. Associated with these plants is *Salsola sclerantha,* hairy but thornless.

In this locality with a stony subsoil, most of the plants are dry or thorny, and no pronounced succulents occur. *Reaumuria oxiana* seems to be the one which is most halophytic in structure.

12. Sand-desert at Ak-Rabat (right bank of the Amu Darya). June 21. 1899.

Almost level sand with small stones, no sand-drift and no salts on the surface. In the lower, more sheltered parts *Alhagi Camelorum* and *Lycium ruthenicum* occur, while *Aristida* comes at higher levels. A low hill is covered with Saxaul, mixed with *Calligonum sp.*, *Lycium*, and *Alhagi*, very similar to the vegetation seen at Chodsha Dawlet, but here it is a spontaneous vegetation. A thick-stemmed Saxaul tree about 7 metres high was growing on sandy soil in the valley of the oasis.

The vegetation here is undoubtedly influenced by the neighbourhood of the river, the occurrence of *Lycium* in the desert is strongly suggestive of this. It is very plentiful in the riverside-forest, and the desert specimens no doubt originate from there.

13. Sand-desert near Nukus (Chiwa). The desert lies beyond a narrow fringe of thickets along the bank of the river and is limited by a glissade-slope descending to the river. In the desert near this slope are seen some darker patches which are hard rocks *in situ* drifted over by sand and protruding above it. These patches are almost devoid of vegetation, only a few specimens of *Salsola sogdiana* and *Halimocnemis sp.* being seen. On the fine loose yellowish sand where the sand-drift is very slight, the vegetation is far richer, the soil being occasionally rather closely occupied with tufts of plants. *Artemisia maritima*(?) is here very common and the following were also noted: *Reaumuria oxiana*, small *Calligonum* bushes, *Ammodendron sp.* (with the shrubby form although attaining a height of 3 metres), low Saxauls and *Salsola Arbuscula, Heliotropium sogdianum, Haplophyllum obtusifolium* and a few poorly developed tufts of *Aristida pennata.*

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# SECTION III. GROWTH FORMS

## CHAPTER 12

### Plant-list and Statistics.

The following gives a list of the plants of the desert-area treated in this memoir. Mountain-plants and species which only occur on cultivated land are excluded, but it includes aquatic and marsh-plants and the species occurring in the thickets along the river-banks. This list must be regarded as an experiment. It is based on all the sources of information which have been available to me. The most important of these are: BUNGE's Reliquiae Lehmannianae, Madame FEDTSCHENKO's and BORIS FEDTSCHENKO's various works, LIPSKY's systematic memoirs in Acta Horti Petropolitani, LITWINOW's descriptions some in the schedules to Herbarium florae Rossicae, others in "Travaux de la Musée de l'Académie", and finally it is based on my own collections.

Two great difficulties had to be contended with in composing the list. First the records of occurrence in the various memoirs are not always sufficiently exact to allow of an accurate determination as to whether the plant in question occurs on the territory dealt with in this work, or north of our selected boundary, or on the mountains to the east or south of it; secondly it is difficult to determine the limits of any particular species in a flora which is still insufficiently investigated. I have therefore adopted a somewhat broad outlook as regards this question and have therefore excluded several "minor species" described in recent years by WINKLER, LITWINOW and others. The synonymy also presents difficulties which, however, I hope have been surmounted in most cases.

I am fully aware that the list as such has many deficiencies, but hope that it may serve the purpose for which it has been prepared, namely to give fairly accurate information about the growth-forms of the desert.

As regards the growth-forms I have chosen the system proposed by RAUNKIÆR, partly because, in spite of its one-sidedness, it emphasises one of the most important features of plant-life, also because it is easier to handle than other classifications of growth-forms, and finally because by using RAUNKIÆR's system it is possible to express statistical data which may be compared with corresponding data for other regions.

The biological types (growth-forms) of RAUNKIÆR (see Raunkiær 1904, 1905, 1907) are arranged according to the way in which plants live through unfavourable seasons, and special emphasis is laid on the degree and kind of protection afforded to the dormant shoot-apices. In countries where the conditions are always favourable the Fanerophytes are dominant, their dormant buds being attached to branches which project freely into the air. The group thus includes shrubs and trees. RAUNKIÆR subdivides them into four groups according to size. Only the two lower of these groups are represented in the Transcaspian desert namely Microfanerophytes (2—8 metres) and Nanofanerophytes (less than 2 metres) whereas Mega- and Mesofanerophytes are absent. In the second column of our list Fanerophytes are denoted by F.

The next group is the Chamaephytes. The dormant buds of this group are found on the surface of the ground or just over it. In the former case they are plants with above-ground creeping and persistent shoots; in the latter case they are cushion-plants or undershrubs, the latter being conspicuous by their stunted stature and by the distal or apical parts of the year-shoots dying away during the unfavourable season. Chamaephytes are denoted by Ch.

Then follow the Hemicryptophytes, with their dormant buds situated in the uppermost soil just in the surface, while the aerial shoots are not perennial. In the list they are denoted by H.

The Cryptophytes form the fourth group, characterised by the dormant buds being subterranean or subaquatic. They include aquatic and marsh-plants denoted by H H and Geophytes denoted in the list by G.

The Therophytes or plants of the favourable season are the best protected, as they live through the unfavourable season as seeds, they are thus annual plants and are denoted in the list by Th.

An attempt has been made to allocate each species in the list to the growth-form to which it belongs. This has been no easy task because of incomplete knowledge of many species, especially as descriptions and herbarium specimens are very often unsatisfactory in this respect. It is therefore probable that some mistakes have been made. Some will no doubt neutralize others, but later on it will be shown that the results arrived at by enumeration agree fairly well with statistics from other areas with similar conditions of life, which seems to justify the assumption that the errors of my list are excusable.

The third column of the list contains figures which denote the months in which the species in question blossoms, 3 stands for March, 4 for April, 5 for May etc.

The last column contains information as to the distribution of the species outwith the Transcaspian plain; with this, however, is here included the Balkash basin (see p. 4) while Fergana is excluded. H means High-Asia, that is the mountainous parts towards the East from Hindokush and Pamir to Dsungaria and farther East. R means Russia, including the Kirghiz-steppe and Siberia, and V means Western Asia (Asia Minor Persia etc.) and the countries of the Mediterranean. E means endemic.

The asterisks have the following signification: V* means that the species is distributed towards the South to Syria and Palestine (Post), R* that the species is distributed towards the North as far as Yekaterinoslaw (Békétoff), H* that the species occurs in Pamir (O. Fedtschenko).

The distribution of the species will be further referred to in Section 4.

| Name | Growth-form | Flowering-month | Distri-bution |
|---|---|---|---|
| *Alismaceae.* | | | |
| Butomus umbellatus L. . . . . . . . . . . | HH | 6? | HR*V* |
| *Amaryllidaceae.* | | | |
| Ixilirion Pallasii F. & M. . . . . . . . . . | G | 4—5 | HRV |
| *Apocynaceae.* | | | |
| Apocynum venetum L. . . . . . . . . . . . | H? | 7 | HRV* |
| *Araceae.* | | | |
| Eminium Ledebouri Scott . . . . . . . . . | G | 3—4 | E |
| *Asclepiadaceae.* | | | |
| Cynanchum acutum L. . . . . . . . . . . . | H | 5—6 | HR*V* |
| *Berberidaceae.* | | | |
| Leontice Ewersmanni Bge . . . . . . . . . | G | 3 | V |
| — incerta Pall . . . . . . . . . . . . | G | 3—4 | H |
| *Borraginaceae.* | | | |
| Anchusa hispida Forsk. . . . . . . . . . . . | Th | 5—6 | HV* |
| — italica Retz. . . . . . . . . . . . . | H | 5 | HR*V* |

| Name | Growth-form | Flowering-month | Distribution |
|---|---|---|---|
| Arnebia decumbens (Vent.) Gürke . . . . . | Th | 5 | HRV |
| — orientalis (Pall.) Lipsky . . . . . . | Th | 4—5 | V* |
| Asperugo procumbens L. . . . . . . . . | Th | 4—5 | HR*V* |
| Echium italicum L. . . . . . . . . . . . . | H[1] | 9 | V* |
| Heliotropium acutiflorum Kar. Kir. . . . . . | Th | 7 | HV |
| — chorassanicum Bge. . . . . . . | G | 5 | V |
| — dasycarpum Ldb. . . . . . . . | Ch | 6—7 | HV |
| — Eichwaldi Steud. . . . . . . . | Th | 6? | HRV |
| — europaeum L. . . . . . . . . | Th | 6 | R*V* |
| — lasiocarpum F. & M. . . . . . . | Th | 7—8 | V |
| — micranthum (Pall.) Bge . . . . | Th | 6—7 | R |
| — Radula F. & M. . . . . . . . | G | 5—6 | H |
| — sogdianum Bge . . . . . . . . | G | 5 | E |
| — transoxanum Bge . . . . . . . | Ch | 6—7 | V |
| Lappula barbata (M. B.) Gürke . . . . . . | Th | 4—5 | H*R*V* |
| — divaricata (Bge.) Gürke . . . . . . | H | 4 | E |
| — echinophora (Pall.) Kze. . . . . . . | Th | 4 | HRV |
| — laevigata (Kar. Kir.) Gürke . . . . . | Th | 4 | HR |
| — macrantha (Ldb.) Gürke . . . . . . | Th | 5 | HR |
| — polymorpha (Lipsky) . . . . . . . | Th | 4 | HV |
| — semiglabra (Ldb.) Gürke . . . . . . | Th | 5 | HR |
| — spinocarpos (Forsk.) Asch. . . . . . | Th | 4 | V* |
| Lindelofia anchusoides (Lindl.) Lehm. . . . . | H | 8 | HV |
| Lithospermum tenuiflorum L. . . . . . . . | Th | 4—5 | V* |
| Myosotis refracta Bois. . . . . . . . . . | Th | 4 | V* |
| Nonnea picta F. & M. . . . . . . . . . . | Th | 4—5 | HRV |
| Onosma setosum Ldb. . . . . . . . . . . | H | 5 | RV |
| — stamineum Ldb. . . . . . . . . . | H | 4 | R |
| Paracaryum micranthum Bois . . . . . . . | Th | 4 | V* |
| Rindera cyclodonta Bge . . . . . . . . . | H | 4 | H |
| — tetraspis (Pall.) . . . . . . . . . | H | 4? | HR* |
| Rochelia cardiosepala Bge . . . . . . . . | H | 4 | H |
| — leiocarpa Ldb. . . . . . . . . . | Th | 4 | H |
| — macrocalyx Bge. . . . . . . . . | Th | 4 | V |
| — retorta (Pall.) Rchb. . . . . . . | Th | 4 | H |
| Solenanthus Kuschakewiczi Lipsky . . . . . | H? | 4 | H |
| — petiolaris D. C. . . . . . . | H | 5 | HV |
| Suchtelenia calycina C. A. M. . . . . . . . | Th | 4 | V |
| Tournefortia sibirica L. . . . . . . . . . | G | 7 | HR*V |
| Trichodesma incanum Bge. . . . . . . . | H? | 9 | V |

*Capparidaceae.*

| | | | |
|---|---|---|---|
| Capparis spinosa L. . . . . . . . . . . . . | Ch | 6—7 | V |
| Cleome Raddeana Trautv. . . . . . . . . . | Th? | 5 | E |

[1]) biennial.

| Name | Growth-form | Flowering-month | Distribution |
|---|---|---|---|
| *Caryophyllaceae.* | | | |
| Acanthophyllum Borsezowii Litw. | Ch? | 5 | E |
| — elatius Bge | Ch | 7 | V |
| — glandulosum Bge. | Ch | ? | V |
| — Korolkowi Rgl. & Schm. | Ch | ? | E |
| — paniculatum Rgl. | Ch? | ? | H |
| — pungens (Bge.) Bois. | Ch | 5 | HR |
| — stenostegium Freyn & Sint. | Ch | 5 | E |
| Arenaria serpyllifolia L. | Th | 5 | HR*V* |
| Dianthus angulatus Royle | H | 5 | H |
| — crinitus Sm. | H | 5 | HV |
| Gypsophila alsinoides Bge. | Th | 5 | V |
| — elegans M. B. | Th | 5 | V* |
| — spathulifolia F. & M. | Th | ? | E |
| — trichotoma Wendl. | H | 7 | HRV |
| Herniaria diandra Bge. | Th | 5 | E |
| Holosteum liniflorum Stev. | Th [1]) | 2—4 | HV* |
| — umbellatum L. | Th | 2—4 | HR*V* |
| Saponaria parvula Bge. | Th | 4 | E |
| Silene nana Kar. Kir. | Th | 4 | H |
| — odoratissima Bge. | Ch | 6—7 | H |
| — Olgae Rgl. & Schm. | H? | 5 | E |
| — suffrutescens M. B. | Ch | 5 | HV |
| — turkestanica Rgl. & Schm. | H? | 5 | E |
| Spergularia diandra (Guss.) | Th | 5 | HRV* |
| — salina Presl. | Th | 5 | HR*V |
| *Ceratophyllaceae.* | | | |
| Ceratophyllum demersum L. | HH | 6? | H*R*V* |
| *Chenopodiaceae.* | | | |
| Agriophyllum arenarium M. B. | Th | 6? | HRV |
| — latifolium F. & M. | Th | 6—8 | V |
| — minus F. & M. | Th | 6—7 | E |
| — Paletzkianum Litw. | Th | 7? | E |
| Anabasis aphylla L. | Ch | 7—8 | HRV |
| — brachiata Bge. | H | ? | HV |
| — eriopoda (C. A. M.) | H | 5 | H |
| — hispidula Bge. | H | 5 | H |
| — jaxartica Bge. | H? | 5 | E |
| — salsa (C. A. M.) | Ch | 6—8 | HRV |
| Arthrophytum subulifolium Schrenk. | Ch | 6? | H |
| Atriplex dimorphostegium Kar. Kir. | Th | 5 | HV |
| — laciniatum L. | Th | 5 | H*R*V* |

[1]) biennial.

| Name | Growth-form | Flowering-month | Distribution |
|---|---|---|---|
| Atriplex serpyllifolium Bge. | Th | ? | H |
| — turcomanicum F. & M. | Th | 5 | V |
| — verruciferum M. B. | Ch? | ? | HRV |
| Bassia hirsuta (Nolte) Volk. | Th | 5? | HRV |
| — hyssopifolia (Pall.) | Th | 5? | HRV |
| — latifolia (Fres.) | Th | 4—5 | V |
| — sedifolia (Pall.) | Th | 5 | HR*V |
| Bienertia cycloptera Bge. | Th | ?—8 | V |
| Borszcowia aralo-caspica Bge. | Th | 7? | E |
| Ceratocarpus arenarius L. | Th | 5 | HR*V |
| Corispermum hyssopifolium L. | Th | 6—7 | H*RV |
| — laxiflorum Schrenk. | Th | 6 | HR |
| — Lehmannianum Bge. | Th | 7? | E |
| — nitidum Kit. | Th | 6? | HR*V |
| — orientale Lam. | Th | 7? | HRV |
| Cornulaca Korschinskyi Litw. | Th | 9 | E |
| Girgensohnia diptera Bge. | Th | 6—7? | E |
| — oppositiflora Pall. | Th | 8 | HRV |
| Halanthium gamocarpum (Moq.) | Th | 6—8 | V |
| — Lipskii Pauls. | Th | 8 | E |
| — ovinum Bge. | Th? | 7? | E |
| Halimocnemis Karelini Moq. | Th | 7 | HR |
| — macranthera Bge. | Th | 6—7 | E |
| — pilosa Moq. | Th | 7 | V |
| — villosa Kar. Kir. | Th | 6—7 | H |
| Halocharis hispida C. A. M. | Th | 6—7? | HV |
| Halocnemum strobilaceum (Pall.) M. B. | F | 7—8 | HRV* |
| Halogeton glomeratus C. A. M. | Th | 7? | H*RV |
| Halopeplis pygmaea (Pall.) Bge. | Th | 5? | HRV |
| Halostachys caspica (Pall.) C. A. M. | F | 6—7 | HRV |
| Haloxylon Ammodendrom (C. A. M.) Bge. | F | 6 | HV |
| Horaninowia juniperina C. A. M. | Th | 7 | RV |
| — ulicina F. & M. | Th | 7—8 | HR |
| Kalidium caspicum L. | Ch? | 7—8 | HRV |
| — foliatum Pall. | Ch? | 7? | HR |
| Kirilowia eriantha (Kar. Kir.) Bge. | Th | 5 | HV |
| Kochia prostrata Schrad. | Ch | 4—8 | H*R*V |
| — stellaris Moq. | Th | 5 | H*V |
| Nanophytum erinaceum Pall. | Ch | 7? | HR |
| Noëa spinosissima L. | Ch | 7—10 | V* |
| Panderia pilosa F. & M. | Th | 7 | HRV* |
| Petrosimonia brachiata (Pall.) Bge | Th | 7? | HRV |
| Piptoptera turkestana Bge. | Th | 7? | E |
| Salicornia herbacea L. | Th | 7? | HR*V* |
| Salsola Androssowi Litw. | Th | 9 | E |

| Name | Growth-form | Flowering-month | Distri-bution |
|---|---|---|---|
| Salsola aperta Pauls. | Th | 6 | E |
| — Arbuscula Pall. | F | 8 | HRV |
| — clavifolia Pall. | Th | ? | HR |
| — collina Pall. | Th | 7 | HR |
| — crassa M. B. | Th | 7? | HRV |
| — gemmascens Pall. | F? | ? | RV |
| — hispidula (Bge.) Bge. | F | ? | V |
| — incanescens C. A. M. | Th | 8? | R |
| — Kali L. | Th | 6—7 | HR*V* |
| — lanata Pall. | Th | 7? | HRV |
| — laricina Pall. | F | 7? | HRV |
| — obtusifolia (C. A. M.) Litw. | Th | 8 | E |
| — Paulseni Litw. | Th | 8 | E |
| — rigida Pall. | F | 6—7 | HRV* |
| — sclerantha C. A. M. | Th | 6 | HV |
| — sogdiana Bge. | Th | 6 | V |
| — spissa M. B. | Th | 7 | HRV |
| — subaphylla C. A. M. | F | 7 | HV |
| — turcomanica Litw. | Th | 8 | E |
| — verrucosa M. B. | F | 7? | RV |
| Spinacia tetrandra Stev. | Th | 4 | V* |
| Suaeda altissima Pall. | Th | 7 | HR*V |
| — arcuata Bge. | Th | 7—9 | H |
| — corniculata (C. A. M.) Bge. | Th | 7—8 | H |
| — dendroides (C. A. M.) Moq. | Ch? | ? | V |
| — heterophylla (Kar. Kir.) Bge. | Th | 9 | H |
| — linifolia (C. A. M.) | Th | 7 | HRV |
| — Lipskii Litw. | Th | 5 | E |
| — maritima Dumort. | Th | 7 | H*R*V |
| — microphylla Pall. | F | 7 | HRV |
| — microsperma Fzl. | Th | 7—8 | HV |
| — obtusifolia (Bge.) Trautv. | Th | 7? | H |
| — physophora Pall. | F | ? | HRV |
| — pterantha (Kar. Kir.) Fzl. | Th | 6 | H |
| — salsa Pall. | Th | 7? | HRV |
| — setigera Moq. | Th | 9 | H*RV |
| *Colchicaceae.* | | | |
| Bulbocodium robustum Bge. | G | 3—4 | H |
| — soboliferum C. A. M. | G | ? | V |
| *Compositae.* | | | |
| Achillea micrantha M. B. | H | 5 | HV* |
| — nobilis L. | H? | 5? | HRV |
| — Santolina L. | H | 5 | V* |

| Name | Growsh-form | Flowering-month | Distri-bution |
|---|---|---|---|
| Acroptilon Picris (Pall.) | G | 5 | HRV |
| Anthemis altissima | Th | 5 | RV* |
| Artemisia Absinthium L. | H | 7–8 | HR*V |
| — annua L. | Th | 8—9 | HRV* |
| — Cina Berg | Ch | 8? | E |
| — eriocarpa Bge. | Ch? | 4 | V |
| — herba alba Asso | Ch | 9 | H*V* |
| — maritima L. (var. div.) | Ch | 9 | H*R*V |
| — procera Willd. | F? | ? | HR*V |
| — scoparia W. K. | Th | 6? | HR*V |
| — serotina Bge. | Ch | 9 | E |
| — songorica Schrenk. | Ch | 5? | H |
| — vulgaris L. | H | 8 | HRV |
| Aster altaicus W. | Ch | 5? | H |
| — tripolium L. | H | 7? | HR*V |
| Carduus tenuiflorus Sm. | Th | ? | V |
| Calendula persica C. A. M. | Th | ? | V* |
| Carthamus oxyacantha M. B. | Th | 7 | HV |
| Centaurea albispina (Bge.) | Th | 5 | E |
| — depressa M. B. | Th | 4 | V* |
| — iberica Trev. | H | 7 | V* |
| — moschata L. | Th | 5 | V |
| — phyllocephala Bois. | Th | 5 | V |
| — pulchella Ldb. | Th | 4 | HRV |
| Chardinia xeranthemoides Desf. | Th | 4 | V* |
| Chrysanthemum achilleifolium (M. B.) Kze | H? | ? | R |
| Cousinia affinis C. A. M. | H [1] | 6 | H |
| — alata C. A. M. | H [1] | 7 | H |
| — annua Winkl. | Th | 6 | E |
| — Antonowii Winkl. | H? | ? | E |
| — aralensis Bge. | Th | 5 | E |
| — Beckeri Trautv. | H | ? | E |
| — bipinnata Bois. | H [1] | 5 | V |
| — caesia Winkl. | H [1] | 5 | E |
| — decurrens Rgl. | H? | 5 | V |
| — dichotoma Bge. | Th | 7 | E |
| — dissecta Kar. Kir. | H [1] | 7 | V |
| — lepida Bge. | H? | ? | V |
| — microcarpa Bois. | H [1] | 5 | V |
| — minuta Bois. | Th | 5 | V |
| — mollis C. A. M. | H [1]? | 4? | H |
| — onopordioides Ldb. | H [1] | ? | V |
| — platylepis C. A. M. | H [1] | 7 | H |

[1] biennial.

| Name | Growth-form | Flowering-month | Distribution |
|---|---|---|---|
| Cousinia pusilla Winkl. | Th | ? | E |
| — Raddeana Winkl. | H? | 5 | E |
| — Regeli Winkl. | H | 5 | E |
| — tenella F. & M. | Th | ? | V |
| — triflora C. A. M. | H [1]) | 5 | H |
| — xiphiolepis Bois. | H | ? | V |
| Crupina vulgaris Cass. | Th | 5 | HRV |
| Dipterocoma pusilla F. & M. | Th | 5 | V |
| Echinops jaxarticus Bge. | H? | 7 | E |
| Evax filaginoides Kar. Kir. | Th | ? | R |
| Garhadiolus Hedypnois F. & M. | Th | 5 | V* |
| — papposus Bois. & Buhse | Th | ? | V |
| Helichrysum plicatum D. C. | H | ? | V* |
| Heteracia Szovitsii F. & M. | Th | 4 | HV |
| Heteroderis pusilla Bois. | Th | 4—5 | V |
| Inula caspica Blum. | H [1]) | 7 | HR |
| — divaricata Cass. | Th | 6 | V |
| Jurinea adenocarpa Schrenk | H? | 5 | H |
| — chaetocarpa (Ldb.) Bois. | H | 5 | HR |
| — derderioides Winkl. | H | 6 | E |
| — Korolkowi Rgl. | Th | ? | E |
| — Lehmanni (Bge.) | Th | 4 | H |
| — linearifolia (D. C.) Bong. | Ch | ? | HR* |
| — Pollichii D. C. | H | 6 | HR*V |
| Koelpinia linearis Pall. | Th | 4—5 | HRV* |
| Lachnophyllum gossypinum Bge. | Th | 8—9 | E |
| Lactuca canescens Rgl. & Schm. | Th | ? | E |
| — persica Bois. | H [1]) | 5 | V |
| — undulata Ldb. | Th | 4 | HRV* |
| Lagoseris obovata Bois. | Th | 4 | HRV |
| Launaea nudicaulis (L.) Hook. | H | 4—5 | V |
| Leontodon asperrimum (Willd.) | H | 5 | V* |
| Matricaria lamellata Bge. | Th | 4 | E |
| — lasiocarpa Bois. | Th | 4 | V |
| Micropus erectus L. | Th | ? | HV* |
| Mulgedium tataricum D. C. | G | 5—6 | H*R*V |
| Pluchea caspica (Pall.) Hoffm. | G? | 7—9 | HR |
| Pterotheca aralensis Bge. | H | 4—5 | E |
| Rhaponticum nitidum Fisch. | H? | 5? | E |
| Saussurea salsa (Pall.) Spreng. | H | 7—8 | H*R |
| Scorzonera acrolasia Bge. | Th | 4 | E |
| — ammophila Bge. | Th | 5 | E |
| — cenopleura Bge. | Th | 4 | E |

[1]) biennial.

| Name | Growth-form | Flowering-month | Distri-bution |
|---|---|---|---|
| Scorzonera ensifolia M. B. | H | 5? | HR |
| — hemilasia Bge. | Th | 4—5 | E |
| — intermedia Bge. | Th | 4 | E |
| — ovata Trautv. | H? | 5? | E |
| — pusilla Pall. | H | 4—5 | HRV |
| — Raddeana Winkl. | H | 5 | E |
| — stricta Horn. | H | 4 | H*R |
| — tuberosa Pall. | H | 4 | E |
| Senecio dubius Ldb. | Th | 6? | HR |
| — subdentatus Ldb. | Th | 4 | HV |
| Taraxacum glaucanthum D. C. | H | 5 | H |
| Tragopogon brevirostre D. C. | H [1]) | 5 | H*RV |
| — majus Jacq. | H [1]) | 5 | R*V |
| Zollikoferia acanthodes Bois. | F | ? | V |
| *Convolvulaceae.* | | | |
| Convolvulus Cantabricus L. | H | 4 | V* |
| — divaricatus Rgl. & Schm. | Ch | 5 | E |
| — eremophilus Bois. & Buhse | Ch | 6—7 | V |
| — erinaceus Ldb. | Ch | 6—7 | R |
| — fruticosus Pall. | Ch | 5 | HR |
| — lineatus L. | H | 6 | HR*V* |
| — Korolkowi Rgl. & Schm. | H? | 6? | E |
| — pilosellifolius Desr. | H? | 6 | V* |
| — subhirsutus Rgl. & Schm. | H? | 5 | E |
| Cressa cretica L. | G | 7? | V* |
| Cuscuta Lehmanniana Bge. | Parasite | 7—8 | E |
| *Cruciferae.* | | | |
| Alyssum dasycarpum Steph. | Th | 4 | HRV |
| — linifolium Steph. | Th | 4 | HR*V |
| — marginatum Steud. | Th | 4 | V |
| — minimum W. | Th | 4 | HR*V* |
| Brassica Tournefortii Gouan | Th | ? | V* |
| Camelina microcarpa Andrz. | Th | 4 | HR*V |
| Capsella procumbens (L.) Fr. | Th | 5 | H*V* |
| Chartoloma platycarpum Bge. | Th | 4 | E |
| Clorispora tenella (Pall.) D. C. | Th | 3—4 | HR*V* |
| Cithareloma Lehmanni Bge. | Th | 5—6 | E |
| — vernum Bge. | Th | 4—5 | E |
| Crambe Kotschyana Bois. | Th | 5 | V |
| Cryptospora falcata Kar. Kir. | Th | 4—5 | HR |
| Diptychocarpus strictus (Fisch.) Trautv. | Th | 5? | HRV |

[1]) biennial.

| Name | Growth-form | Flowering-month | Distri-bution |
|---|---|---|---|
| Euclidium syriacum (L) R. Br. | Th | 4 | HR*V* |
| — tenuissimum (Pall.) Fedtsch. | Th | 4 | R |
| Goldbachia laevigata (M. B.) D. C. | Th | 4—5 | H*RV |
| Hymenophysa pubescens C. A. M. | H | 7? | H |
| Isatis Armena L. | Th | 4 | V |
| — emarginata Kar. Kir. | Th | 4—5 | HR |
| — minima Bge. | Th | 4—5 | HRV |
| — turcomanica Korsh. | Th | 5 | E |
| Lachnoloma Lehmanni Bge. | Th | 5 | HRV |
| Lepidium Draba L. | H | 4 | HR*V* |
| — obtusum Bois. | H? | 6 | R |
| — repens (Schrenk) Bois. | H? | 4—5 | RV |
| Leptaleum filifolium (W.) D. C. | Th | 4 | HRV* |
| Malcolmia africana R. Br. | Th | 4 | HRV |
| — brevipes (Kar. Kir.) Bois. | Th | 4 | HRV |
| — Bungei Bois. | Th | 4 | HRV* |
| — circinnata (Bge.) Bois. | Th | 4 | E |
| — scorpioides (Bge.) Bois. | Th | 3—4 | R |
| — turkestanica Litw. | Th | 5 | E |
| Matthiola chenopodiifolia F. & M. | Th | 4 | V |
| — Stoddarti Bge. | Th | 4 | R |
| Octoceras Lehmannianum Bge. | Th | 4 | V |
| Pachypterygium lamprocarpum Bge. | Th | 4—5 | V |
| Peltaria turkmena Lipsky | Th | 4—5 | E |
| Sisymbrium junceum M. B. | Th | 5 | HRV |
| — pumilum Steph. | Th | 4 | H*R*V* |
| — runcinatum Lag. | Th | 4 | RV* |
| — Sinapistrum Crz. | Th [1]) | 4 | HRV |
| — sumbarense Lipsky | Th | 4 | H |
| — toxophyllum (M. B.) C. A. M. | Th | 4 | HR |
| — Trautvetteri Lipsky | Th | 3—4 | E |
| Spirorhynchus sabulosus Kar. Kir. | Th | 4 | RV |
| Streptoloma desertorum Bge. | Th | 4 | R |
| Syrenia siliculosa (D. C.) Andrz. | H [1]) | 5 | HR* |
| Tauscheria lasiocarpa Fisch. | Th | 4—5 | H*RV |
| Tetracme quadricornis Bge. | Th | 5 | HR |
| — recurvata Bge. | Th | 4 | V |

*Cucurbitaceae.*

| | | | |
|---|---|---|---|
| Ecballium Elaterium (L.) Rich. | H | 4—5? | V* |

[1]) or biennial (H).

| Name | Growth-form | Flowering-month | Distri-bution |
|---|---|---|---|
| *Cyperaceae.* | | | |
| Carex paludosa Good. | HH | 5? | HR*V |
| — physodes M. B. | H | 3—4 | HRV |
| — stenophylla Wbg. | H | 4—5 | H*R*V* |
| Cyperus fuscus L. | Th | 6? | HR*V* |
| — longus L. | HH | 5? | RV* |
| — rotundus L. | HH | 7? | V* |
| Heleocharis argyrolepis Kier. | HH | 5 | H |
| — palustris R. Br. | HH | 4—5? | R*V* |
| Schoenus nigricans L. | HH | 5? | RV* |
| Scirpus hamulosus Stev. | HH? | 6—8? | R |
| — littoralis Schrad. | HH | ? | V |
| — maritimus L. | HH | ? | R*V* |
| — Tabernaemontani Gm. | HH | ? | R*V |
| *Dipsacaceae.* | | | |
| Scabiosa Olivieri Coult. | Th | 5? | HV* |
| *Elaeagnaceae.* | | | |
| Elaeagnus hortensis M. B. | F | 5—6 | HRV* |
| *Equisetaceae.* | | | |
| Equisetum ramosissimum Desf. | G | ? | HRV |
| *Euphorbiaceae.* | | | |
| Andrachne telephioides L. | H | 5 | V* |
| Crozophora gracilis F. & M. | Th | 7? | H |
| — tinctoria L. | Th | ?—7 | V* |
| Euphorbia caesia Kar. Kir. | H | 6? | H |
| — cheirolepis F. & M. | Th | 6—7 | V |
| — densa Schrenk | Th | ? | HV |
| — Gerardiana Jacq. | H | 6? | HR*V |
| — pygmaea F. & M. | Th | 4—5 | R |
| — turcomanica Bois | Th | ? | V |
| — Turczaninowii Kar. Kir. | Th | 5 | H |
| — turkestanica Rgl. | Th | 4 | E |
| *Frankeniaceae.* | | | |
| Frankenia hirsuta L. | Ch | 6—7 | HR*V* |
| — pulverulenta L. | Th | 5—7 | HRV* |
| *Fumariaceae.* | | | |
| Corydalis Schangini (Pall.) Fedtsch. | G | 5? | H |
| — Sewerzowi Rgl. | G | 4 | H |
| Fumaria Vaillantii Lois. | Th | 3—4 | HR*V* |

| Name | Growth-form | Flowering-month | Distri-bution |
|---|---|---|---|
| *Gentianaceae.* | | | |
| Erythraea pulchella Fr. | Th | 5 | HR*V |
| Gentiana Olivieri Gris. | H | 5 | HV |
| *Geraniaceae.* | | | |
| Erodium bryoniaefolium Bois. | Th [1]) | 4—5 | V* |
| — ciconium L. | Th | 4 | V* |
| — Hoefftianum C. A. M. | Th | 4 | R |
| — oxyrrhynchum M. B. | Th [1]) | 4 | V |
| Geranium tuberosum L. | G | 5 | HV* |
| *Gnetaceae.* | | | |
| Ephedra alata Dcne. | F | 4—5 | V* |
| — distachya L. | Ch | 5 | HRV |
| *Gramineae.* | | | |
| Aeluropus littoralis Parl. | G | 5—6 | HRV |
| — repens Parl. | G | 5 | RV |
| Agropyrum squarrosum Link | Th | 4 | V* |
| Apera interrupta Beauv. | Th | 5 | RV |
| Aristida arachnoidea Litw. | G? | 5—6 | E |
| — pennata Trin | G | 5—6 | HV |
| Avena sterilis L. | Th | 5? | RV* |
| Boissiera bromoides Hochst. & Steud. | Th | 5 | H*V* |
| Bromus crinitus Bois. | Th | 5 | H*V |
| — Danthoniae Trin. | Th | 5 | V |
| — oxyodon Schrenk | Th | 4—5 | HR |
| — tectorum L. | Th | 4—5 | R*V* |
| Calamagrostis pseudophragmites Baumg. | G | 6 | H*RV |
| Crypsis aculeata Ait. | Th | 5? | R*V* |
| — Borszowii Rgl. | Th | 5? | E |
| Danthonia Forskalei Trin. | H | 5 | V* |
| Elymus aralensis Rgl. | H | 6 | E |
| — sabulosus M. B. | G | 5 | R |
| Erianthus Ravennae L. | H | 6 | V* |
| Festuca ciliata Danth. | Th | 5 | V* |
| Hordeum crinitum Desf. | Th | 4—5 | V |
| — maritimum W. | Th | 5 | HRV* |
| — murinum L. | Th | 5 | RV |
| — secalinum Schreb. | H | 5 | H*RV |
| Imperata cylindrica P. B. | H | 5 | V |
| Koeleria phleoides Pers. | Th | 4 | RV* |
| Lasiagrostis splendens Kth. | H | 6? | HR |

[1]) or biennial (H).

| Name | Growth-form | Flowering-month | Distribution |
|---|---|---|---|
| Lepturus hirtulus Rgl. | Th | 5 | E |
| Nardurus maritimus (L.) Hack. | Th | 5 | V* |
| Panicum crus galli L. | Th | 6 | R*V* |
| Pappophorum persicum Bois. | H | 5 | V |
| Phragmites communis Trin. | G | 6 | H*RV* |
| Poa bulbosa L. (vivipara) | H | 4-5 | R*V* |
| Saccharum spontaneum L. | G? | 7 | V |
| Schismus minutus Rgl. & Schm. | Th | 5 | HRV |
| Sclerochloa dura Beauv. | Th | 5 | RV* |
| Secale fragile M. B. | Th | 4 | HR*V |
| Stipa Lessingiana Trin. | H | 4 | H*R*V |
| — Szovitsiana Trin. | H | 4—5 | HRV |
| Trisetum Gaudinianum Bois. | Th | 5 | V |
| Triticum Aegilops Beauv. | Th | 5? | V* |
| — desertorum Fisch. | H? | 6 | RV |
| — orientale M. B. | Th | 4—5 | HRV |
| — pumilum Steud. | Th | 5? | R*V |
| *Haloragidaceae.* | | | |
| Myriophyllum spicatum L. | HH | ? | H*R*V* |
| *Hydrocharidaceae.* | | | |
| Vallisneria spiralis L. | HH | ? | RV |
| *Iridaceae.* | | | |
| Iris caucasica Hoffm. | G | 4 | V |
| — ensata Thunb. | G | 5 | HRV |
| — falcifolia Bge. | G | 3 | V |
| — filifolia Bge. | G | 5? | E |
| — Güldenstädtiana Lep. | G | 5? | HR*V |
| — longiscapa Ldb. | G | 4 | R |
| — songorica Schrenk. | G | 3—4 | HV |
| — tenuifolia Pall. | G | 5? | HR |
| *Juncaceae.* | | | |
| Juncus acutus L. (var. littoralis Trautv.). | H | 6? | V* |
| — bufonius L. | Th | 4—5? | HR*V* |
| — compressus Jacq. | G | 5? | R*V |
| — Gerardi Lois. | G | 5? | HR*V* |
| — lampocarpus Ehrh. | H | 5? | H*R*V* |
| *Labiatae.* | | | |
| Chamaesphacos ilicifolius Schrenk | Th | 5—6 | H |
| Eremostachys aralensis Bge. | H | 5 | HV |
| — desertorum Rgl. | H? | ? | E |

| Name | Growth-form | Flowering-month | Distri-bution |
|---|---|---|---|
| Eremostachys labiosa Bge. | H | 5 | V |
| — molucelloides Bge. | H | 5? | HV |
| — paniculata Rgl. | H? | ? | E |
| — transoxana Bge. | H | 5 | V |
| — tuberosa Bge. | H | 5? | R |
| — uniflora Rgl. | H? | ? | E |
| Hypogomphia turkestana Bge. | Th | 5 | E |
| Lagochilus acutilobus Bge. | H | 5—6 | H |
| — inebrians Bge. | H? | 6? | E |
| Lallemantia Royleana Bth. | Th | 5 | HV* |
| Lycopus europaeus L. | HH | 5 | RV |
| Mentha longifolia Huds. (subsp. Royleana Briq.). | HH | 5 | RV |
| Nepeta micrantha Bge. | Th | 5 | HV |
| Perowskia abrotanoides Kar. | Ch? | ? | HV |
| Phlomis thapsoides Bge. | H | 6? | E |
| Tapeinanthus persicus Bois. | Th | 4 | V |
| Ziziphora tenuior L. | Th | 5 | HV* |
| *Lemnaceae.* | | | |
| Lemna minor L. | HH | 4—6? | HR*V* |
| — trisulca L. | HH | 4? | R*V |
| *Lentibulariaceae.* | | | |
| Utricularia vulgaris L. | HH | 6? | H*R*V* |
| *Liliaceae.* | | | |
| Allium Borszcowii (Rgl.) Lipsky | G | 4 | E |
| — caspicum (Pall.) M. B. | G | 4—5 | HR |
| — inderiense Fisch. | G | 4—5 | R |
| — Lehmannianum Merckl. | G | 5 | V |
| — sabulosum Stev. | G | 5—6 | HR |
| — Schuberti Zucc. | G | 4 | V* |
| — tataricum L. | G | 4—5 | HRV |
| — Tschulpias (Rgl.) Lipsky. | G | 4—5 | E |
| Asparagus verticillatus L. | G | ? | HRV |
| Eremurus anisopterus (Kar. Kir.) Rgl. | G | 4 | E |
| — Capusii Frch. | G | 3 | E |
| — inderiense (Stev.) Rgl. | G | 4 | HR |
| — Olgae Rgl. | G | 7 | E |
| Eremurus velutinus Bois. & Buhse | G | 5 | V |
| Gagea chlorantha (M. B.) Schult. | G | 2—3 | V* |
| — Liotardi Schult. | G | 2—3 | V* |
| — reticulata (Pall.) Schult. | G | 2—3 | H*V* |
| Rhinopetalum Karelini Fisch. | G | 4—5 | HRV |
| — stenantherum Rgl. | G | 4 | E |

| Name | Growth-form | Flowering-month | Distribution |
|---|---|---|---|
| Tulipa Androssowi Litw. | G | 3 | E |
| — biflora Pall. | G | 3 4 | RV* |
| — chrysantha Bois. | G | 3 | V |
| — Greigi Rgl. | G | 4—5 | E |
| — sogdiana Bge. | G | 3 | E |
| *Lythraceae.* | | | |
| Lythrum Salicaria L. | HH | 6 7 | HR*V* |
| *Malvaceae.* | | | |
| Alcea sulphurea Bois. | H | 5? | HV |
| Malva Aegyptia L. | Th | 5 | RV* |
| *Najadaceae.* | | | |
| Najas major Roth. | HH | 8? | HR*V |
| — minor All. | HH | 8? | RV* |
| *Oenotheraceae.* | | | |
| Epilobium hirsutum L. | HH | 6 | R*V* |
| *Orchidaceae.* | | | |
| Limodorum turkestanicum Litw. | G | 5 | E |
| *Orobancheaceae.* | | | |
| Cistanche ambigua (Bge.) | G [1] | 4—5 | E |
| — flava (C. A. M.) | G [1] | 4—5 | E |
| — salsa (C. A. M.) | G [1] | 4—5 | E |
| — trivalvis (Trautv.) | G [1] | 4—5 | E |
| Orobanche amoena C. A. M. | G [1] | 5 | H |
| — coerulescens Steph. | G [1] | 4 | HRV |
| *Papaveraceae.* | | | |
| Glaucium elegans F. & M. | Th | 4 | V |
| Hypecoum parviflorum Barb. | Th | 4 | HV* |
| — pendulum L. | Th | 3—4 | V* |
| — trilobum Trautv. | Th | 4 | E(?) |
| Papaver arenarium M. B. | Th | 4 | R*V |
| — pavoninum Schrenk. | Th | 4 | HV |
| Roemeria orientalis Bois. | Th | 5 | V* |
| — rhoeadiflora Bois. | Th | 4—5 | RV |
| *Papilionaceae.* | | | |
| Alhagi Camelorum Fisch. | Ch | 6—7 | HRV* |
| Ammodendron Conollyi Bge. | F | 5 | E |

[1]) or Th.

| Name | Growth-form | Flowering-month | Distribution |
|---|---|---|---|
| Ammodendron Eichwaldii Ldb. | F | 5 | E |
| — Karelini F. & M. | F | 5 | V |
| — Lehmanni Bge. | F | 5 | R |
| — Sieversii Fisch | F | 5? | E |
| Ammothamnus Lehmanni Bge. | F | 4 | E |
| Astragalus Alopecias Pall. | H? | 5 | HV |
| — Ammodendron Bge. | F | 5 | R |
| — Ammodytes Pall. | F | 5 | HR |
| — ammophilus Kar. Kir. | Th | 4—5 | HV |
| — ammotrophus Bge. | H | 5 | E |
| — Androssowii Litw. | H? | 5 | E |
| — ankylotus F. & M. | Th | ? | R |
| — arpilobus Kar. Kir. | Th | 5 | E |
| — bakaliensis Bge. | Th | 4 | V |
| — Barrovianus Ait. & Bak. | H | 5 | E |
| — brachylobus Fisch. | F | 5? | HR |
| — brachypus C. A. M. | F | 5 | E |
| — campylorhynchos F. & M. | Th | 4 | HV |
| — campylotrichus Bge. | Th | 4 | H |
| — chaetodon Bge. | H | 5 | H |
| — chiwensis Bge. | H? | ? | E |
| — commixtus Bge. | Th | 4 | HV* |
| — contortuplicatus L. | Th | 5 | HRV |
| — corrugatus Bert. | Th | 4 | V |
| — Dianthus Bge. | Ch | 5 | E |
| — eremospartoides Rgl. | Ch | 5 | E |
| — erioceras F. & M. | H | 4—5 | R |
| — farctus Bge. | H | 5 | H |
| — filicaulis F. & M. | Th | 4 | HV |
| — flexus Fisch. | H | 4—5 | HV |
| — grandiflorus Bge. | H? | 4—5 | E |
| — gyzensis Del. | Th | 4 | HV* |
| — hyrcanus Pall. | F | 5 | E |
| — karakugensis Bge. | F | 5—6? | E |
| — Lehmannianus Bge. | H? | 4—5 | E |
| — leiophysa Bge. | H? | 5 | E |
| — longiflorus Pall. | H | 4? | HR |
| macrocladus Bge. | F | 4 | E |
| — macronyx Bge. | H | 4—5 | E |
| — macropus Bge. | H | ? | HR* |
| — macrotropis Bge. | Ch | ? | H |
| — mucidus Bge. | H | 4—5 | H |
| — orbiculatus Ldb. | H | 5 | HV |
| — oxyglottis Stev. | Th | 5 | RV* |
| — Pallassii Fisch. | H | 4—5 | HR |

| Name | Growth-form | Flowering-month | Distri-bution |
|---|---|---|---|
| Astragalus paucijugus C. A. M. | F | 4 | H |
| — Petunikowii Litw. | H | 5 | E |
| — salsugineus Kar. Kir. | H? | 4—5 | H |
| — scabrisetus Bong. | H | 5 | H |
| — Schmalhausenii Bge. | Th | 5 | E |
| — Schrenkianus F. & M. | H | 4 | H |
| — scleroxylon Bge. | F | 4—5 | E |
| — sesamoides Bois. | Th | 4 | HV |
| — sogdianus Bge. | H | 5 | H |
| — sphaerophysa Kar. Kir. | H? | 5 | H |
| — squarrosus Bge. | F | 4 | V |
| — subbijugus Ldb. | Ch? | 4—5 | H |
| — tetrastichus Bge. | H | 5 | E |
| — tribuloides Del. | Th | 5 | HV* |
| — turbinatus Bge. | H? | 5 | V |
| — turcomanicus Bge. | Ch? | ? | E |
| — Turczaninowii Kar. Kir. | H? | 5—6 | H |
| — unifoliatus Bge. | F | 5—6 | E |
| — ustiurtensis Bge. | H | 5 | E |
| — villosissimus Bge. | F | 5 | E |
| — vulpinus Willd. | H | ? | R |
| Eremosparton aphyllum F. & M. | F | 5—6 | H |
| Ewersmannia subspinosa (Fisch.) Fedtsch. | F | 5 | HR |
| Glycyrrhiza aspera Pall. | H | 5 | RV |
| — glabra L. | H | 5—6 | HRV* |
| — uralensis Fisch. | H | 6? | R |
| Goebelia alopecuroides L. | H? | 6 | HRV |
| — pachycarpa Schrenk. | Ch? | 5—6 | HV |
| Halimodendron argenteum (Lam.) D. C. | F | 4—5 | HRV |
| Lotus tenuifolius Rchb. | H | 5 | HV* |
| Oxytropis riparia Litw. | H? | 6 | E |
| Prosopis Stephaniana Willd. | F | 5—7 | V* |
| Psoralea drupacea Bge. | Ch? | 5—8 | H |
| Smirnowia turkestana Bge. | F | 4 | E |
| Sphaerophysa salsula (Pall.) | H | 5 | HR |
| Trigonella grandiflora Bge. | Th | 5 | E |
| — incisa Bth. | Th | 4 | V |
| — monantha C. A. M. | Th | 4—5 | V* |
| *Plantaginaceae.* | | | |
| Plantago arenaria W. K. | Th | 4 | HR*V* |
| — Coronopus L. | Th [1]) | 5? | RV* |
| — lachnantha Bge. | Th | 4 | E |

[1]) or biennial (H).

| Name | Growth-form | Flowering-month | Distribution |
|---|---|---|---|
| Plantago lagocephala Bge. | Th | 4—5 | E |
| — lanceolata L. | H | 5? | HR*V* |
| — major L. | H | 5? | HR*V* |
| — minuta Pall. | Th | 4—5 | HR |
| — tenuiflora Kit. | Th | 5 | HR |
| *Plumbaginaceae.* | | | |
| Statice caspica Willd. | H | 6—7 | HRV |
| — Gmelini Willd. | H | 6? | HR*V |
| — leptostachya Bois. | Th | 5 | V |
| — otolepis Schrenk. | H | 5—6 | H |
| — perfoliata F. & M. | H | 7—8 | V |
| — spicata Willd. | Th | 5 | RV* |
| — suffruticosa L. | Ch | 7—8 | HR |
| *Polygonaceae.* | | | |
| Atraphaxis compacta Ldb. | F | 4—5 | HR |
| — spinosa L. | F | 5 | HRV* |
| Calligonum[1]) acanthopterum Borsz. | F | 5? | E |
| — anfractuosum Bge. | F | 5 | E |
| — aralense Borsz. | F | 5? | E |
| — arborescens Litw. | F | 5? | E |
| — Calliphysa Bge. | F | 5 | HV |
| — Caput Medusae Schrenk. | F | 6 | H |
| — Colubrinum Borsz. | F | 5 | E |
| — densum Borsz. | F | 6 | E |
| — erinaceum Borsz. | F | 5 | E |
| — eriopodum Bge, | F | 5? | E |
| — flavidum Bge. | F | 6 | H |
| — horridum Borsz. | F | ? | E |
| — leucocladum Schrenk. | F | 4 | H |
| — macrocarpum Borsz. | F | 6 | E |
| — microcarpum Borsz. | F | 5 | E |
| — Murex Bge. | F | 5 | E |
| — Pallasia l'Hérit. | F | 5 | HR |
| — platyacanthum Borsz. | F | 5? | E |
| — Rotula Borsz. | F | 6 | E |
| Polygonum amphibium L. | HH | 7 | HR*V |
| — Bellardi All. | Th | ? | R*V* |
| Rheum tataricum L. f. | H | 4 | HR |
| Rumex crispus L. | H | 5 | HR*V* |
| — Marschallianus Rchb. | Th | 4 | HR |

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[1]) This genus, after BORSZCZOW: Die aralo-kaspischen Calligoneen (Mém. Ac-St. Pb. III 1860).

| Name | Growth-form | Flowering-month | Distri-bution |
|---|---|---|---|
| *Potamogetonaceae.* | | | |
| Potamogeton crispus L. | HH | 5? | H*R*V* |
| — lucens L. | HH | 6? | HR*V* |
| — natans L. | HH | 5? | R*V* |
| — pectinatus L. | HH | 5? | H*R*V* |
| — perfoliatus L. | HH | 5? | H*R*V* |
| Ruppia maritima L. | HH | 6? | RV* |
| Zanichellia pedicellata Fr. | HH | 6? | HRV* |
| *Primulaceae.* | | | |
| Androsace maxima L. | Th | 5? | HR*V* |
| Glaux maritima L. | H | 6? | H*R*V |
| *Ranuculaceae.* | | | |
| Anemone biflora D. C. | H | 3—4 | H*V |
| Ceratocephalus falcatus (L.) Pers. | Th | 3—4 | V* |
| — testiculatus (Crz.) Bess. | Th | 3—4 | HR*V |
| Clematis orientalis L. | Ch? | 7—8 | H*RV |
| Delphinium camptocarpum F. & M. | Th | 4—5 | HRV |
| — divaricatum Ldb. | Th? | ? | RV |
| — leiocarpum Huth | H? | 5 | V |
| — longipedunculatum Rgl. & Schm. | H? | ? | E |
| — persicum Bois. | Th | 5 | V |
| — pilosulum (Trautv.) Fedtsch. | H? | ? | E |
| — rugulosum Bois. | Th | 4—5 | V |
| — Zalil Ait. & Hemsl. | H | 6 | V |
| Eranthis longistipitata Rgl. | G | 3—4 | H |
| Myosurus minimus L. | Th | 5 | RV |
| Nigella integrifolia Rgl. | Th | 4—6 | H |
| Ranunculus leptorhynchus Ait. & Hemsl. | H | 4 | V |
| — linearilobus Bge. | H | 3—4 | E |
| — Meinshauseni Schrenk. | H? | 4—5 | H |
| — oxyspermus Willd. | H | 5 | RV |
| — paucistamineus Tausch. (var. Drouetii (Sch.)) | HH | 4—6 | H*R*V |
| — platyspermus Fisch. | H? | 5? | HR |
| — sceleratus L. | Th | 5? | HR*V* |
| — Sewerzowi Rgl. | H? | 4—5 | H |
| *Rosaceae.* | | | |
| Hulthemia berberifolia Dumort. | Ch | 5 | HV |
| Potentilla songorica Bge. | H | 5 | H |
| — supina L. | Th | 4 | HRV |

| Name | Growth-form | Flowering-month | Distribution |
|---|---|---|---|
| *Rubiaceae.* | | | |
| Asperula Danilewskiana Bas. | Ch? | 5 | R |
| Callipeltis Cucullaria (L.) Stev. | Th | 4 | V* |
| Crucianella filifolia Rgl. & Winkl. | Th | 4 | E |
| Galium tricorne With | Th | 5 | V* |
| *Rutaceae.* | | | |
| Haplophyllum lasianthum Bge. | H | 5 | E |
| — obtusifolium Ldb. | Ch | 5—6 | E |
| — robustum Bge. | H? | 5? | V |
| — Sieversii Fisch. | H | 5—6 | HV |
| — thesioides (Fisch.) Ldb. | H? | 5? | E |
| — versicolor F. & M. | H | 5? | HV |
| *Salicaceae.* | | | |
| Populus euphratica Oliv. | F | 3—4 | HRV* |
| — pruinosa Schrenk | F | 3—4 | HR |
| Salix augustifolia L. (var. carmanica Bornm.). | F | 5? | HRV |
| — songorica Anders. | F | 5? | H |
| *Salviniaceae.* | | | |
| Salvinia natans (L.) All. | HH | | R*V |
| *Scrophulariaceae.* | | | |
| Dodartia orientalis L. | G | 5—6 | HRV |
| Linaria odora Chav. | G | 5—6 | HR* |
| Scrophularia leucoclada Bge. | F | 5? | E |
| Veronica biloba L. | Th | 3—4 | H*RV* |
| *Solanaceae.* | | | |
| Hyoscyamus pusillus L. | Th | 5 | H*RV* |
| Lycium ruthenicum Murr. | F | 5—7 | HR* |
| — turcomanicum F. & M. | F | 6? | H |
| *Tamaricaceae.* | | | |
| Reaumuria fruticosa Bge. | F | 7? | V |
| — oxiana (Ldb.) Bois. | F | 7 | V |
| — squarrosa Jaub. Sp. | Ch | 6—7 | V |
| Tamarix Androssowii Litw. | F | 5 | E |
| — arceuthoides Bge. | F | 7? | H |
| — elongata Ldb. | F | 5 | H |
| — Ewersmannii Bge. | F | 6 | R |
| — florida Bge. | F | 5 | V |
| — hispida Willd. | F | 7—9 | HR |
| — karakalensis Freyn & Sint. | F | 6 | E |

| Name | Growth-form | Flowering-month | Distri-bution |
|---|---|---|---|
| Tamarix Karelini Bge. | F | 9 | R |
| — Korolkowi Rgl. & Schm. | F | 5 | H |
| — laxa Willd. | F | 4—5 | HV |
| — leptostachya Bge. | F | 6 | H |
| — Meyeri Bois. | F | 4—5 | V |
| — Pallasii Desv. | F | 6—8 | HV* |
| — polystachya Ldb. | F | 4 | R |
| — pycnocarpa D. C. | F | 6 | RV |
| *Thymelaeaceae.* | | | |
| Diarthron vesiculosum (F. & M.) C. A. M. | Th | ? | HRV |
| Stellera Lessertii (Wickstr.) C. A. M. | Ch | 7 | HV |
| *Typhaceae.* | | | |
| Sparganium ramosum Huds. | HH | 5? | R*V* |
| Typha angustifolia L. | HH | 6 | R*V* |
| — latifolia L. | HH | 6 | HR*V* |
| — Laxmanni Lep. | HH | 6 | HRV |
| — stenophylla F. & M. | HH | 6 | HRV |
| *Umbelliferae.* | | | |
| Aphanopleura capillifolia (Rgl. & Schm.) Lipsky | Th | 4—5 | E |
| Cachrys didyma Rgl. | H | 5 | E |
| Carum Capusi Frch. | H [1]) | 5 | H |
| — elegans Fzl. | H [1]) | 5 | V* |
| — sogdianum Lipsky | H | 4—5 | H |
| — trichophyllum Schrenk. | H [1]) | 5 | H |
| — turkestanicum Lipsky | H? | 5 | E |
| Caucalis leptophylla L. | Th | 5 | V* |
| Cryptodiscus ammophilus Bge. | H | 4—5 | E |
| — rutaefolius Bge. | H | 4—5 | E |
| Cuminum hispanicum Mer. | Th | 4 | V |
| Daucus pulcherrimus Koch | H [1]) | 5 | RV* |
| Dorema Ammoniacum D. Don. | H | 5 | V |
| Eremodaucus Lehmanni Bge. | Th | 5 | H |
| Eriosynaphe longifolia D. C. | H? | 5 | R |
| Ferula Asa foetida L. | H | 5 | V |
| — diversivittata Rgl. & Schm. | H | 5 | H |
| — Karelini Bge. | H | 5 | H |
| — nuda Spreng. | H | 5 | HR |
| — Schair Borsz. | H | 4—5 | E |
| — Schtschurowskiana Rgl. & Schm. | H | 5 | E |
| Galagania fragrantissima Lipsky | H | 5 | H |

[1]) Perennial or biennial.

| Name | Growth-form | Flowering-month | Distribution |
|---|---|---|---|
| Holopleura carioides Rgl. & Schm. | H [1]) | ? | E |
| Hyalolaena jaxartica Bge. | H | 5 | E |
| Peucedanum rapiferum Trautv. | H?[1]) | 5 | H |
| — tenuisectum Rgl. & Schm. | H | 5 | H |
| Psammogeton Borszczowii (Rgl. & Schm.) Lipsky | H [1]) | 5 | E |
| — setifolium Bois. | Th | 5 | V |
| Scaligeria allioides (Rgl. & Schm.) Bois. | H [1]) | 5 | HV |
| — hirtula (Rgl. & Schm.) Lipsky | H?[1]) | 6? | H |
| Zozimia absinthifolla D. C. | H | 5 | RV* |
| *Urticaceae.* | | | |
| Ulmus campestris Sm. | F | 4 | R*V* |
| *Valerianaceae.* | | | |
| Valerianella Dufresnia Bge. | Th | 5 | V* |
| — Szovitsiana F. & M. | Th | 4 | HV* |
| — orientalis Bois. & Bal. | Th | 5 | V* |
| — turkestanica Rgl. & Schm. | Th | 5 | E |
| — uncinata M. B. | Th | 4 | RV |
| *Zygophyllaceae.* | | | |
| Biebersteinia multifida D. C. | H | 5 | HV* |
| Miltianthus portulaccoides (Cham.) Bge. | H? | 4—5 | E |
| Nitraria Schoberi L. | F | 5—6 | H*RV |
| Peganum Harmala L. | H | 5 | HR*V* |
| Tetradiclis tenella (Ehrb.) Litw. | Th | 4 | HRV* |
| Tribulus terrestris L. | Th | 5 | HRV* |
| Zygophyllum brachypterum Kar. Kir. | H? | 6? | HV |
| — Eichwaldii C. A. M. | H | 4—5 | E |
| — eurypterum Bois. & Buhse | F | ? | V* |
| — Fabago L. | H | 5 | H*R*V* |
| — Karelini F. & M. | Th | 5 | E |
| — macrophyllum Rgl. & Schm. | H | ? | E |
| — macropterum C. A. M. | H | 5 | HV |
| — miniatum Ch. & Schl. | H | 5 | H |
| — ovigerum Fisch. | H | 5 | E |
| — turcomanicum F. & M. | H | ? | E |

[1]) Perennial or biennial.

A summary of the species and growth-forms in the above list gives the result that out of 768 species 87 are Fanerophytes, 52 Chamaephytes, 210 Hemicryptophytes, 70 Geophytes, 38 Hydro- and Helophytes, and 310 Therophytes. There is also one species of *Cuscuta*. These numbers calculated as percentages give the top line in table 3, so that this is the "biological spectrum" of the territory. It shows, that the

**Table 3.**

| | Number of species | Percentage of species under each growth-form | | | | | |
|---|---|---|---|---|---|---|---|
| | | F | Ch | H | G | HH | Th |
| Transcaspian Lowlands | 768 | 11 | 7 | 27 | 9 | 5 | **41** |
| Government of Yekaterinoslaw ........... | 1046 | 5 | 3 | **55** | 8 | 5 | 24 |
| Pamir ................. | 514 | 1 | **12** | **63** | 5 | 5 | 14 |
| Death Valley .......... | 294 | **26**[1] | 7 | 18 | 2 | 5 | **42** |
| Samos .................. | 400 | 9 | 13 | 32 | 11 | 2 | 33 |
| Libyan desert ......... | 194 | 12 | **21** | 20 | 4 | 1 | **42** |
| Cyrenaica ............. | 375 | 9 | 14 | 19 | 8 | .. | **50** |
| Normal spectrum...... | 400 | **47**[2] | 9 | 27 | 3 | 1 | 13 |

[1]) Inclusive of 3 % stem-succulents.
[2]) Inclusive of 1 % stem-succulents and 3 % epiphytes.

Therophytes are the most abundant growth-form, then follow the Hemicryptophytes and the Fanerophytes. The other series of numbers ("spectra") are inserted for comparison. The first two series are prepared from my own calculations: Yekaterinoslaw according to Békétof's Flora, and Pamir from O. Fedtschenko's "Flore du Pamir" with supplements, and additions of my own. The others, namely Death Valley (in western North-America), Samos, the Libyan desert and Cyrenaica (Barka), and the "Normal Spectrum" I have quoted from Raunkiær (1908 p. 55). The "Normal Spectrum" is the biological spectrum for 400 species taken at random from a list of the plants of the whole earth, it should accordingly be the spectrum of the whole earth. If we now compare it with the spectrum of Transcaspia it will be seen that the latter has proportionately a much larger number of Therophytes and a much smaller number of Fanerophytes than the earth as a whole, the other deviations being less important. Transcaspia thus lies outside the region of Fanerophytes, the region with a fanerophytic climate i. e. a tropical climate with abundant precipitation.

On the other hand the spectrum of Transcaspia agrees in the main with the spectra for Samos, the Libyan desert, Cyrenaica and Death Valley respectively. The point of maximum intensity for all these spectra lies in the Therophytes. In the hotter of these areas, the Libyan desert and Death Valley, the Chamaephytes and the Fanerophytes are also prominent.

As regards its biological spectrum, Transcaspia thus presents the same type as the countries of the Mediterranean, at least the eastern parts. We are further led to the conclusion that parts at least of the western countries of the Mediterranean should also be included here because 35 per ct. Therophytes are found on the Iberian steppes (Willkomm 1894 p. 280).

[illegible] these Therophyte-spectra [illegible] contingent upon the same climate: winter-rains and [illegible] hot summer. This forms a link in what is termed by Raunkiær a C-climate series, i. e. a series starting at the Equator with a tropical moist climate, its continuation northwards being determined in this way, that although the heat decreases so does the precipitation at least as regards the summer. Thus we get a dry climate characterised by a "Therophyte spectrum". Still farther north the precipitation again increases, and we have here a temperate Hemicryptophyte-climate which in arctic countries is succeeded by a Chamaephyte-climate. Such C-climate series are especially met with in the western parts of large continents. Death Valley shows the unfavourable dry climate in the series which runs through western America. Transcaspia and the countries of the Mediterranean represent the corresponding link in the series through the western parts of the continents of the Old World.

The B-Climate series passing through the eastern parts of the continents, and which has a favourable precipitation throughout does not come within the scope of this memoir.

If on the other hand we compare the spectrum of Transcaspia with those of Yekaterinoslaw and Pamir, we arrive at the result that whether we proceed from Transcaspia northwards to the south Russian steppe, or upwards into the mountains, the Therophytes decrease, while the Hemicryptophytes increase in number. This is in accordance with Raunkiær's statement that the Therophytes are the growth-form best adapted to a dry hot climate, but that they decrease in numbers where the temperature is low.

As already stated the most important characteristic of the biological spectrum of the Transcaspian lowlands is the great number of Therophytes or annual plants (41 per ct.). This is also characteristic of countries to the south and south-west, and in the desert areas of western North-America. (see table 3 p. 159). According to Mac Dougal (1909) and Cannon (1909), the Sonora desert has two precipitation-maxima with spells of dry weather between (comp. p. 59); during the two wet periods there is a great abundance of mesophytic annual plants (ephemerals), the species of the two periods being different although some of them appear twice a year both in summer and winter. (See also Thornber l. c.)

Most of the annual plants of Transcaspia belong to what Volkens (l. c. p. 20) terms ephemerals, that is plants which complete their life-history from germination to the ripening of seeds during the short and comparatively moist spring-time (see above p. 59). In countries where the winter is warm, germination sometimes takes place during autumn or winter (Volkens p. 19), but in the cold winter of Transcaspia this is not likely to be the case.

The existence of the ephemeral plants is dependent on a short comparatively moist favourable period, sufficiently warm and long enough to permit them to complete their development. The adaptations of the plants consist in the capacity for rapid development and in the resistance of the seeds to prolonged dessication; their vegetative parts on the other hand show only slight adaptation against dessication, so that they must be termed mesophytic in structure.

An important condition for the welfare of the ephemeral plants, which also holds good as regards the longer lived annual plants, is that sufficient open ground is available and that the perennials or the ligneous species do not grow so close as to hamper the germination and growth of those plants which must start afresh from seeds every year. This condition is fulfilled in the Transcaspian lowlands where a dense vegetation is only found in the valleys of the rivers and under the most favourable conditions. Thus conditions which bring about a scattered growth of perennial plants favour the annual ones (See for instance M. Vahl 1904 p. 67).

The summer-annuals, fairly numerous in the Transcaspian lowlands, are adapted in a different way and to different conditions. The plant lives through the summer, hence it must endure desiccation and is xerophytic in structure. They do not die till winter sets in.

**Table 4.**

| | Number of Annuals | Percentage of annuals | |
|---|---|---|---|
| | | already flowered by 1. July | flowering wholly or partially after 1. July |
| Denmark | 210 | 20 | 80 |
| Yekaterinoslaw | 240 | 45 | 55 |
| Samos | 117 | 62 | 38 |
| Spain (Halophytes) | 122 | 65 | 35 |
| Transcaspian Lowlands | 310 | 79 | 21 |

The last line in Table 4 gives the percentages of early and late flowering annual plants in the Transcapian lowlands. As some ephemeral plants may be seen in flower at the beginning of June, I have fixed the limit at July 1. Plants which may be found flowering on the first of July and later are thus considered late-flowering, those which have completed flowering before the end of June are termed early flowering. When the flowering season of any species is unknown to me, it is generally given as early flowering. This table is intended to give some notion as to the proportion between ephemerals and summer-annuals. Even though these definitions do not perfectly differentiate between early and late flowering, yet they do so to a certain extent. An attempt was made to draw up a list of summer-annual plants, regardless of the flowering season. but owing to insufficient knowledge of the life-history of certain species, I shall not give it here. It is noteworthy however, that 74 per ct. of the (86) species flower after July 1. The division according to flowering season thus makes the number of late-flowering species somewhat smaller than the number of summer-annuals. In the case of several of the other countries given in the table, there was the same difficulty in obtaining reliable comparative data as to the life-period of the plants, therefore I am obliged to limit the table to a comparative statement of the flowering season for all the countries. This table will to some extent illustrate the proportion between ephemerals and summer-annual plants.

The four upper lines are given for comparative purposes. The figures for Denmark are calculated from RAUNKIÆR'S Excursion-Flora, for Yekaterinoslaw according to BÉKÉTOFF, for Samos according to STEFANI, FORSYTH MAJOR & BARBEY, and HALACSY, and the figures for Spain according to WILLKOMM (1852)[1]. No figures are given for the Libyan desert, as the flowering season is not recorded in ASCHERSON and SCHWEINFURTH'S flora, also because many of the annual plants are facultative biennials or perennials, and some flower both in spring and winter. The following species of annual summer-plants comparable to those occurring in the Transcaspian desert — i. e. not facultative perennials — are given by VOLKENS for the Libyan desert: *Moricandia clavata, Diplotaxis Harra, Monsonia nivea, Mesembryanthemum crystallinum, M. nodiflorum, M. Forskalei, Aizoon canariense.* Although this list be not complete, it indicates that there are very few summer-annual plants in the Libyan desert, so that probably this locality should have been placed at the foot of the table, being the one with the greatest number of ephemeral plants.

The desert of western North America might be placed in the table beside Transcaspia. According to THORNBER there are in the desert of Tucson about 20 per ct. "long-lived annuals" and 80 per ct. short-lived ones. By counting up SPALDING'S list (1909) of the plants of the Tucson country I obtained respectively 21 and 79 per ct. of these two categories. The proportion thus agrees approximately with that found in Transcaspia.

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[1]) See also WILLKOMM 1896 p. 150. This work cannot be employed for statistics, as all the species of the formations are not recorded.

The figures in table 4 show that while in Denmark four-fifths of the annuals flower after the first of July, we have in the South-Russian steppe (Yekaterinoslaw) about one half, in Greece and Spain about one third, and in the Transcaspian lowlands about one fifth which are late-flowering.

In the series: Libyan desert, Transcaspian desert, Spain, South-Russian Steppe, Denmark, the number of summer-annual plants thus steadily increases. And throughout the same series the summer becomes less warm and less dry. In Cairo there is no rain during 4—6 summer months and the mean temperature of July is 29° C.; in Merw 3—4 summer months are rainless, and the mean July temperature is $30{,}2^{0}$ C., (Askhabad $29{,}7^{0}$ C., Petro Alexandrowsk $28{,}7^{0}$ C.; Table 1 p. 17). In Spain no month is perfectly rainless though July and August are very dry, and the mean July temperature is, for instance, Murcia 29° C., Madrid $24{,}5^{0}$ C. Yekaterinoslaw has as mean July temperature of $23{,}0^{0}$ C. and the precipitation is greatest in July and smallest during winter.[1]

This leads us to the conclusion that the number of summer-annual plants is more especially dependent on the summer rainfall, as might be expected. From north towards the south the conditions of life during summer become more and more unfavourable, so that fewer and fewer annual species are able to endure, namely only those adapted to withstand increasingly unfavourable conditions.

But the winter temperatures may also play a part in determining the relative number of annual summer-plants, since plants have a better chance of hibernating in countries with warmer winters than where the cold is severe. In this way annual summer-plants might become perennials. The statement by VOLKENS (l. c. p. 21), that facultative annual and perennial plants are characteristic for the Libyan desert, is perhaps not only correlated with the summer but also with the winter conditions.

The mean temperature at Cairo for Jan. is $11{,}9^{0}$ C., and even if (according to HANN) a few degrees of frost are some-

[1]) The temperature records are cited from HANN 1897, III.

times recorded, this is nothing compared with Merw which has a mean temperature for January of — $0{,}_6{}^0$ C. (Askhabad — $0{,}_2{}^0$ C., Petro Alexandrowsk — $5{,}_5{}^0$, table 1) and Yekaterinoslaw which has — $7{,}_4{}^0$ C., the minimum temperatures of both localities being nearly — $20^0$ C. or even less.

Spain, which as regards July-temperature takes third place, becomes second in this respect since the winter there is much warmer than in Transcaspia (Murcia $9{,}_3{}^0$ C., Zaragoza $5{,}_2{}^0$ C., Madrid $4{,}_9{}^0$ C. in January). The number of annual summer-plants in this case is thus in accordance with the July temperature, not that of January. This leads us to the conclusion that the January temperature may be a major factor only when it is high, while marked differences in the lower temperatures do not seem to be of any importance. The data are, however, too scanty to allow us to come to any decisive conclusion.

## Table 5.

Distribution of the growth-forms of Transcaspian species amongst certain natural orders.

| | Number of species | Percentage of species occurring as growth-forms | | | | | |
|---|---|---|---|---|---|---|---|
| | | F | Ch. | H | G | HH | Th. |
| Borraginaceae ........ | 42 | .. | 4 | 29 | 10 | .. | **57** |
| Caryophyllaceae ..... | 25 | .. | 36 | 20 | ... | .. | **44** |
| Chenopodiaceae ..... | 94 | 13 | 11 | 4 | ... | .. | **72** |
| Compositae........... | 103 | 2 | 8 | **45** | 3 | .. | **42** |
| Cruciferae ............ | 51 | . | .. | 10 | ... | . | **90** |
| Gramineae... ........ | 44 | .. | .. | 25 | 18 | .. | **57** |
| Labiatae........... ... | 20 | .. | 5 | **55** | ... | 10 | 30 |
| Liliaceae ... ... ..... | 24 | . | .. | .. | **100** | .. | .. |
| Papilionaceae.. ...... | 85 | **27** | 10 | **42** | ... | .. | 21 |
| Polygonaceae .. ... | 26 | **80** | .. | 8 | ... | 4 | 8 |
| Ranunculaceae ...... | 23 | .. | 4 | **48** | 4 | 4 | **40** |
| Umbelliferae.......... | 31 | .. | . | **84** | ... | .. | 16 |
| Tamaricaceae......... | 18 | 95 | 5 | .. | .. | .. | .. |
| Zygophyllaceae .... .. | 17 | 12 | .. | 69 | ... | .. | 19 |

From table 5 it will be seen which natural orders are specially represented by annual species in the Transcaspian desert; as the distribution of the growth-forms of the species of larger families are here given as percentages. The orders which are especially represented by annual species are the *Cruciferae* and the *Chenopodiaceae*, the percentage of these being respectively 90 and 72. Of these the Cruciferae are all early flowering ephemerals, whereas about 82 per ct. of the annual Chenopodiaceae are summer-plants which flower after the beginning of July. A large proportion of the early flowering annual Chenopodiaceae also live far into the summer.

These two families, the *Cruciferae* and the *Chenopodiaceae* are thus typical representatives of two widely different series of adaptations to desert-life: the one shows itself in the quick development of plants of mesophytic structure during the favourable season; the other is characterised by slow development combined with the power to withstand the unfavourable conditions of the dry season. The former series include all the other families in table 5 with a large number of annual plants, e. g. *Borraginaceae*, *Gramineae* and *Ranunculaceae*. Outside the Chenopodiaceae there are very few annual summer-plants.

That the adaptation of the ephemeral planfs is advantageous is easily seen; the continuity of the race is ensured with a slight expenditure of material. Life with these plants seems a much simpler matter than in the case of the annual summer-plants which have to contend with a long hot summer before their seeds are ripened. The existence of the latter is far more expensive, because for one thing material must be produced for the development of mechanical, water-storing, and other specialised tissues which the ephemerals do not require; moreover many of the annual summer-plants do not complete their natural span of life because they are buried by the sand, or the soil blows away, or they die of thirst.

In this connection attention is drawn to the outstanding difference between the mode of occurrence of the ephemerals and the annual summer-plants. As already described, the former often appear in masses during spring, while the latter almost always occur as single plants standing widely apart. This is of course largely due to the greater number of species of the ephemerals, but my opinion is that the number of individuals of most of the ephemeral species is much larger than that of the summer-annuals. This question ought to be more closely investigated.

Even though the adaptations of the summer-annual plants must be regarded as favourable, otherwise the plants would not be able to exist, they seem to be much less favourable than the adaptations of the ephemerals or those of the perennials. The latter remain alive year after year, capable of storing nutriment and of developing a strong root-system, while as regards propagation by seeds they have the same chance as the annual plants.

The annualness of the annual summer-plants inherent in their nature thus seems to be an unfavourable point in their adaptation to the conditions of the Transcaspian desert. That so few species of them occur there is perhaps a result of this.

Next to the Therophytes the Hemicryptophytes are the most abundant type in the Transcaspian desert. Their percentage (27) ranges between the figures from the North-African and North-American desert (19, 20, 18) and Samos (32) as shown in Table 3. They are far less numerous here than in the South-Russian steppe (Yekaterinoslaw) and Pamir.

Most of them flower early, about the month of May. After calculation, I find that only about 10 per ct. of the Hemicryptophytes flower after July 1, so that about 90 per ct. are early flowering. These figures are only approximate, as details on the flowering season of many species are lacking.

Actual numbers have less interest here than in the case of annual plants, because the latter usually die after they have produced flower and fruit, whereas perennial plants in many cases continue to be vegetative after that time. Statistics of the flowering season therefore give no information about the vegetative period of perennials.

Most Hemicryptophytes flower early and have completed flowering before the end of June. As previously stated (p. 59) many of them wither when the seeds are ripe. This is probably the case with the majority, some of them have already been referred to. They have also ephemeral shoots, mesophytic in structure and arising from perennial hypogeal parts. In other Hemicryptophytes the epigeal shoots live through the whole summer, e. g. in species of *Zygophyllum*, *Anabasis*, *Statice*, probably also in a few *Cousinia* and *Astragalus;* their shoots are xerophytic in structure and have this biological character in common with the annual summer-plants that the shoots die when winter sets in.

No information is available on the few plants recorded as biennials, for instance *Tragopogon*. It is unlikely that the species of *Tragopogon* carry fresh leaves throughout the whole summer.

The *Chenopodiaceae* as a group are strikingly deficient in hemicryptophytes, they have only 4 per ct. The *Tamaricaceae* and the *Liliaceae* have none at all. The paucity of hemicryptophytes in the Chenopodiaceae, so many of which seem specially adapted to desert-life, may perhaps be explained in this way, that this type is not well adapted to the natural conditions prevailing during summer in the desert. Yet the correctness of this supposition may be questioned when we consider the *Zygophyllaceae*, likewise true summer-plants and with 11 hemicryptophyte-species (69 per ct.).

Of the remaining orders the *Umbelliferae* in particular include a large number of hemicryptophytes all or most of which are spring-plants. (See table 5).

Next in order to the Hemicryptophytes (Table 3) follow the F a n e r o p h y t e s, the trees and shrubs. These all belong to RAUNKIÆR's Micro- and Nanofanerophytes.

In the Transcaspian desert there are 11 per ct. Fanerophytes, about the same proportion as in the North-African deserts (Libyan desert 12, Cyrenaica 9) and in Samos (9), but much less than in Death Valley with 23 p. ct. On the other hand, the South Russian Steppe shows only 5 per ct. and the Spanish Steppe about the same number[1]). Denmark has 7, Stuttgart 9 per ct. (RAUNKIÆR).

Only 14 out of 87 Fanerophytes in the list may still be found flowering after July 1$^{st}$ and of these 8 are Cheno-

[1]) WILLKOMM 1895 p. 280.

podiaceae. What was said of the Hemicryptophytes is still more the case here: that the early flowering species may be summer-plants; here every one is such, and not one is known to rest during the summer-periods, although some of the species of *Astragalus* may shed their leaflets.

The Transcaspian Fanerophytes occur in greatest numbers and attain their highest development in the Sand-desert. As already stated (p. 79), the Sand-desert has a rain-absorbing soil, but its capillary action is slight, hence there must be larger supply of water in the deeper layers than in the Clay-deserts. This is naturally correlated with the occurrence of trees since these have long roots capable of extending down to the water; compare also p. 48.

Another factor of importance for the ground-water and therefore for the Fanerophytes, is the density of the vegetation. Wherever in dry regions there is a rich vegetation of herbs or small shrubs, these will intercept and absorb the water, so that it is not allowed to sink into the soil. Kostytscheff points out that forests might grow on the South-Russian steppe if the surface were loosened, so that water might penetrate the soil. Why this does not take place is, he states, because the surface of loess is impervious to water, especially when covered by plants.

Without entering into the question why the Russian steppe is treeless, it is noteworthy that Transcaspia presents better conditions for growth of trees than South-Russia; this is a result of the absorptive capacity of the soil due to its structure and to the open plant-covering, aided also by climatic conditions. Reference may be made in this connection to Schimper's statement (p. 527) that the South-Russian steppe has a dry as well as a cold winter, an element hostile to the growth of trees. For when dry winds blow at the same time as the ground is frozen, the trees with their branches and buds more exposed than smaller plants, will be unable to compensate for loss by transpiration.

Somewhat similar conditions prevail on the Spanish steppes; the winter is cold, dry and windy [1]). May has the greatest amount of precipitation.

[1]) Climatic tables for Zaragoza and Valladolid in Meteorol. Zeitschrift 9. 1874. p. 218.

In Transcaspia the conditions are just the reverse. As may be seen from table 1 (p. 17), the precipitation is greatest in winter so that the coldest season is comparatively humid. In this respect the climate to a certain degree favours the growth of trees. But as a whole it is only to a slight degree favourable! The long dry period which occurs during the vegetative period for trees necessitates the utmost economy as regards water. Therefore only the more xerophytic trees are able to live; their external and internal structure will be described below (chap. 13).

Fanerophytes occur in comparatively few of the natural orders represented in Transcaspia (Table 5). For instance in *Borraginaceae, Caryophyllaceae, Cruciferae, Labiatae, Ranunculaceae* and *Umbelliferae* they are totally absent. On the other hand, the numerous species of *Tamarix* and *Calligonum* have this effect that the *Tamaricaceae* and *Polygonaceae* consist mainly of trees and bushes. The species of *Calligonum* are more especially true desert-plants. Many of the fanerophytic *Papilionaceae* (*Astragalus*, *Ammodendron*, *Eremosparton)* and *Chenopodiaceae (Salsola, Haloxylon*), are likewise true desert plants, xerophytic in structure. On the contrary the only two fanerophytic *Compositae* (*Artemisia procera* and *Zollikoferia acanthodes*) are unimportant species, rarely recorded.

The 10 per ct. of Geophytes in the Transcaspian desert is a rather high figure compared with the "Normal-Spectrum", but it is in agreement with Samos and Cyrenaica (Table 3). Of the 72 geophytes, 33 (46 per ct.) are rhizome-plants, 24 (33 per ct.) are bulbous plants, 9 tuberous plants (13 per ct.), and 6 parasites (8 per ct., *Orobancheaceae*).

As far as known only 5 geophytes may be found flowering after July 1. Only one of these *Eremurus Olgae* is a bulbous plant. The others *(Tournefortia sibirica, Pluchea caspica, Cressa cretica, Saccharum spontaneum*) have rhizomes. The term early flowering when applied to the rhizome-geophytes does not indicate that the epigeal shoots die after that time, for they continue to vegetate e. g. in *Heliotropium Radula* and *chorassanicum, Acroptilon, Dodartia, Aristida* and *Elymus.* Bulbous and tuberous plants, on the contrary, almost all finish the aerial period of their life before the end of June and thus belong to the mesophytic aspect of the vegetation, whereas many Rhizome-geophytes are very xerophytic e. g. *Heliotropium, Cressa, Aristida, Elymus, Dodartia.* The Irises and some others are mesophytic.

The natural order *Liliaceae* consists entirely of geophytes. (Table 5). The grasses include some very important and characteristic desert-forms of geophytes: *Aristida, Elymus, Aeluropus* and several species on the river-banks e. g. *Phragmites, Saccharum, Calamagrostis pseudophragmites.* The *Borraginaceae* include important species of *Heliotropium.* Most of the orders have no geophytes at all. (Table 5).

There are few Chamaephytes in the Transcaspian desert. Assuming that the classification of growth-forms is correct, 52 species belong to this type, all undershrubs with the exception of *Nanophytum erinaceum,* which is rather a cushion-plant. The aerial shoots of such chamaephytes die back until near the surface of the soil, and the buds for rejuvenation are situated at the base of the lignified and persistent stems. This is also the case with *Capparis spinosa* and *Hulthemia berberifolia,* but the shoots of these lie prostrate on the ground as in the more typical chamaephytes.

The species given in the list as Chamaephytes are generally desert-plants, with green shoots which live through the whole summer and contribute to the xerophytic aspect. More than half of them — at least 29 — flower after July 1. Some species play a rather prominent part in the desert, thus *Anabasis salsa, Arthrophytum, Noaea spinosissima, Artemisia, Convolvulus erinaceus* and *fruticosus, Alhagi, Psoralea drupacea, Hulthemia berberifolia, Haplophyllum obtusifolium, Reaumuria squarrosa* and *Stellera Lessertii.* These chamaephytes seem to have attained a high degree of adaptation to desert-life. The generally follow the clay-soil although some of them appear on the less fugitive sandy soils (*Convolvulus erinaceus).*

Although there are relatively few Chamaephytes in the Transcaspian desert (7 per ct.), they are far more numerous there than in temperate countries. Denmark for instance has only 3 per ct. But if we go southwards from Transcaspia we find in certain tropical or semi-tropical deserts a far greater percentage, thus in the Libyan desert 21 and at Aden 27 per ct. (RAUNKIÆR). This would seem to suggest that the cold winter of the Transcaspian desert is unfavourable to the chamaephytes.

It is known that aridity and heat favour lignification (WARMING 1909 p. 127), and this may sufficiently explain the occurrence of the chamaephytes — at any rate the undershrubs — in dry desert areas. That the Chamaephyte form is in itself a favourable adaptation for the plants is not directly obvious. Lignification and mechanical strength must be favourable (WARMING l. c.), and perhaps it may have this effect that the assimilating shoots are removed from the surface of the soil.

The *Caryophyllaceae*, *Chenopodiaceae* and *Papilionaceae* include proportionately the greater number of chamaephytes, while most of the other orders in Table 5 have few or none.

As to the 39 species of Aquatics and Marsh-plants I can add nothing of special interest for Transcaspia. Besides a number of *Cyperaceae* and *Potamogetonaceae*, the list includes plants like *Valisneria spiralis*, *Lycopus europaeus*, *Lemna*, *Najas*, *Epilobium hirsutum*, *Polygonum amphibium*, *Salvinia*, *Typha*. So far as the biological type is concerned, there is nothing about these plants to characterise them as especially Transcaspian. Something might be found by a closer study of their finer adaptations, such as anatomical structure, flowering, etc., an investigation I have not attempted.

The Aquatics and Marsh-plants are so far as known early flowering, only 5 species flowering entirely or partially after July 1.

Summarising what has been said about the growth-forms and their vegetative season, we may divide the growth-forms into those characteristic for the xerophytic aspect (the summer aspect), allowing at the same time that they may live and vegetate in spring; and those which vegetate only in spring and belong to the mesophytic aspect.

The Xerophytic Aspect includes:

All the Fanerophytes;
All the Chamaephytes;
A few Hemicryptophytes;
Some Rhizome-Geophytes (but only a few);
A few Therophytes.

The Mesophytic Aspect includes:
Many Hemicryptophytes;
Most of the bulbous Geophytes and some Rhizome-Geophytes;
Many Therophytes.

The percentages of early and late-flowering species already given show that by far the greater proportion of the plants of Transcaspia are early flowering. The number of late-flowering species in the list of plants is 123, which is 16 per ct. of all the species. The species whose flowering season is not stated, are as a rule taken as early flowering.

It holds good for most growth-forms that the majority of the species flower early. This also applies to the Therophytes, but for one group of these the summer-annuals, the opposite is the case; the same is seen in the Chamaephytes.

## CHAPTER 13

### Descriptions of the Growth-Forms.

In this chapter an attempt is made to give a description of some of the structural features of Transcaspian desert-plants. Even a brief description of each of the desert-plants of our area would fill a large volume, hence the following is limited to species known from personal observation and collected by myself supplemented in some cases by other material. In this respect the "Herbarium florae Rossicae" has been of great service.

The plant-species are arranged according to their "biological types" in the sense adopted by Raunkiær, a method of arrangement which offers the best opportunities for comparison between morphological and biological characteristics, especially those of shoot-structure and branching in relation to the nature of the leaves. Amongst the various types I have given most attention to those contributing to the summer-aspect, i. e. the true Xerophytes, more especially the Fanerophytes and Chamaephytes. This course was adopted because I had more material of these plants at my disposal, and partly because of the special interest attached to the structure of plants with persistent epigeal shoots.

In what follows, the occurrence, foliage and ramification of each species are described, flowering and fructification being also referred to. Some of the descriptions are accompanied by photographs of herbarium specimens, or by sketches some of which are taken from material preserved in alcohol. So far as material permitted, the anatomy of the assimilating organs has been examined. Axial organs which are not assimilatory I have not examined, first because the material was too limited for such an investigation so that any comparative conclusions would be rather doubtful, secondly in order to limit the work, and finally because thorough descriptions of the anatomy of the axial organs of a number of species are given in B. Jönsson's valuable memoir.

## A. Fanerophytes.

The trees and shrubs have been included as far as possible. The descriptions begin with the "dry" plants and proceed towards the more succulent.

### Eremosparton aphyllum F. & M.

A leafless shrub or small tree, generally about 1—2 metres high, rarely exceeding 4 metres. It is at home in the sand-desert where it is one of the most characteristic plants. The roots are long and some are horizontal. According to Palezkij, the roots are capable of producing aerial shoots and although this species might for this reason be cultivated in the plantations, this is not done, because the seeds are destroyed by insects and it does not grow well from cuttings.

*Eremosparton* has slender, pliant branches (fig. 23). The bark is yellow in older specimens, green in younger ones.


Fig. 23. *Eremosparton aphyllum* with fruits. The middle thicker branch is the year-shoot of the previous year, broken at the point. X, X: last year's assimilation-branches, now dead. Beyond these new branches have arisen. June.

The year-shoots have small, scattered, scaly leaves, mere rudiments which can play no part in assimilation. In their axils lateral shoots occur which are smaller than the main shoot and bear scale-leaves. The year-shoots are therefore branched. The lateral shoots (year-shoot branches) bear flowers in the upper leaf-axils.

Fig. 24. A year-old branch of *Eremosparton aphyllum*. A bunch of new assimilation-shoots arising from an old leaf-axil at the base of three dead (strongly shaded) assimilation-shoots.

Before the beginning of the next vegetative period, the ultimate parts of the year-shoot and all its smaller branches die, and only the primary axis (the main shoot in fig. 24) remains, after losing its green bark and assuming the yellow, smooth, hard bark instead. The branches of the year-shoot thus live only through one vegetative period, they are biologically equivalent to leaves and may be termed assimilation-branches. (Rindowsky, see below p. 178).

The next year-shoot arises from the nodes of the primary year-shoot where the assimilation-branches formerly were or where their remains may still be seen, so that serially the new shoots arise below the old ones. During the first year, between the assimilation-branch and the scale-leaf subtending it, one may find the little bud which develops into a new year-shoot (fig. 25). Sometimes not one but several shoots are formed from a node, some of these being vigorous and persistent, while others are short-lived assimilating shoots. It has not been possible to determine whether these serial shoots are lateral shoots on an assimilation-branch of the first year, or on each other, or whether they are lateral shoots on the main shoot of the first year. The new shoots of the third year may again arise from the same nodes. Some of these may be plainly seen to be placed low down on the second year's shoot; others are situated further towards the end of it, at the nodes, in bunches or singly.

*Eremosparton* flowers in May or June. The flowers are red, short-stalked, and being arranged widely apart they form loose racemes. Even at the beginning of June fruits are found on the lower parts of the plant. The flowers developed last do not seem to yield

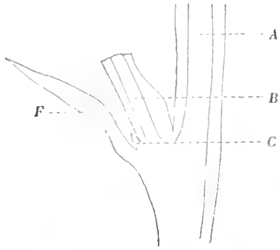


Fig. 25. *Eremosparton aphyllum.* Longitudinal section through part of a year-shoot *(A)*. This bears a leaf *(F)*, an assimilation-branch *(B)* and a bud *(C)*, from which a new branch will arise next year. × 11.


Fig. 26. *Eremosparton aphyllum. A*, Transverse section of year-shoot. Sclerenchyma shown black; palisade-tissue hatched in one direction; Vascular bundles cross-hatched. Dead hairs cover part of the surface. *B*, Detail of *A* : *S*, storage sheath; *Phl.*, Phlœum; *Camb.*, Cambium; *Vas.*, Vessels. *C* & *D*, Hairs; *D*, shows a stoma *(St)*, and *K*, inner limit of the cuticularised layer. *A*, × 47. *B—D*, × 230.

fruit, probably they are burned by the heat of summer. The fruit is a crescent-shaped, one-seeded, woolly-haired pod about 1 centimetre in length and easily transported by the wind (see fig. 23).

The anatomical structure of the assimilation-shoots and the year-shoots is very similar, but the former have no cambium; Fig. 26 shows the inner structure. There are 8 or 9 grooves within which the palisade tissue lies in V-shaped tracts bounded towards the interior by a row of storage-cells. At the apex of each ridge there is a mass of collenchyma and deeper-seated is a band of sclerenchyma of which another band is found outside each vascular bundle. Stomata only occur in the grooves, they are slightly sunk and hidden by scale-hairs.

### Calligonum Caput Medusae Schrenk.

A shrub or small tree, 1 to about 3.5 metres high and leafless. Its home is the sand-desert and it is extensively utilised in the plantations along the railway; 90 p. cent. of the cuttings strike root, and year-old plants from the nurseries always transplant successfully. Comparatively speaking the plant is distinctly green, but in this respect it is far behind the *Salsola* species.

The year-shoots are long (about 40 centimetres), thin and jointed. The leaves are scale-like and membranous, and form a sheath round the stem (Polygonaceae). All or most of the leaves subtend branches, the upper ones often flowers, the lower ones annual assimilation-shoots. Rindowsky (1875 l. c.) drew attention to the difference in *Calligonum* between "rami assimilationis" and "rami lignosi", see also B. Jönsson (l. c. p. 18). There is, however, no very hard and fast limit between the two sorts of branches. The outer part of the year-shoot dies away after the cessation of the vegetative-period, generally together with the branches. New year-shoots arise singly or several together from the leaf-bases of the old shoots, sometimes on branches several years old (see figures 11 and 27). Where several are present together, some are generally more strongly developed than the rest, and these become rejuvenescence-shoots; the others (secondary shoots) fall off at the end of the summer. They often bear flowers (fig. 28). The same leaf-bases may

Fig. 27. *Calligonum Pallasia.*
Year-shoot from last year with bunches of new, flowering branches. May.


Fig. 28. *Calligonum Caput Medusae.* June.
*A*, The horizontal two-year-old branch bears two year-shoots of last year, with the upper parts dead (strongly shaded); at their bases bunches of new shoots arise, while others are borne on more distal still living parts. The shoots now bear fruits, most of which have fallen. *B*, a fruit with the setae cut away from the side in view. *C*, a fruit of *Calligonum Pallasia.*

produce annual assimilation-shoots several years in succession and by degrees a low cushion is formed from which others arise. Even nodes bearing year-old branching shoots, may again be seen to produce new shoots.

*Calligonum Caput Medusae* flowers in June. The flowers are small and reddish, the fruits (figures 11 and 28) are very characteristic (see above p. 88), they are easily transported by the wind and are found massed together in sheltered places in the desert.

As regards anatomical structure we refer to fig. 29; there are sclerenchyma bands below the epidermis 14 in number, two palisade layers of which the outer one is very loose, an

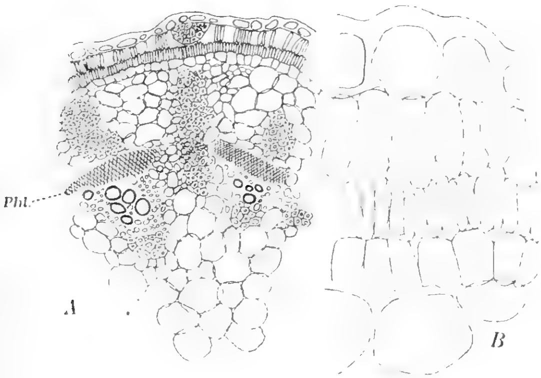


Fig. 29. *Calligonum Caput Medusae.*
*A*, Part of transverse section of a young branch: *Phl.*, Phloem, × 71. *B*, Detail of *A*: epidermis, two palisade layers, starch sheath and outer cells of the water-storage tissue of the cortex. × 250.

amyloid or starch sheath, and the inner bark formed of bands of sclerenchyma between which is aqueous tissue; this contains much tannin. Other bundles of mechanical tissue occur between the vascular bundles and between them and the pith. The pith is a large-celled, water-storage tissue containing tannic acid. The stomata are sunk. Volkens, who (p. 142) described the anatomy of *Calligonum comosum* found under the epidermis a layer of loose, thin-walled cells, but only one palisade layer. B. Jönsson, who examined an undetermined species from Turkestan, found on the contrary a thick-walled hypodermal layer, and only one palisade layer.

With *Calligonum Caput Medusae* are related the other species of this genus which grow in Transcaspia, see the plant-list p. 154. Borszczow has described many species; as to the systematic value of these I have no definite views. Variations are especially common in the fruits, but there is also considerable variety in height and in usefulness as sheltering plants. Palezkij states that most of the species have a tendency to lose their branches in summer, a result of the heat of the sun. This shows itself first as rust-coloured spots which gradually make their way through the branches. *Calligonum eriopodum* is the species which suffers least from this injury, it is also of high stature and being hardy in several respects it is more extensively used in planting shelter-belts than the other species. *Calligonum arborescens* is also employed on account of its size, it is said to attain a height of 6 metres.

Calligonum plants are raised in the nursery; one-year-old specimens are about one metre high. They can only endure water as seedlings during the cotyledonary stage.

Under natural wild conditions *Calligonum Caput Medusae* and *C. Pallasii* (= *Pterococcus aphyllus*) seem to be the most common. The fruits of the latter have eight broad wings instead of tufts of setae (fig. 28 C). All the species have thin assimilation-branches.

### Ephedra alata Dcne. (= *E. strobilacea Bge.*).

I have seen this plant in the sand-desert as a shrub one foot high, but it is said to become much higher. Part of a stem I saw was 14 centimetres in circumference.

The leaves are membranous and sit three and three together at the joints. The year-shoots may grow long, they are placed laterally on the previous year-shoot, and arise one, two or three together. Some nodes may for several successive years be the starting point of new branches which thus form bunches. My notes include no other observations on the shoot-structure.

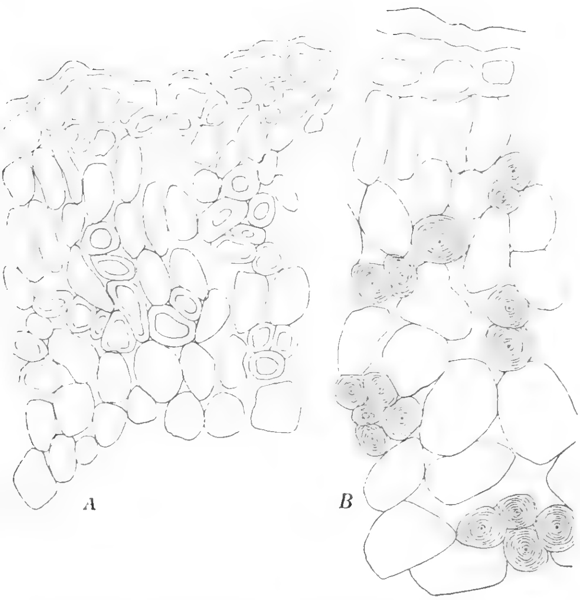


Fig. 30. *Ephedra alata.* *A*, Transverse section of bark of a young branch. *B*, T. S. of a year-old branch. × 230.

The anatomical structure of the green bark is briefly described by VOLKENS (p. 151), and ROSS (p. 17) describes an undetermined *Ephedra* species. Fig. 30 shows the assimilating cortex of a young and of a somewhat older branch. The outer wall is very thick with a strong cuticularised layer. The palisade cells become more rounded towards the interior and at the same time contain less chorophyll. Below the epidermis and in the deeper layers there are numerous sclerenchyma-cells which traverse the stem longitudinally; in the older branch their lumen has almost disappeared.

Ammodendron Conollyi Bge. (The Sand-Acacia).

This species is found in the sand-desert and prefers deep sand. It attains a height of 2—4 (—8) metres and is a shrub (on the more stationary soils) or more frequently a slender and in most cases a one-stemmed tree. The hairiness of the leaves gives it a whitish grey appearance, the crown is very open and casts only a light shade. The ends of the branches are pendulous, long, thin, pliant and whip-like. Two branches are shown in Fig. 10. Palezkij has measured roots 19 metres in length.

The leaves are scattered and pinnate with two linear-lanceolate leaflets densely coated with silky hairs. The rachis sometimes ends in a slender thorn one centimetre long, which frequently persists till the next year. Stipules are absent or represented by two small spines.

The distal part of the year-shoot probably always dies away before the next vegetative period, also when it is not an inflorescence, which is, however, generally the case (see fig. 10). The succeeding year-shoot arises from the middle part of the first year-shoot. Vigorous year-shoots may be branched, but there is no indication that we have here assimilating branches lasting only one summer. The plant has likewise true leaves.

The flowers are purple and are arranged in terminal racemes. Only the lower flowers in a raceme set fruit; these are also the earliest to develope (April): the later flowers are dried up by the heat of summer. The fruit-bearing branches in fig. 10 show the inflorescence bare above the fruits, and it is seen how few fruits there are compared with flowers.

The fruit is a yellow, one-seeded, indehiscent, winged "pod" which ripens in May. When ripe it is spirally twisted and this with its lightness enables it to be easily carried off by the wind. The seeds are very hard. According to Palezkij only 2 per ct. of the fresh seeds germinate but they can all be made to do so by cutting the skin. The leaves are isolateral in structure. The epidermis is thick with sunk stomata on both surfaces. Its coating of unilateral hairs is shown in fig. 31. There are about three layers of palisade cells on each side and hardly any spongy mesophyll. The veins have sheaths of hard bast.

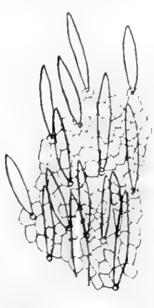

Fig. 31. *Ammodendron Conollyi.* Epidermis with hairs. × 53.

As to the other *Ammodendron* species, *A. Karelini* is closely related to the species just described. *A. Siewersii*, which can hardly be distinguished from *A. Lehmanni*, is more thorny, the petiolar rachis-thorn being longer, while the stipules are always present as thorns. *A. Eichwaldii* is a stunted, closely branched shrub with two pairs of leaflets. Biologically these species are closely related.

### Ammothamnus Lehmanni Bge.

This I have not examined in its habitat, and only know from herbarium-specimens and descriptions. It is a shrub scarcely attaining the height of one metre. The leaves which have small linear stipules are long and pinnate with 7—13 leaflets. These are obovate, cuneate at the base and broad, but small (less than one centimetre long). They are green, but like the year-shoots are provided with stiff hairs. The distal part of the year-shoot dies away (always?), and the new shoots arise from the apex of the surviving part. The white flowers are arranged in a raceme, they come out in April. The fruit is a long velvet-haired pod, spirally twisted, and containing many seeds.

The leaves are isolateral in structure with stomata on both sides, 3—4 layers of short palisade cells on each side and almost devoid of spongy mesophyll.

### Smirnowia turkestana Bge.

A shrub attaining the height of about 1 metre. It is a true desert-plant and is most frequently found on clayey soil. The outer bark peels off the older branches in long shreds and then the branches turn yellowish. A coat of hairs makes all the younger parts look greyish. The leaves are simple and almost circular with a diameter not exceeding 1,5 centimetres. As a result of the petioles turning or bending, the leaves assume a vertical position.

The year-shoots are branched, many of the axils bearing rather short leafy branches which only live through one vegetative period; they are thus true assimilation-branches. The distal part of the year-shoot itself is also annual; sometimes only a very short piece at the base survives. The new year-shoots arise on the surviving part beyond and below the dead assimilation-shoots, their buds may as in *Eremosparton* be found the year before; several successive series of new year-shoots may arise from the same place, so that they are arranged in bunches.

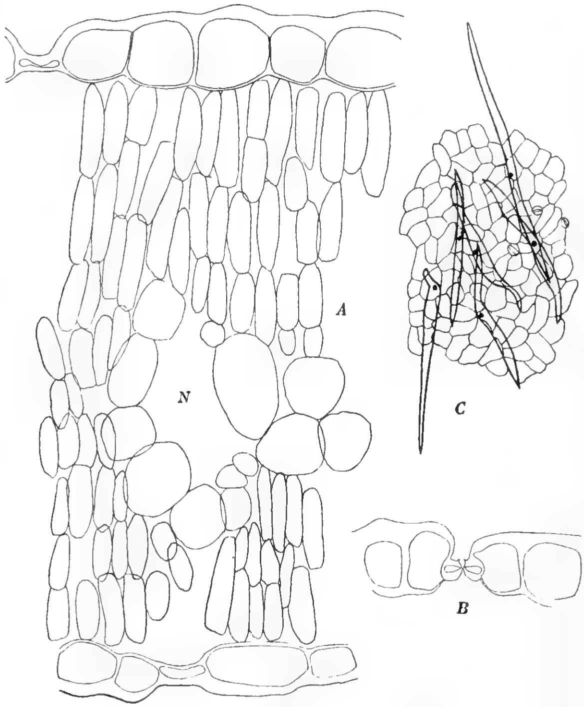


Fig. 32. *Smirnowia turkestana.* *A*, Transverse section of leaf: *N*, vein. *B*, a stoma. *C*, epidermis with bipartite hairs. *A* and *B*, × 220; *C*, × 53.

The flowers are arranged in few-flowered racemes which are placed laterally on the year-shoots.

The fruit is an inflated hairy pod 2—3,5 centimetres long, it contains about 3 seeds which are hard-shelled, flat and reniform; as the pod is swept along by the wind, the seeds may be heard rattling inside.

The structure of the leaf is isolateral (fig. 32) with stomata on both sides, and 3—4 layers of palisade cells filled with starch on the upper side and about the same number on the lower side. Round the veins, which are numerous, there are rings of large translucent cells between which there are very narrow bands of chlorophyllous tissue.

Astragalus unifoliatus Bge.

A shrub attaining a height of until 0,7 metre. It is strongly branched, the branches being spread out and crooked. The bark of older branches shows a network of fibres. The green parts are densely coated with greyish or whitish hairs. The leaves are small and pinnate with four leaflets at the beginning of the vegetative season, but later they are ternate or only single-leaved. Towards summer most of the leaflets fall off and the rachis remains like a wooden peg 0,5—2 centimetres long, later during the summer it likewise withers. The leaflets are elliptical or lanceolate and small, generally no more than a centimetre long, but occasionally they may be 2 centimetres. The stipules are connate, clasping the branch.

Part of a young year-shoot is shown in fig. 33 where the branching is seen. Sometimes the branches again produce lateral shoots. These branches are assimilating shoots which do not persist. In their place one or more new shoots will arise next year so that here again, sometimes in a very marked degree, we find branches arranged in bunches.

Fig. 33. A year-shoot of *Astragalus unifoliatus* (red.) June.

The small red flowers which appear in May or June are arranged in small terminal racemes. The fruit is a pod, 6 mm. in length, densely coated with white hairs and containing 1—2 seeds.

The leaf is isolateral in structure. The epidermis is covered with bipartite hairs on short bases, and has stomata on both sides, not sunk. There are 2—4 layers of palisade cells (filled with starch) on each side, and 1—3 layers of translucent cells surround the veins. The larger veins have sclerenchyma on the phloem side. Sometimes, though rarely, lignified bast-cells issue from this bast-sheath and traverse the palisade layers till they reach the epidermis (fig. 34). "Speichertracheïden" are found in great numbers in the mesophyll. Among the palisade cells are a few translucent, globular bodies which seem to consist of mucilage.

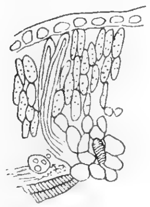

Fig. 34. *Astragalus unifoliatus* Part of transverse section of leaf with sclerenchyma and a "Speichertracheïde". × 71.

The green bark of the young branches has about 4 layers of short palisade cells below a single-layered, hairy epidermis. Bast bundles are found outside the vascular bundles.

Closely related to *Astragalus unifoliatus* are a number of other shrubby species of *Astragalus* e. g. *A. Ammodendron*, *paucijugus*, *hyrcanus*, *villosissimus*, *macrocladus*, *brachypus*, *squarrosus*. All belong to the section *Ammodendron* which is characterised by connate, clasping stipules, by a small inflated hairy and few-seeded pod and by the frequency of persistent petioles. The section belongs to the sub-genus *Cercidothrix*, characterised by bipartite hairs. *A. brachylobus* with the same type of fruit, and *A. sleroxylon* with linear, curved pods also belong to this group.

All the species named are early flowering shrubs or dwarf shrubs with a few small and hairy leaflets. In some of them the petiole persists till next summer though dead, thus in *A. paucijugus*, *hyrcanus*, *villosissimus*, *squarrosus* and perhaps others; in the first-named it attains a length of about 30 centimetres. The shoots are often curved and the bark in older branches is fibrous. In some of them the branches are arranged in bunches *(A. Ammodendron, hyrcanus* and perhaps others).

My knowledge of these *Astragalus*-species is mainly derived from literature and herbarium material.

## Halimodendron argenteum D. C.

A shrub attaining a height of about 2 metres, which prefers clayey soil. It is also common in the neighbourhood of rivers and is often met with in oases, by roadsides and such places. It has long, horizontal roots from which aerial shoots issue at long intervals.

Fig. 35. *Halimodendron argenteum.* Part of transverse section of a year-old branch: *P*, Pith; *V*, Wood; *Phl.*, Phloeum; *C*. Cork. The black part is sclerenchyma. The largest sclerenchyma-band belongs to a leaf-rachis thorn, the next largest to a stipular thorn. × 24.

The year-shoot seems to become completely lignified and to remain alive throughout its whole length. The primary bark is green, the secondary brown. Within the bark and surrounding the branch there is a circle of six large bast-bundles (fig. 35), three larger ones on one side corresponding to the nearest leaf above with its two stipules, and three smaller ones on the other side corresponding to the next but one set of leaves higher up. All the bundles disappear at a distance about $1^1/_2$ nodes below the leaf from which they issue. The lower part of each node of the stem has therefore only three bast-bundles. The rachis of the leaf and the stipules form thorns, and the larger bundles of sclerenchyma in the bark are the downward prolongations of the thorns. The intervening spaces are not quite regular as the leaf-arrangement is a $^2/_5$ spiral. The structure of the bark (and the pith) has been described by B. Jönsson (p. 31) who has found mucilage-cork and air-lacunæ; I have not examined these. Jönsson calls the persistent leaf-rachis a thorn-branch bearing leaves arranged in pairs and accompanied by secondary thorns. The real condition is that the leaves are pinnate with four cuneate leaflets. The rachis remains as a thorn which may attain a length of more than 4 centimetres, and this is accompanied by two smaller stipular thorns. The

Fig. 36. Branch of *Halimodendron argenteum*. A new year-shoot is seen at the top of the left-hand branch. Other flowering (now fruit-bearing) short-shoots arise from each leaf-axil on the shoot of the previous year. End of May.

leaflets are silvery haired and motile since by curvature of the petiole they can assume a vertical position.

On the year-old shoot (see fig. 36) short-shoots arise in the leaf-axils, they bear flowers two together on a slender, furcate stalk. These open in April or May, and by the end of May ripe fruits occur. The fruit is a hard, few-seeded, inflated pod, 1—2 centimetres long, placed on a short gynophore (fig. 36). Owing to its lightness, hardness and roundness the fruit may roll a long time before the wind without being injured.

The anatomy of the leaves has been described by J. WEYLAND and B. JÖNSSON. I have found the same structure as these authors, but like WEYLAND I have not seen the hypoderm on the underside of the leaf which JÖNSSON figures. The leaf is isolateral, with about three layers of palisade cells containing starch on each side, a translucent tissue of rounded cells, and strong sclerenchyma bands along the veins. On each side the stomata are slightly sunk. The leaf, like the bark, contains numerous tannin cells lying almost exclusively amongst the palisade cells, but different in shape.

### Ewersmannia subspinosa (Fisch.) Fedtsch.

A low shrub occurring at least in the northern part of the territory dealt with here, but which I have not seen growing. The bark of the branches is fibrous. The leaves are two-rowed, pinnate with 9—11 leaflets half a centimetre long; they have small membranous stipules each of them subtending two thorn-branches one of which is generally longer than the other. The flowers arise from the longer thorn-branch which attains a length of 3—4 centimetres, they appear in May. The fruit is a few-seeded, flat pod with one or more S curves; it is carried swiftly by the wind.

### Prosopis Stephaniana Spr.

A small strongly branched shrub which attains the height of about half a metre. It seems to thrive best on sandy clay.

The leaves are bipinnate with about 10 leaflets on each pinna, these are 3—9 mm. long, oblique, hairy and when the sun shines they are directed upwards. Older branches have white bark and are covered with prickles.

The year-shoot is branched. During the same year each axil gives off either an inflorescence or a branch, or two branches, or a branch and an inflorescence. The longest year-shoot branches are about 15 centimetres long at the beginning of June and only the outermost 2 centimetres are not fully lignified. The year-shoot branches bear many leaves which often subtend inflorescences, but apparently no new branches. The year-shoot branches cannot be termed assimilating shoots as they are persistent.

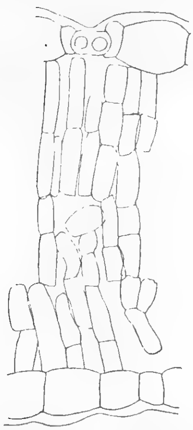

Fig. 37. *Prosopis Stephaniana.* Section through the leaf. × 230.

*Prosopis* flowers from May to July. The inflorescences are long racemes with small flowers. The fruit is a fleshy pod 3—4 centimetres long.

The leaf is isolateral in structure (fig. 37). The epidermis contains tannin and has stomata on both surfaces; 6—7 layers of palisade cells fill up the whole leaf. The veins have bast sheaths on both sides. "Speichertracheïden" are present.

## Zollikoferia acanthodes Bois.

is said to be a stunted thorny shrub with forked angular branches and with thorn-like short-shoots. A few ovate or oblong leaves occupy the base of the branches, they are thickly coated with white spines and soon fall off. (From Boissier fl. orientalis.)

## Atraphaxis spinosa L.

A strongly branched shrub never exceeding a height of one metre. The leaves are shortly petiolate, circular-ovate, rather thick and about one centimetre long. The bark is white. The distal part of the year-shoot dies before the next vegetative period but persists as a point often thorny. The year-shoots may be branched and are often twice branched. The inflorescences are short racemes placed on branches of secondary order. Under unfavourable conditions, for instance on rocky ground, no long-shoots are formed but only short-shoots. (A. *compacta*).

The white or reddish flowers appear in April or May. The fruit is a nut enclosed in the three-winged perianth.

### Salsola Arbuscula Pall.

A characteristic and very variable plant. Its varied aspect was described and illustrated so long ago as 1833 by Eichwaldt. On clay it is a stunted, twiggy, stiff shrub with short shoots and hard stiff leaves. But where it occurs on moving-sand it may become a small tree with long pliant shoots and leaves. In the sand-desert it varies in pliancy and hardness, in length of shoots, and in hairiness of shoots and leaves. It has very long roots which in the dune-valleys may be seen exposed and stretching from dune to dune, thus showing that some at least are horizontal.

The best developed form (*var. angustifolia* Fzl.) will be considered first (fig. 12.) As a tree it attains a height of 3—5 metres, with foliage greener and denser than that of any other desert-plant in these parts; the stem is light-coloured and elegant. It appears thus on the moving-sand, and here also may be found specimens with fasciated branches, a character which often accompanies luxuriant growth.

*Salsola Arbuscula* is one of the most important plants for sand-binding purposes along the Transcaspian railroads. Small pieces of the stem are stuck into the sand and of these 100 per ct. germinate, but many of them are injured by lepidopterous larvæ. In the course of two years the plants attain a height of about 3 metres. The hardihood of the plant in withstanding sand-drift has already been considered (p. 88).

In vigorous specimens from the sand-desert the leaves are 7 centimetres long or rather longer. They are cylindrical almost filiform, and pendulous. The year-shoots may attain the length of half a metre, they are always branched, often twice branched. The bark is green at first, but soon turns white and glossy.

The distal part of the year-shoot often dies away before the next vegetative period. The new year-shoots arise close up to the dead part, the lower part of the old year-shoot being branchless.

The year-shoot generally bears flowers towards its apex; a flower is placed in each axil and the length of the inter-nodes decreases upwards. In less luxuriant plants the branches are formed high up, and arise in the axils below the lowest flowers. These branches have rather short nodes, bear flowers in every leaf-axil and die away after the ripening of the fruits. They are thus annual assimilating as well as flowering shoots. In more vigorous plants the branches of a year-shoot are long, drawn out and zigzag, they are also numerous as they arise from almost every leaf-axil on the year-shoot (fig. 12). In the most strongly developed specimens the branches of the year-shoot are lignified, and are then scarcely assimilating shoots but rejuvenescence shoots. They may bear flowers in each leaf-axil or only in the upper ones, and as a rule they have flowering branches towards the apex.

The year-shoot branches of secondary order are similar to the primary branches described above for the more feebly developed plants; they are flower-bearing, with short inter-nodes, and quickly perish.

The year-shoot branches which bear flowers throughout their whole length — such as those in fig. 12 — live, to all appearances, only one vegetative period, and one often finds dead ones bearing the scars of fruits, they are thus assimilating and flowering shoots; on the other hand, the year-shoot branches, which bear leaves at the base, become so strong and thick that the lower part probably survives the winter. The tips of the branches, however, which in September are soft and still growing, probably die away like the tips of the main shoots.

The small form of *Salsola Arbuscula* which prefers a clay soil is a dwarf shrub attaining a height of 30—50 centimetres; a branch of it is seen in fig. 38. The leaves are 1 or perhaps 2 centimetres long, thick and erect, fresh green and often coated with fine setaceous hairs (comp. pp. 70 &

Fig. 38. *Salsola Arbuscula.* Clay-desert form. June. (The upper branches are broken and bent to one side, and do not show the natural habit).

88). The year-shoots are erect, stiff, 3 to 7 centimetres long and frequently bear flowers in the upper axils. The distal flower-bearing part of the year-shoot generally seems to die away, though it is lignified and remains as a dry and almost thorny point. The next series of year-shoots arise lower down on the older one, and as these in turn lignify and die away at the tip, a system of short stiff branches is produced spreading in all directions. New shoots may also arise on branches several years old.

The flowers in *Salsola Arbuscula* are inconspicuous as in other Chenopodiaceae. Some open in June and July, but the

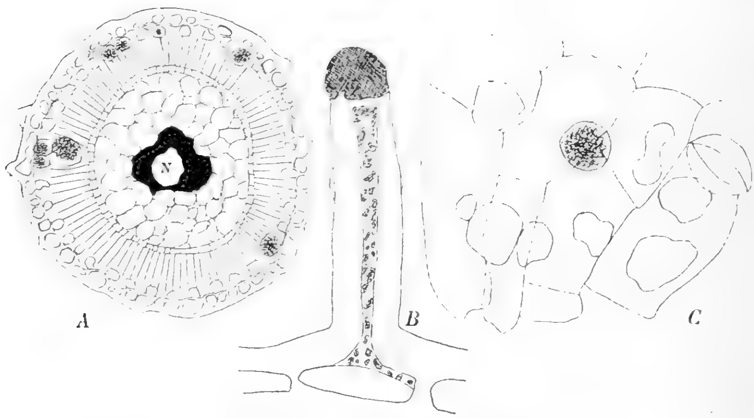


Fig. 39. *Salsola Arbuscula*.
*A*, Cross section of a leaf: *N*, vein; sclerenchyma shown black. *B*, Hair. *C*, Surface view of a leaf: beneath the epidermal layer the cells of the crystal-layer are shown, one of them with a group of crystals. *A*, × 47; *B* and *C*, × 202.

majority in August or September. The flower is surrounded by three leaves; in front a subtending foliage leaf with a spoon-shaped base, and at each side a broad thick green prophyll or bract, sometimes scale-like, and sometimes with a short blade. The perianth-segments are thick-walled on both surfaces; before and after anthesis they fold together forming a pyramid in which the stamens and carpels are enclosed. Such is the protection of these late-expanding flowers. The fruit (a nut) remains enclosed in the perianth the five parts of which form a broad horizontal wing. The fruit is not ripe till

October. Being light and provided with wings it is easily carried along by the wind.

The leaves are centric in structure, of the type so often described, with a palisade layer and a starch sheath towards which the veins pass obliquely through the central aqueous tissue. (See VOLKENS p. 138). The vein is surrounded by sclerenchyma (fig. 39).

Between the epidermis and the palisade cells is a layer of cells with very thin walls and large intercellular spaces (fig. 39 A and C). Some of them contain clusters of crystals, also described and illustrated by VOLKENS (tab. XII, 3). This crystal-layer appears to be distinct from the epidermis but it may be compared with the corresponding one in *Haloxylon* (WARMING 1897 p. 218). where it is included amongst the epidermal tissues, and in both cases it may probably be regarded as a hypoderm; there must be air between its cells.

In *var. longifolia* the leaves are perfectly cylindrical; in the stunted form they are often slightly concave or flat on one side.

## Salsola subaphylla C. A. M.

A shrub or small tree attaining a height of about 2 metres. It somewhat resembles the last species, but does not attain the same height, its foliage is less dense, and it sets fruit earlier. According to PALEZKIJ its life-period does not at the most exceed four years, hence it is not employed for sand-binding purposes. It is by preference a sand-plant and attains its highest development where the sand is moving. On clay or stony soil it appears as a small shrub of about 30 centimetres high.

The leaves (fig. 13) are thick, cylindrical or half-cylindrical and attain the length of about two centimetres.

The year-shoots are branched, sometimes twice. The distal parts of the year-shoots and branches are in the month of July covered with flowers (fig. 13) subtended by scale-like bracts; the fruit-bearing branches may be quite hidden under the broad wings of the numerous fruits.

After the cessation of the vegetative period the tips and all the branches of the year-shoots generally die; the new year-shoots arise on the outermost living part of the old

Fig. 40. *Salsola rigida.* Branched and flowering year-shoots of the present year arising from the bases of older branches of which the dead tips are seen. June.

ones, beyond the year-shoot branches of last year, and from buds which may be seen the preceding year.

The flowers and fruits are very similar to those of the last species.

The anatomy of the leaf is also similar to that of *Salsola Arbuscula,* but the crystal-layer below the epidermis is absent.

### Salsola hispidula Bge.,

which I have not seen, is according to descriptions very much like S. *subaphylla.*

### Salsola rigida Pall.

A stumpy shrub attaining the height of 30 to 50 centimetres, and almost an undershrub. It is one of the characteristic plants of the clay-desert (p. 69). The leaves are cylindric, and although the lower ones disappear in July, foliage leaves are present through the whole summer. The whole plant is hairy and grey.

The year-shoots, which may be 30 centimetres long, bear flowers in all the axils at their extremities and here in this region there are generally a few curved, ascending branches (fig. 40). In the axils lower down, vegetative short-shoots are frequently present, which probably next year develope into rejuvenescence shoots. The distal parts of the year-shoot and the flowering branches die away before the next vegetative period.

The flowers are hidden between three bracteoles and open in June or July; the fruits are of the ordinary *Salsola* type and ripen in the autumn.

The anatomy of the leaf is the usual type. Central aqueous tissue, palisade cells with starch-sheath towards which veins pass from the midrib; the hypodermal crystal-layer consists of scattered thin-walled cells.

### Salsola laricina Pall.,

which I have not seen alive, resembles the preceding species as regards ramification.

### Salsola verrucosa M. B.

A shrub attaining the height of about one metre, and most frequently found in the clay-desert. The cylindrical leaves soon fall off, and during summer the main assimilating organs of the plant are the subtending leaves and bracts of the flowers which as fleshy, spoon-shaped scales, three together enclose the flowers. The plant is thus what we have called (p. 71) a bracteole-succulent. Small globular short-shoots with 3 to 5 leaves are sometimes seen replacing the flowers.

The year-shoots are branched, sometimes twice branched. The branches, especially those of secondary (or tertiary) order bear flowers so close together that the branches are hidden. The tips of the year-shoots and all the secondary branches die away before the next vegetative period.

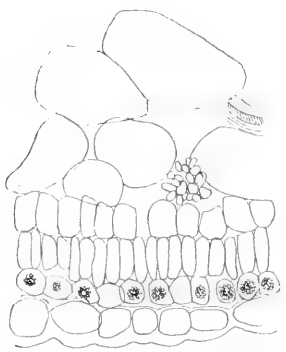

Fig. 41. *Salsola verrucosa.* Transverse section from the underside of a bracteole. × 202.

*Salsola verrucosa* flowers in summer. The fruit is of the ordinary *Salsola* type.

The anatomy of the foliage leaves was not examined. The bracteoles have green tissue of the usual type on the outer (under) side (fig. 41). On the inner (upper) side the aqueous tissue is bounded by a thin epidermis.

### Haloxylon Ammodendron (C. A. M.) Bge. (Saxaul).

A shrub or tree thriving best on sand with a subsoil of clay or lime. It may become very old (see B. Jönsson p. 8) and may attain considerable dimensions, but large specimens are rarely found as they are cut down for firewood by the nomads (comp. above pp. 89 and 126). I have seen a thick-stemmed tree which I estimated at 7 metres high. Aitchison records a tree 14 feet high with a stem 12 feet in circumference. The wood is known to be hard and heavy, and old stems have deep irregular furrows. The roots are long, Palezkij says about $10^1/_2$ metres and more, and Jönsson states that Saxaul has both deep-seeking vertical and long horizontal roots. The latter, according to Antonow (p. 29), can form aerial shoots.

On account of its slow growth Saxaul is not much employed in sand-binding plantations. Yet, as stated above (p. 89), Lipsky denies that the growth is very slow.

The leaves are reduced to small scales arranged in pairs opposite each other and united together. The young branches are long, slender and drooping (see for instance Bessey, pl. 10, Lipsky 1911 pl. 4 and 5).

The year-shoot is green, its bark containing the only assimilating tissue of the plant. Most of the shoots are set together towards the apex of the previous year-shoot, the distal part of which frequently dies away. Sometimes two shoots of the same age are seen in the same leaf-axil, one outside the other, but the outer one is generally more feebly developed, and it is improbable that both of them ever persist. The year-shoots are branched and they bear flowering short-shoots (see fig. 14).

The flowers are inconspicuous and open in May. Each flower is protected by its subtending leaf-sheath and by two bracts. The perianth, on the contrary, is small before the anthesis but afterwards it grows larger. The fruit is a small nut loosely enveloped by the broad-winged perianth, and is ripe in October.

The anatomy of *Haloxylon* has been described by Gernet, Gheorghieff, Warming and B. Jönsson. The structure of the assimilating shoot I found to be quite in accordance with that described and illustrated by Warming (1897, p. 217), it is of the ordinary centric type. The epidermal tissue is three-layered. Assimilating tissue is also said to be present in the secondary bark. (B. Jönsson p. 7). As regards the mucilaginous cork in the bark mentioned by Jönsson, we refer to his memoir.

### Halostachys caspica (Pall.) C. A. M.

A shrub which belongs to the clay- and salt-desert. Under specially favourable conditions it may attain a height of two metres, but in the desert it does not as a rule exceed half a metre. The shoot is of *Salicornia* type with reduced scale-like opposite leaves. The position of the branches is also regularly opposite (decussate or brachiate).

The year-shoot ends in a large paniculate inflorescence which is still present next year in a more or less dead condition. Underneath the inflorescence the year-shoot bears many branches; some of these are assimilating shoots which fall off before the next vegetative period, while others are persistent rejuvenescence shoots. New assimilating shoots arise both from the old and the new year-shoots in places where vegetative or inflorescence-branches were formerly present, and sometimes two branches issue from the same leaf-axil.

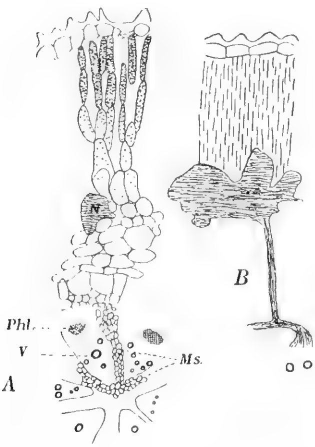


Fig. 42. *Halostachys caspica.* *A*, Part of transverse section of an assimilating branch: *N*, vein; *Phl.*, phloem; *V*, vessel; *Ms*, medullary rays. — *B* shows a vein leading from the central cylinder to the palisade tissue. × 47.

The flowers are small, and sit three together in the axils of peltate bracteoles; they open in July. The fruit is a nut ($^3/_4$ m. m. long) enclosed in the enlarged perianth; it may still be found on the plant in the following year.

The green assimilating bark is enclosed in a one-layered, strongly papillose epidermis (fig. 42). There are about 5 layers of loose palisade cells of which the outermost contain the greatest, the innermost the smallest number of chlorophyll grains. Underneath the palisade cells there is no starch-sheath, but numerous veins are spread out there (fig. 42 B.) which lead to the central cylinder through the adjacent aqueous tissue.

The anatomy of the wood has been described by Gernet and Gheorghieff.

Halocnemum strobilaceum (Pall.) M. B.

A stumpy, often decumbent shrub which grows on clayey soil rich in salts.

The year-shoot has a thick bark containing aqueous tissue and green tissue, and is covered with opposite, reduced leaves, united in pairs to form a sheath. Almost every axil on a year-shoot is occupied by a branch or short-shoot shaped like a more or less elongated bud or a short catkin. An illustration of a branch is given by Volkens in Nat. Pflanzenfamilien III (Chenopodiaceae) fig. 35. In fig. 43 is

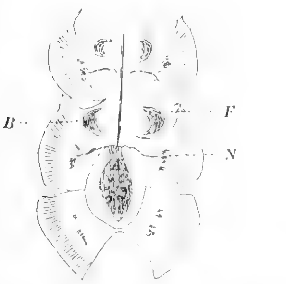


Fig. 43. *Halocnemum strobilaceum.* Longitudinal section through part of a short-shoot: *A*, Base of a lateral shoot which projects forwards (towards the reader); *B*, Bud; *F*, Base of a leaf; *N*, Vein; the short line-shading indicates palisade tissue. × 12.

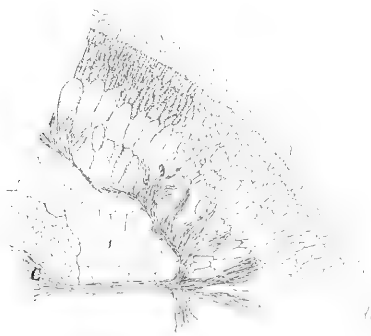


Fig. 44. *Halocnemum strobilaceum.* Part of a transverse section of an internode. A vein from the central cylinder *(C)* branches out in the inner green tissue. In part of the green tissue the number of chlorophyll-grains is indicated. × 71. (Slightly diagrammatic).

represented a longitudinal section of part of such a short-shoot. As stated by Warming (1897, p. 206), the leaves are somewhat peltate. Sometimes they support three buds (B. fig. 43), which are presumably flower-buds as the leaves on many short-shoots each subtend a triplet of flowers in the autumn. The flowering short-shoots die after the ripening of the fruits, and along with the distal part of the year-shoot drop off before the next vegetative period.

Beyond the dead short-shoots, new shoots are formed next year, often several together, either elongated year-shoots or new short-shoots.

The anatomy of the leaf has been described by Warming

(1897, p. 206). Transcaspian specimens correspond with his description, but I have not found stone-cells in the basal part of the leaf, nor the layer of short subepidermal cells recorded by Warming. In the leaf, as in the bark of young stem-internodes (fig. 44), there are three (or four) layers of small palisade cells which inwards are abruptly replaced by larger ones containing only a few chlorophyll grains. These adjoin a system of veins which branch out in great numbers through a certain zone of the bark or the mesophyll, and only within this zone is there a perfectly translucent aqueous tissue; this last is divided into two parts, an outer zone of large cells, and an inner zone of smaller cells.

The epidermis is thick and papillose, and the stomata are sunk.

### Suæda microphylla Pall.

This species is known to me only from descriptions and herbarium material. Perhaps it should be considered as a chamaephyte as the stem is said to be decumbent. The stem may attain a thickness of 4 centimetres. The branches are long and widely spread out. The year-shoots are branched both in the inflorescence and in the vegetative portion, sometimes twice branched.

The leaves are typical *Suæda*-leaves, rather short. The plant flowers in July and the fruit is ripe in October.

### Suæda physophora Pall.

This plant is said to be a shrub about one metre high, but I have not seen it.

### Lycium ruthenicum Murr.

A shrub from 10 to about 60 centimetres high, spiny and with outspread branches. It is a salt-bush not generally found on sand.

Under specially favourable circumstances the year-shoots may attain a length of more than 60 centimetres, but as a rule they do not exceed 30 centimetres. They have a white bark, and are usually branched, branch-thorns arising in the leaf-axils; the leaf-base is thick and persistent. The branch-thorns are generally short, about 1 centimetre long, and often bear only two leaves placed low down near the base. The branch-thorns may, however, become longer and bear several pairs of leaves. The flowers arise from the base of the branch-thorns either in the axils of the two low-set leaves, or next year they form part of the rosette-shoots which appear in the axils of these leaves. On long branch-thorns the flowers may also arise higher up.

The year-shoots generally terminate in a thorn; their distal part always seems to die away.

They flower during summer.

The leaf is isolateral in structure. There are stomata on both sides, generally flush with the surface but some of them are slightly raised and below them is a group of cells, 2—4 on each side, which are round and devoid of chlorophyll; throughout the rest of the leaf these cells are wanting (fig. 45). The palisade tissue is 2—3 cells thick, and towards the interior it merges gradually into a large-celled aqueous tissue containing a slight amount of chlorophyll. The veins which lie a little nearer the upper side than the lower, have bundles of bast on both sides and here are found a few perfectly translucent cells.

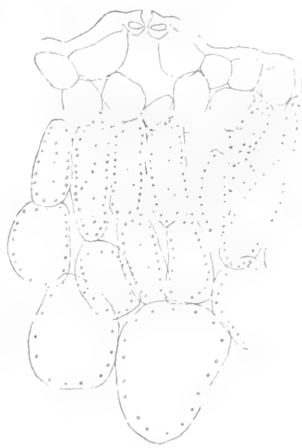

Fig. 45. *Lycium ruthenicum.* Part of leaf in transverse section. × 203.

## Nitraria Schoberi L.

A shrub, barely one metre high which prefers the clay-desert. The bark is white, the leaves are thick and spathulate with short hairs, and are placed 2—4 together on a small cushion, with small scales between them. The leaves and the scales surround a bud. According to Velenowsky (1907 p. 501) this has the following significance:

*Nitraria* has a pinnate leaf (or bipinnate) the petioles of which are reduced so that the leaflets are placed beside each other, and the scales between them are then partly stipular scales partly rudiments of leaflets. The bud between these leaflets is thus in reality the axillary bud of the leaf. This may during the same year give rise to a short-shoot which forms several of these whorls of leaflets one above another so that a leaf-rosette is developed — this is thick at the base and may have as many as 20 leaves (leaflets). Besides these year-shoot branches, shorter thorn-branches may occur. The year-shoot itself terminates in a branched inflorescence which of course dies after the fruit is ripe, or it ends as a thorn.

Normal buds which have not formed a rosette during the first year, seem next year only to be able to form either rosettes or vegetative long-shoots, whereas the rosettes developed during the first year may give rise to both vegetative and floral long-shoots.

The plant flowers in May or June. The fruit is a black berry which is eaten by the natives.

The anatomy of the leaf has been described by B. Jönsson (p. 26, tab. III), whose observations are confirmed by my own. The leaf is isolateral with sunk stomata on both sides, and 2—3 layers of palisade cells the inner ones being larger and less green. Amongst the palisade are large mucilage-cells. Like Jönsson I have found no tannic acid. — Compare also Volkens (table XI) illustrations of the structure of *Nitraria retusa*.

Jönsson also describes the anatomy of the stem and the bark, the latter with mucilaginous cork.

### Reaumuria oxiana (Ldb.) Bois.

A much-branched dwarf shrub about 30 centimetres high, which prefers a firm soil, clay or stone. The stem is crooked and bent. The non-branching year-shoots may attain a length of about 15 centimetres, but only a portion of this survives till the next vegetative period. The bark of the persistent part is brown.

The leaves are 2—4 centimetres long, linear-lanceolate. They are grey with salt-excretions which take the form of small white spots over depressions at the bottom of which the secreting glands are found. The structure of these (fig. 46 B) is very similar to that of the glands figured by Volkens (tab. V) from *R. hirtella.* Volkens was of opinion that during the night the excreted salts absorbed water from the atmosphere (dew), which might then be absorbed by the

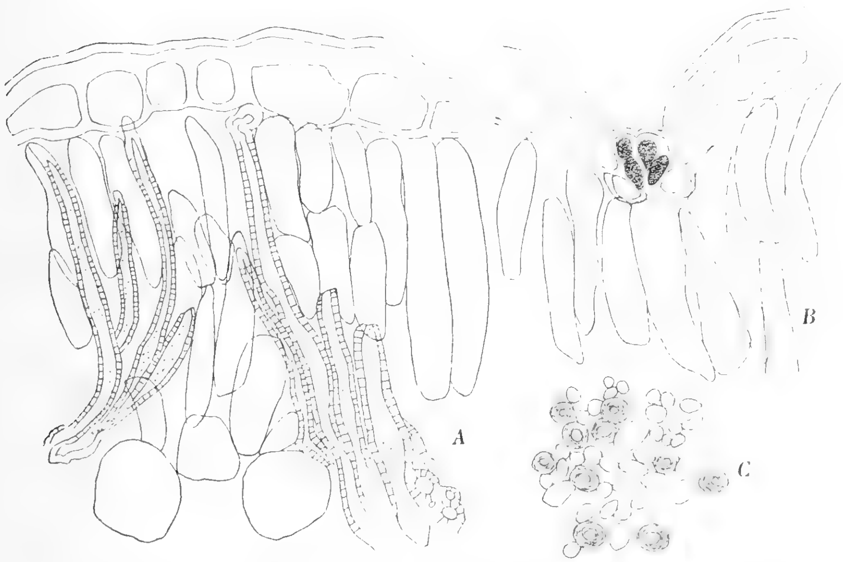


Fig. 46. *Reaumuria oxiana.* *A* and *B* parts of leaf in transverse section; in *A* sclerenchyma-cells are seen; *B*, a salt-gland. × 202. *C*, Surface section of palisade tissue, showing palisade-cells and sclerenchyma-cells intermingled.

gland and thus be utilised by the plant. Marloth (1887 p. 321) denies this and states that it is impossible for the glands of the leaf to absorb water from the surface without at the same time absorbing the salts. On the contrary the salt solution on the surface must absorb water from the gland, and according to Fitting this is what takes place (l. c. p. 267 note). And still more important, Fitting has arrived at the result that plants in the desert store salt internally up to a certain specific maximum varying for different species, and that in this physiologically determined limitation of salt storage they have a sufficient means for securing the high osmotic pressure which FITTING has pointed out in the desert-plants and which enables them to obtain water from the soil. In addition to sodium chloride, there is also excretion of carbonate of lime often in great quantities, so it is not at all certain that the excretion of sodium chloride is of any special importance. And finally FITTING points out that dew is exceedingly rare in the Sahara.

The flowers of *Reaumuria* are large and terminal on the branches, they appear in July. Below the calyx there are several bracteoles forming an involucre. The fruit is a capsule with about a score of white woolly seeds.

The leaf anatomy of *Reaumuria oxiana* has been briefly described by VESQUE. The thick epidermis consists of one layer, and the stomata and salt-glands are depressed. The leaf is isolateral with about two layers of palisade cells and a central water-storing tissue. Between the green tissue and the water-storing tissue, or amongst the palisade, are numerous bands of sclerenchyma running longitudinally within the leaf, and from these issue long, thin sclerenchyma-cells which as idioblasts stretch through the palisade to the epidermis as if to support it from the inside (fig. 46 A C; also VESQUE tab. 8, fig. 7).

### Reaumuria fruticosa Bge.

On moderately stable sandy soil I have found shrubs of this species scarcely attaining the height of one metre.

It is strongly branched, the branches being strikingly thick and light in colour. The year-shoots may attain a length of 5 centimetres, and apparently always die back at the apex, which remains as a dry stick. Branches of two different kinds occur on the year-shoot, some are short but quite evidently branches with elongated internodes, others are rosette-like short-shoots. The former may be wanting, but when present they are generally placed towards the apex of the year-shoot. They are rarely 2 centimetres long, generally less than 1 cm., and bear leaves like the year-shoot. The leaves are small about 2 mm. long, but comparatively broad and flat and besprinkled with salt-grains. The rosette short-shoots are found in every axil except occasionally the ones which bear the branches with extended internodes. They carry about 12 leaves, shorter, thicker and more persistent than the subtending leaves. Rosette-shoots are also formed on old year-shoots, and altogether they are the most important assimilating organs of the plant.

I have not seen the flower.

The anatomy of the leaves is similar to that of *R. oxiana* and *R. hirtella* (Volkens), and also discussed by Vesque, but his statements do not quite agree with what I have found; for instance he finds no mechanical tissue. — The epidermis is very thick and the epidermal cells are almost filled with mucilage from the outer wall. Sunk stomata and salt-glands occur, the latter being similar in structure to those of the preceeding species. There are two or more layers of palisade cells extending all the way round, and starch-sheaths enclose the veins. Large bands of sclerenchyma are present, irregularly arranged, but I have not found idioblasts between the palisade cells.

## Tamarix.

Fifteen species of this genus have been recorded for Turkestan. They only thrive as a rule in places which are not too dry. On river-banks they are very abundant and Antonow says (see above p. 33) that Tamarisk in the desert is a sign of water not far off. In the sand-desert they are able to some extent to hold their own against the sand (comp. above p. 127—128) and where they are present water is presumably not very far down. They have long, vertical and obliquely descending roots. Under favourable conditions they are trees with thick foliage, but are only small shrubs under unfavourable conditions.

The leaves of Tamarisks, as is well known, are small green scales. The plant does not shed its leaves but the branches which bear the leaves, except in the case of persistent branches where only the leaves are cast. They thus have assimilating shoots which biologically play the part of leaves. In many (perhaps all) species the leaves are coated

Fig. 47. *Tamarix laxa.* Last year's year-shoot with floral (fruit-bearing) shoots at the base, vegetative shoots at the top. May.

with salt-concretions; especially is this the case with *T. hispida* and *T. Karelini*, where these are very numerous.

As regards the development of vegetative and floral branches, the species of *Tamarix* may be divided into two groups. In the first group the floral shoots appear on the year-shoot of last year while the present year-shoot is purely vegetative. This group includes *Tamarix laxa, Meyeri, Androssowii, florida, elongata, polystachya.* This characteristic is shown in *T. laxa* (fig. 47). The vegetative and floral shoots are, however, not always separated as in this case, but may be intermingled. A single one or several of the vegetative shoots seen in fig. 47 will become rejuvenescence shoots, the remainder are short-lived assimilating shoots. All the vegetative shoots, as will be noticed, are many times branched. The species of this group flower early, during April and May, and according to Bunge (1852 p. 8) they have as a rule tetramerous flowers.

The species of the second group bear the flowers at the apex of the present year-shoot which has vegetative branches at its base. To this group belong *T. Pallasii, hispida, Karelini, arceuthoides, Ewersmannii, karakalensis, Korolkowii, leptostachya* and *pycnocarpa*.

The branch of *T. hispida* illustrated in fig. 48 is the shoot of this year. All the lower branches of primary order bear much-branched vegetative shoots at the base and inflorescences at the top, or they are purely vegetative. The upper year-shoot branches are entirely floral.

The species included here are said by Bunge (l. c.) to have as a rule pentamerous flowers which open late, from July to September. As the flowers arise on the outmost part of the year-shoot and its branches, they cannot appear until these axes have attained a certain stage of development.

In this group as in the first, the flower axes and the greater part of the vegetative branches fall off, and only a single one or a few become rejuvenating shoots.

Short-lived vegetative branches may appear in all the species on old year-shoots in the axils of leaves which have fallen off. They may bear inflorescences as in the species of the second group.

All the Tamarisks have small red or white flowers arranged in racemes. The fruit is a small capsule with woolly seeds easily transported by the wind.

The anatomical structure of the leaf I have examined

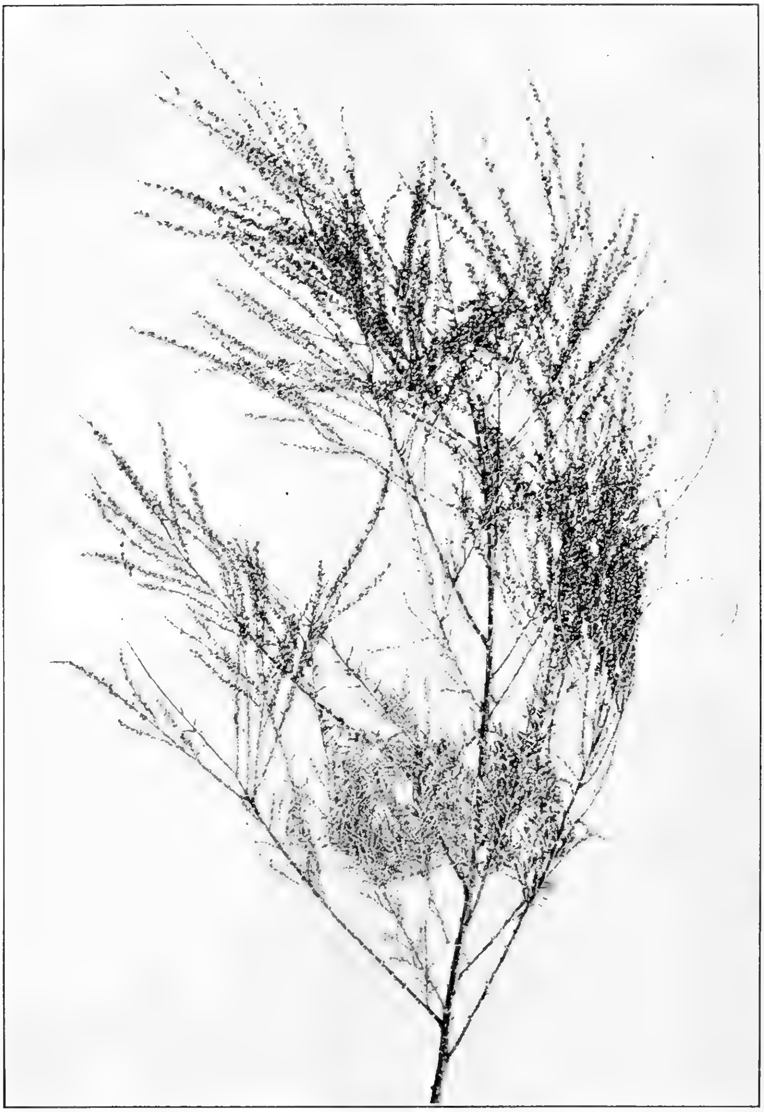

Fig. 48. *Tamarix hispida.* Year-shoot with flowering branches at the top, vegetative at the base. August.

in *T. hispida.* All the cells of the single-layered epidermis are distinctly convex and papilla-like. The stomata on the upper and lower surfaces, and the salt-glands are sunk. One layer of palisade cells all round is present both in the leaves and the assimilating branches. The leaf also has rather open spongy parenchyma and veins with a bast-sheath besides storage-tracheids ("Speichertracheïden").

I have not investigated in detail the more mesophytic fanerophytes (*Elaeagnus*, *Ulmus*, *Morus*, *Populus*, *Salix*). *Elaeagnus hortensis* was observed in August with two series of branches on the year-shoot, but this does not appear to be the rule. The same holds good with regard to *Salix angustifolia.* The species of all the genera just mentioned flower in spring.

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The above Fanerophytes have the following characteristics common to all or some of them.

The leaves are greatly reduced. In one set of species they take no part as assimilating organs (*Eremosparton, Calligonum, Ephedra, Haloxylon, Halostachys, Halocnemum*), while in others they are scale-like, but green (*Tamarix, Reaumuria fruticosa*). *Astragalus* has leaves which are wholly or partly shed during summer, but whether as in the case of *Spartium junceum* (according to Bergen), there is no assimilation or at any rate very little after the leaves are shed, I cannot say, and one can scarcely draw a conclusion from a single case. *Ammodendron*, *Halimodendron* and *Smirnowia* have persistent, small, hairy leaves, while *Prosopis, Atraphaxis, Lycium, Nitraria* and *Reaumuria oxiana* have persistent small and glabrous leaves. The *Salsola* species have cylindrical persistent leaves.

The leaves in *Salsola* and the assimilating shoots in the leafless species are all centric in structure, the latter in most cases have abundant mechanical tissue.

In the flat-leaved species the leaves are without exception isolateral in structure.

The branches in most sand-desert species are slender, pliant and more or less pendulous; in clay-desert species on the contrary they are generally stiff and short.

The year-shoots are branched except in a very few cases (*Halimodendron*, *Reaumuria oxiana*). Branched year-shoots are thus the rule, and non-branching the exception. A similar case has, to my knowledge, never been pointed out for any community of Fanerophytes.

Warming (1892, pp. 408, 252) and after him Malme have drawn attention to a number of South American species with branched year-shoots. Raciborski also gives illustrations of several species of this kind, but without recording this characteristic. These species are mostly forest-plants, but some belong to the Savannas (Malme). Malme regards the branched year-shoot as a primitive character in dicotyledonous trees, non-branching on the contrary being a secondary feature acquired in the course of time. However this condition in the case of the broad-leaved South American plants is of less interest to us than the branch system in other Fanerophytes poor in leaves or leafless. This condition is certainly worthy of special study although in the literature I have only found occasional references to it.

In many cases the year-shoot branches are annual assimilating shoots, more rarely they are continuation shoots which take part in the extension of branches. No definite limit can be drawn however between the two. The assimilating branches have been described in many of the species mentioned (e. g. *Eremosparton*, *Calligonum*, *Tamarix*, *Astragalus*, *Salsola* etc.); biologically they play the part of leaves.

Assimilating branches in many species are not confined to the last year-shoot, but also occur on older branches. In such cases they arise on the exterior side of lateral branches, or where such ones have previously been, and often several together. Thus the characteristic tufts of branches originate, which likewise distinguish so many of the trees and shrubs of the desert; they have been described and illustrated in the case of several species (e. g. *Eremosparton*, *Calligonum*, *Smirnowia*). Similar conditions are also found in *Spartium*, *Carmichaelia*, and others.

A further characteristic of the year-shoots is, that they do not as a rule persist throughout their whole length, but the outer part dies, (probably killed by the heat and drought during the height of summer) and it remains next year as a dead stick, frequently as a thorn. One of the few exceptions to this rule is *Halimodendron.*

As regards the majority of the fanerophytic *Chenopodiaceae* and *Lycium*, flowering takes place in summer; *Haloxylon* and probably all the rest flower during spring, at the latest in June. All the late-flowering species with the exception of *Lycium* have small flowers which are completely enclosed up to the time of anthesis. The early flowering species include a large proportion of *Leguminosae*, and it seems to be the rule, or at any rate is frequently the case, that only the early flowers fructify while the later ones become dried up.

The fruits (or the seeds) are in most cases such as may be easily transported by the wind; they are light and furnished with some kind of parachute, and as a rule they contain only one or a few seeds [1]). The open network on the fruit (fig. 28) of *Calligonum*, the large bladdery pod of *Smirnowia* and *Halimodendron*, the winged fruits of *Salsola, Haloxylon*, *Ammodendron* and *Atraphaxis*, the small light pods of *Astragalus* and *Eremosparton*, and the white woolly seeds of *Reaumuria* illustrate the different adaptations by which wind-transport is achieved.

Fruits with no special adaptation for flight are seen in the berries of *Nitraria* and the small nuts of *Halostachys* and *Halimocnemis.*

## B. Chamaephytes.

As explained in chap. 12 (p. 173) these all belong to the xerophytic aspect, they are summer-plants and a great number of them are late flowering.

### Capparis spinosa L.

A decumbent undershrub found on clay soils and more especially on stony soil. The branches are long and bear

[1]) Comp. E. Gain 1894: Moist soil produces many but small seeds, dry soils few seeds but large.

broad, large leaves, bright green in colour and with two spinous stipules at the base. According to Volkens (p. 97), the leaves during summer acquire a coating of wax so that they lose the bright green colour. I have not observed this, but it may also take place in Transcaspia since my opportunities for observing *Capparis spinosa* in summer were few. The year-shoots are branched· The lower part only is persistent and lignified, and it gradually increases in thickness. The beautiful large white flowers are placed singly in the leaf-axils; flowering begins in May and continues well into July, perhaps longer. The fruit is a stout berry.

The anatomy of the leaf has been illustrated by Volkens (tab. IX, figures 1—2), and my Transcaspian material shows the same structure. Some of the epidermal cells, however, have a thickened inner wall (mucilage?) and I have not observed that the palisade cells are arranged in groups round the large thick-walled tracheids ("Speichertracheïden"). The leaf is isolateral, with mesophyll consisting almost exclusively of palisade cells. The stomata are slightly sunk.

### Hulthemia (Rosa) berberifolia Dum.

This species is likewise a clay soil plant with decumbent shoots and broad leaves. The latter are dentate, hairy, elliptical or spathulate, about 1 centimetre or rather more in length, and closely set because the internodes are shorter than the leaves, sometimes so short as to produce rosettes on short-shoots. The stem bears many strong curved white prickles as well as others which are thin and subulate. I have only seen the plant in May when it carries large, handsome, yellow flowers. The distal parts of the year-shoots may die away, but whether this occurs always I cannot say. No material was available for anatomical investigation.

### Haplophyllum obtusifolium Ldb.

This is a typical undershrub which occurs especially on stationary sand. It is strongly branched but according to Bunge (Rel. Lehm. p. 62) other forms occur in which the branching is only slight. The year-shoots arising from the persistent parts may be branched, but generally this does not seem to be the case. They are numerous and slender, and bear small, lanceolate leaves which attain a length of 1—2 centimetres, bright green in colour and containing many lysigenous oil-reservoirs.

The yellow flowers appear in July or August. The fruit has few loculi and a few seeds in each loculus.

The leaf is isolateral in structure. The epidermis consists of one layer with a thick outer wall and the stomata slightly sunk. There are about three layers of palisade cells on each side and a narrow middle zone of rounded cells. This zone includes many tracheids ("Speichertracheïden") besides the veins which both above and below have a sheath of rather thin-walled, non-lignified bast. There are many lysigenous oil-reservoirs measuring in diameter more than half the thickness of the leaf.

The green cortex has a thick-walled epidermis of two layers overlying 3 or 4 layers of short palisade cells limited towards the interior by a layer of thin-walled, tangentially extended cells which may be regarded as collecting sheath. Many bundles of bast occur in the inner cortex.

### Stellera Lessertii (Wickstr.) C. A. M.

An undershrub 20—50 centimetres in height and occurring in the clay-desert. It is much branched and numerous dead branches are found; whole branch-systems may die off leaving short dry sticks projecting in all directions. New branches are formed from branches of the previous shoot-generation and also from old branches. The year-shoots bear branches the same year, often 2—3; these are unbranched, with long internodes, and they all terminate — if sufficiently long lived — in an inflorescence. This is a short, simple spike, and the small yellow flowers appear in July. The fruit is a pear-shaped nut about 4 mm. long, it is surrounded by the lower strongly woolly-haired part of the perianth.

The leaf is hairy, narrow and small, almost elliptical-lanceolate and directed obliquely or vertically upwards. Its structure is isolateral (fig. 49). The epidermis is thick and most of its cells on both surfaces have a thick mucilaginous inner wall which in transverse section presents a characteristic appearance, two light stripes showing between the green tissue and the cell cavities of the epidermis. These cavities are filled with tannic acid and the contents are therefore dark.

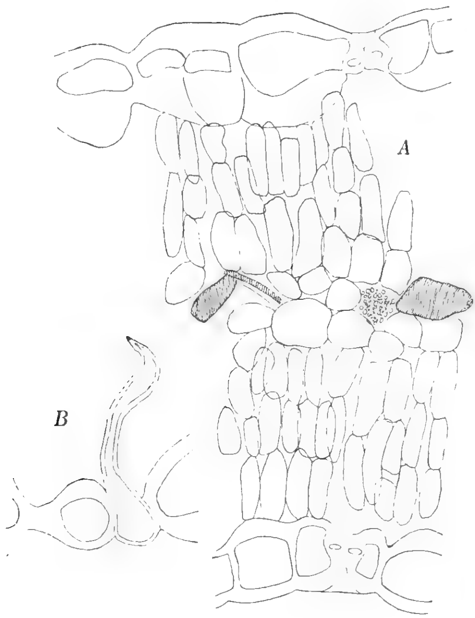


Fig. 49. *Stellera Lessertii.* *A,* Leaf in transverse section. *B,* a hair. × 203.

There are stomata on both surfaces. The palisade cells occur in 2 or 3 layers above and below; the centre is occupied by the veins which take up most of the space; between them there are 2 or 3 layers of rounded cells less rich in chlorophyll, and many "Speichertracheïden" (shaded in fig. 49).

A young stem shows a thick but non-mucilaginous epidermis with stomata which are not sunk; below this are 3 layers of rounded green-cells of which the outer ones are slightly palisade-like. These are followed by about two layers of round or tangentially extended cells containing a small amount of chlorophyll. The inner cortex consists of large groups of sclerenchyma separated by narrow bands of translucent cells. The cortex of the youngest branches is green, but when the epidermis becomes filled with tannin the branch assumes a dark-brown surface which ultimately is ruptured by cork-formation.

### Alhagi Camelorum Fisch.

One of the most common plants in Trancaspia. It looks like a stumpy shrub with green branches. The aerial parts, however, are not persistent and in general *Alhagi* is doubtless a root-geophyte. But as short stems are occasionally found — probably rhizomes originally — from which new shoots rise 10—30 centimetres above the ground, and as the determination of RAUNKLÆR's biological types is dependent on the position of the least protected buds, I propose to classify the species under the chamaephytes.

The light-shoot of *Alhagi* is green and spiny. The plant frequently assumes the globular form since the close-set expanded branches project equally in all directions. The leaves are small, at most a couple of centimetres long, oblong-ovate or spathulate, and the majority fall off during the early part of summer. This is especially the case with the leaves developed later, whereas many of the older, lower leaves persist for a long time. This is probably due to the great heat and dryness of the summer which prevents the perfect development of new leaves.

All the leaf-axils except the very uppermost bear thorn-branches. These are leafless and green, about 4 centimetres long and with a yellow tip; only the upper thorn-branches bear flowers. These branches arise not in the middle of the leaf-axil but obliquely towards the cathodic side of the leaf (the phyllotaxy is a $^2/_5$ spiral). Many of the leaf-axils of the main-shoot give rise to long-shoots beside the spine, on the anodic side; these long-shoots bear leaves which also subtend spines except sometimes the upper ones, more rarely they bear long-shoots.

*Alhagi* has horizontal roots which at intervals send out light-shoots directed upwards. Normally these die during winter down to the surface of the soil and new shoots appear next year from the upper part of the subterranean perennial

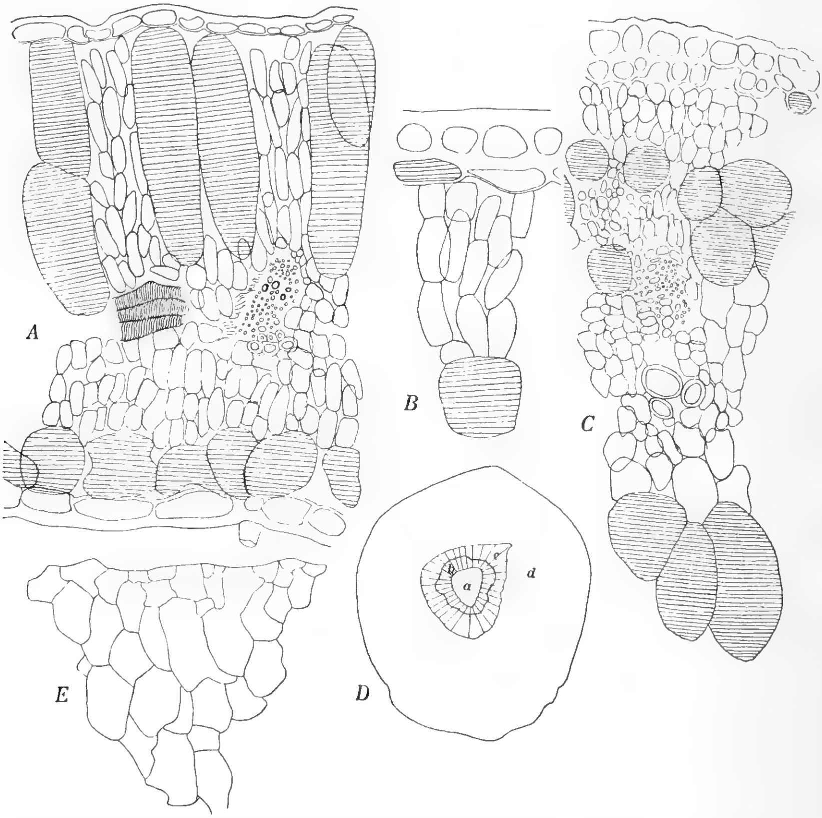


Fig. 50. *Alhagi Camelorum.* *A,* Leaf in transverse section. *B,* Part of a transverse section of the outer cortex of a thorn shoot. *C,* Part of transverse section of a young shoot. *D,* Transverse section of a sandshoot (rejuvenescence-shoot); *a,* pith; *b,* wood; *c,* inner cortex; *d,* outer cortex (cork). *E,* The outermost part of the outer cortex in *D.* *D:* slightly magnified; the others. × 203. Cells containing tannin are hatched.

rhizome. These as well as old roots (?) may become very thick; I have seen them $4^1/_2$ centimetres in diameter.

From what has been already said, it will be understood that the *Alhagi* are gregarious plants, and that their subterranean parts contain food-reserves which enable them to contend against very unfavourable conditions. *Alhagi* has been frequently mentioned in the preceeding pages (e. g. pp. 122, 128).

When buried by the sand axillary shoots encased in a thick corky coating (see below) grow upwards through the sand to the surface (comp. fig. 22 which shows a somewhat similar case in *Heliotropium*). Specimens of *Alhagi* were found where this had taken place twice: The first restoration shoot had after burial formed a new shoot. On the other hand rhizomes or roots laid bare by the sand being blown away from them may form new light-shoots.

The red flowers of *Alhagi* appear in isolated groups 2—7 together on the upper spines, they commence to expand in June. The fruit is an jointed crooked pod, (not a lomentum) with 5—8 joints and as many seeds; it is very light.

The anatomy of *Alhagi* has been examined among others by B. Jönsson who gives a number of somewhat diagrammatic figures.

The structure of the leaf in my Transcaspian specimens agrees with his description and figures. The hypoderm containing tannic acid on the lower surface, (see fig. 50, A) may, however, be wanting. When present it is seen in sections parallel to the surface to form a net-work below the epidermis. The stomata are slightly sunk, the epidermis is one-layered and there are 4—5 layers of short palisade cells on the upper and lower sides.

As most of the leaves fall off early, the branches are well provided with assimilating tissue (fig. 50 B and C). The epidermis consists of two layers, and many of the cells of the inner layer contain tannic acid; the palisades are nearly similar to those of the leaf and are apparently best developed in the thorn-branches (fig. 50 B).

Within the green tissue there lies a parenchyma with many large cells containing tannic acid. In older branches the leptome has bands of sclerenchyma on the outer side. The pith is large-celled, many of its cells containing tannin. The presence of tannin in fig. 50 is indicated by hatching. Reference should also be made to Schube, B. Jönsson and Volkens; the latter (tab. III, fig. 10) gives a transverse section of an internode of *Alhagi manniferum*.

A restoration-shoot grown up through the sand from a buried shrub of *Alhagi* had its subterranean part beset with scale-leaves and with a yellow coating which was thick and spongy to the touch. When cut through the coating proved to be a thick layer of cork (fig. 50, D, E), formed from a phellogen in the cortex; this was double the thickness of pith, wood and inner cortex together. All the cells had exceedingly thin corky walls, easily torn and all empty and dead. Inside such an air-filled case the growing shoot must be well protected.

### Heliotropium dasycarpum Ldb.

An undershrub occurring in the clay-desert. It has leaves 1 to 2 centimetres in length, coated with stiff hairs; the foliage is so open that the whole plant is transparent. The flowers appear in June and July and evidently only the lower flowers of the scorpioid cyme produce fruit. The achenes are long-haired and hard-shelled.

The leaf is almost isolateral in structure. The epidermis is one-layered with stomata on both surfaces and not sunk. Both surfaces are coated with hairs most of which are bent to one side while some are short and somewhat dome-shaped. The cuticle extends over all the epidermis as a warty covering. The hairs arise from large thin-walled epidermal cells which contain stratified cystoliths, the so-called hair-cystoliths (see Solereder 1899, p. 632, fig. 127; the hairs mentioned here are similar to fig. B). The upper face of the leaf has one layer of long palisade cells, the lower face two layers of shorter ones. Grouped around the veins in the middle are some isodiametric or slightly oblong cells, translucent or containing a little chlorophyll.

### Frankenia hirsuta L. (= F *hispida* D. C).

This species occurs in comparatively moist localities and as a rule on a saline soil. It has decumbent, lignified branches. The leaves are about half a centimetre long, revolute, with scattered hairs and with grains of salt. The small red flowers may be found still open in July.

The structure of the leaf is dorsiventral (fig. 51), but the stomata and salt-secreting glands are found on both surfaces, whereas the setaceous hairs are absent on the upper side. There are long palisade cells on the upper side, generally transversely divided, and short palisades on the lower side

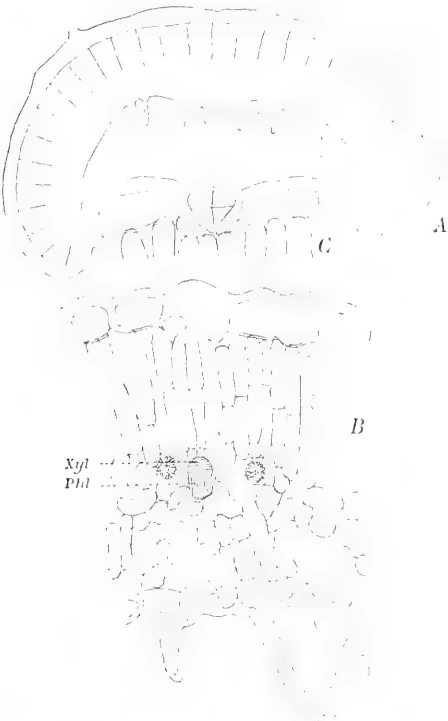


Fig. 51. *Frankenia hirsuta.* A, Outline of leaf in transverse section with epidermis, palisade cells and hairs indicated. *B*, Part of leaf in transverse section. *Xyl.*, Xylem; *Phl.*, Phloëm. *C*: Gland. *A*: × 47; *B*, *C*: × 203.

and a loose spongy parenchyma with crystal-cells in the middle. The air-spaces in the interior of the leaf are generally fairly large. Sclerenchyma is wanting.

## Convolvulus eremophilus Bois. & Buhse.

An undershrub growing on clay or stationary sand. The year-shoots arising from the perennial branches are branched two or three times. The tertiary series of branches and the upper ones of secondary order are apparently always short (up to about 4 centimetres) and rarely have more than 2 or 3 internodes. It seems as if growth were interrupted by the drying up of the terminal bud. Each of these small branches bears one or two flowers.

The lower leaves are lanceolate-linear and may attain a length of about 3 centimetres; the upper ones are small scales, so that the plant is thus practically leafless. All the green parts are covered with slanting bipartite hairs similar in form to those of *C. erinaceus* (see fig. 53).

The white flowers open in June. The capsule contains two large, long-haired and hard-shelled seeds.

I had no opportunity of examining the anatomy of the leaf. The primary cortex resembles that of the next species. The epidermis consists of one layer and contains tannic acid; the stomata are not sunk. There are three layers of palisade cells which towards the interior are supported by one or a few layers of tangentially extended cells, almost devoid of chlorophyll, and among these are a few bast cells opposite the groups of phloëm.

### Convolvulus divaricatus Rgl. & Schm.

An undershrub which grows on stationary sand. The year-shoots, about 30—40 centimetres in length, are sinuous, white-woolly and two or three times branched. The leaves are small, (5 to 15 mm. long) and with a broad cordate base.

The isolated white flowers open in May.

The structure of the leaf is isolateral. About five layers of palisade cells occur, the middle ones being the smaller. The epidermis is one-layered and contains tannic acid. Both surfaces are covered with long projecting hairs which are bipartite but one arm is much reduced. Alongside the veins there are secreting cells (laticiferous cells). The structure of the green cortex of the young branches is similar to that of the previous species, but the hairs are erect and the coating is much denser.

Convolvulus erinaceus Ldb.

An undershrub with very long roots and preferring somewhat stationary sandy soil. It attains a height of about

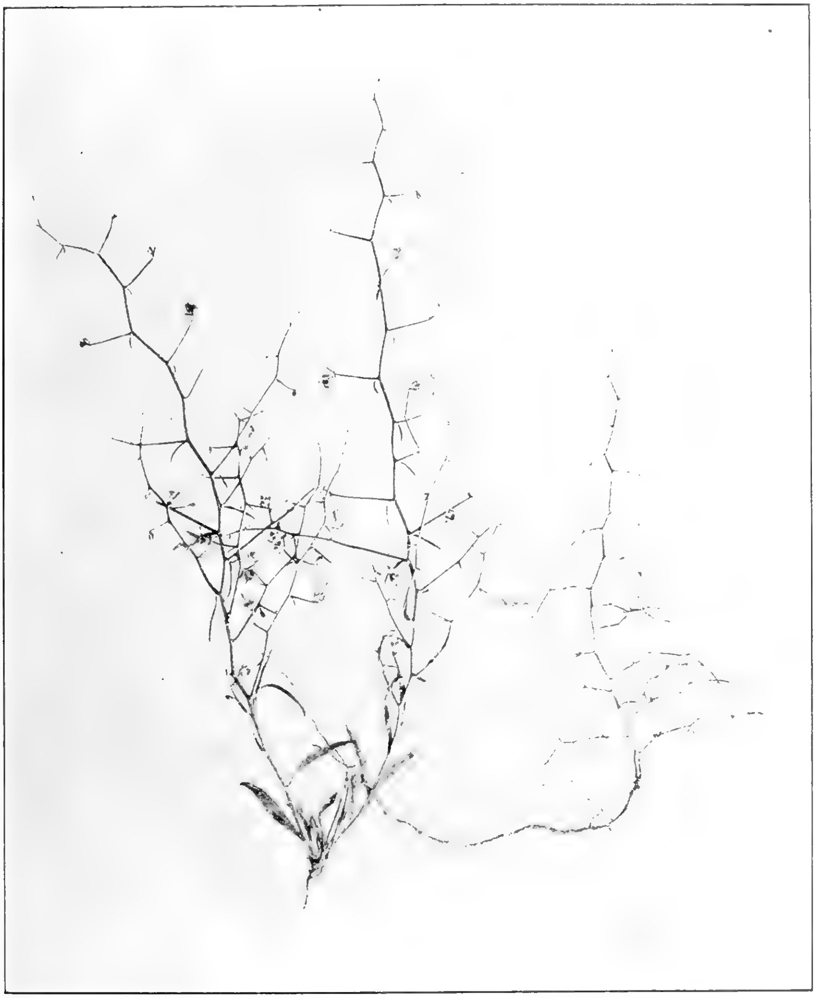

Fig. 52. *Convolvulus erinaceus.* To the left a leaf-bearing plant (June). To the right a specimen which has shed its leaves. (July).

40 centimetres, but according to Aitchison it may reach the height of 1 metre (2—3 feet). The year-shoots are stiff, strongly branched, geniculate at the nodes and the branches

are spread out or reflexed. In spring and early summer the plant developes leaves (see fig. 52) which are linear-lanceolate, 2—3 centimetres long, and white-haired, but the leaves fall off later in the summer so that the branches become the only assimilating organs. In late summer the larger plants are leafless, globular and spiny shrubs. The spines are formed by the year-shoot branches of secondary and tertiary

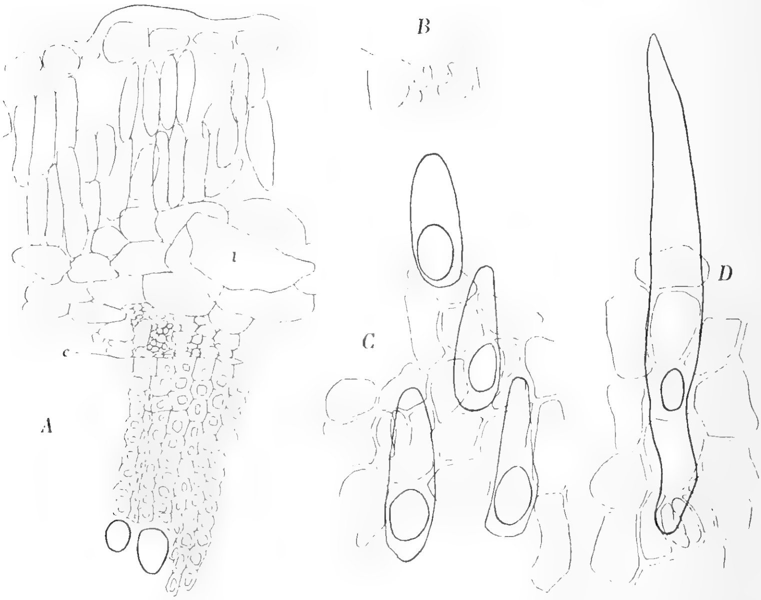


Fig. 53. *Convolvulus erinaceus.* *A*, Transverse section of the green cortex and part of the wood; two vessels are represented; *c*, Cambium; *l*, Secreting cell. *B*, Stoma. *C*, Epidermis with hairs, seen from above. *D*, A similar view of *Convolvulus fruticosus.* (× 203).

order, and also by the uppermost ones of primary order which as a rule have formed only one internode and the beginning of a second one when growth ceases, hence the branch remains as a spine, terminated by a dead, withered point.

The white flowers occur singly on these small branches, and open in June and July. Aitchison says that they open at sunrise, but I have found them open in the middle of the day in a broiling sun.

The capsule often (always?) contains only one seed with short woolly hairs and a hard shell.

I have not examined the anatomy of the leaf. The primary cortex of the branches is similar to that of the two species of *Convolvulus* described above, as will be seen from fig. 53. The inner cortex, as in these species, includes secreting cells (fig. 53, A. l.), which as seen in longitudinal section stand in long rows like piles of barrels. (comp. HALLIER). Similar cells are found in the pith which also encloses leptome tissue (a generic character).

### Convolvulus fruticosus Pall.

Grows on clayey or stony soil. An undershrub with stiff, spiny branches. The year-shoots issuing from the low knotted perennial parts are branched once, twice or three times. The branches, more especially the ones of secondary order, are spread out or bent backwards; the branches of tertiary order and also the upper ones of secondary order are spines, of which the lower ones bear flowers. Each bears only one terminal flower with small foliage-like prophylls each subtending a branch-spine which is generally leafless. After the flower and the two leaves have fallen off, a fork-shaped spine remains behind. (fig. 54 B, C). The upper thorns are unbranched.

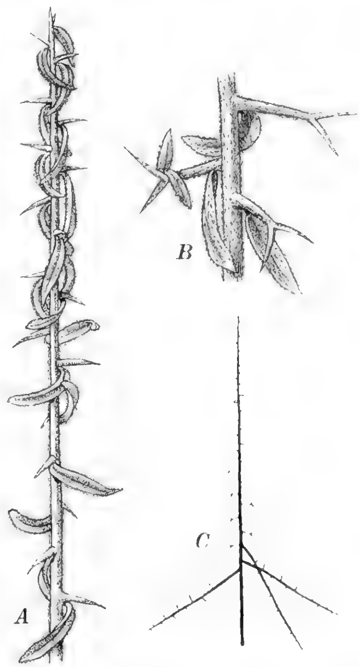


Fig. 54. *Convolvulus fruticosus.* Upper *(A)* and middle part *(B)* of a shoot. *C:* Scheme of branched year-shoot. August.

The leaves are small and lanceolate; the lower ones are the larger and may attain a length of about $2^1/_2$ centimetres, while higher up they are shorter and narrower. In the month of July they all become bent vertically downwards and curl up into something like a spout. (fig. 54).

The plant flowers in May, the corolla being comparatively large, pink and coated with woolly hairs.

The young branches and also the leaves are white with a coating of bifurcate convolvulaceous hairs, the arms of which are very unequal in length (fig. 53, D). The longer arm is directed towards the apex of the organ.

The leaf is isolateral in structure. The outer wall of the epidermis is very thick, as thick as the cell cavity which contains tannic acid. The stomata are sunk. There are two or three layers of palisade cells above and below; strong bundles of bast surround the veins.

The outer cortex of the young branches has the same structure as half a leaf.

### Acanthophyllum elatius Bge.

A plant of stony and clay soils. The woody base gives rise to numerous straight unbranched twigs about half a metre long, with white bark and bearing opposite stiff prickly leaves. Before the next vegetative period the branches have died off almost down to the ground. They bear small axillary leaf-rosettes, and the apex carries a cymose inflorescence.

In the middle of the leaf is found a thick band of sclerenchyma, many times thicker than the midvein which extends along its upper side. Laterally there are a couple of smaller veins partly accompanied by narrow bands of sclerenchyma on the leptome side. From the median strand palisade cells radiate in all directions. The epidermis has very thick outer walls. The stomata are not sunk. The intercellular spaces in the interior of the leaf are of considerable size (fig. 55, B).

*Acanthophyllum pungens* closely resembles the above species. As for the other species recorded, I have not examined them.

### Noaea spinosissima L.

An undershrub which prefers stony soils (on mountains). It is much branched and forms a thick, spiny, globular shrub; the branches die down almost to the ground and arise from a lower, lignified long-lived part. The leaves are

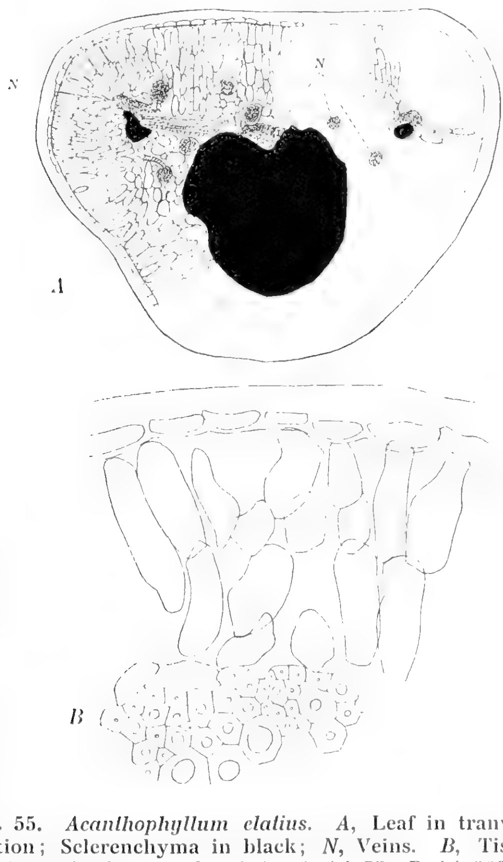


Fig. 55. *Acanthophyllum elatius.* *A*, Leaf in tranverse section; Sclerenchyma in black; *N*, Veins. *B*, Tissues from the lower side of *A*. *A*, × 77; *B*, × 203.

long, triangular and pointed like a spine. They all subtend thorn-shoots which attain a length of 3—6 centimetres and these in their turn frequently bear lateral thorn-shoots.

Flowering season October, the flowers being closely surrounded by bracteoles. The fruit is a nut enclosed in a winged perianth.

Nanophytum erinaceum Pall.

My knowledge of this species is derived solely from herbarium specimens. It is almost a cushion-plant as the

Fig. 56. *Anabasis salsa.* End of June.

shoots have short internodes and many small knotted lateral shoots with the leaves arranged in rosettes. The leaves stand close together and are ovate-lanceolate with a small spinose point.

### Anabasis salsa (C. A. M.) (*Brachylepis*).

This species occurs on clayey or stony and saline soil. Its habit is shown in fig. 56. It is an undershrub-chamaephyte, with slightly branched year-shoots which die off almost down to the surface of the ground. They are richly furnished with flowers which arise in the axils of the small opposite scale leaves. The flowers are out in July or August. The fruit is somewhat fleshy, it is surrounded by the non-winged perianth.

The assimilating stem is constructed after the ordinary centric type of the Chenopodiaceae. The epidermal tissue consists of three layers, of which the inner layer is a thin-walled "crystal-layer". The stomata are slightly sunk. A ring of palisade cells surrounds the starch-sheath and within this is an aqueous tissue with large crystal-cells and the veins.

### Anabasis aphylla L.

This species is a salt-plant like the previous one and relationship is also shown as regards shoot-structure. In its fruit *A. aphylla* is a true *Anabasis*, the leaves of the perianth being broadly winged and the fruit dry.

### Arthrophytum subulifolium Schrenk.

An undershrub growing on firm soils. It probably does

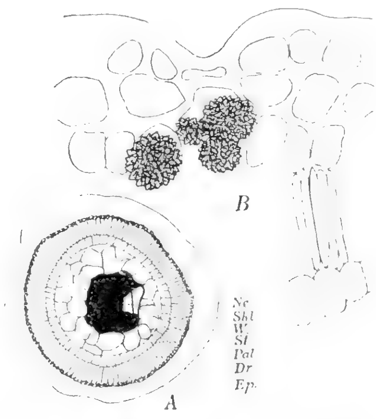


Fig. 57. *Arthrophytum subulifolium*. *A*, leaf in transverse section; *Ne*, vein; *Skl.*, sclerenchyma (black); *W*, aqueous tissue; *St*, starch-sheath; *Pal*, palisade cells; *Dr*, crystal-layer; *Ep*, epidermis. *B*, Part of transverse section of a young branch showing epidermis, hypoderm with crystal-cells, palisade cells and starch-sheath. *A*, × 47; *B*, × 203.

not exceed a height of 30 centimetres. Sometimes it may be a hemicryptophyte, but in its least protected form it is a chamaephyte with a low thick perennial epigeal base, which bears rather short green branches. These bear opposite subulate leaves with the axils woolly-haired, and with the basal part persisting through the winter.

I have not seen the plant in flower. The fruit is said to be somewhat fleshy and wingless.

As regards the assimilating, epidermal, and aqueous tissues, the structure of the leaf and stem is similar, both belonging to the centric type. A thin-walled hypoderm contains crystal-groups. (Fig. 57).

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The Chamaephytes described have the following characters in common: They are undershrubs with a perennial lignified and often thickened base, and with year-shoots the larger distal part of which dies before the next vegetative period. *Nanophytum* alone is a cushion-plant, or nearly so.

With the exception of *Capparis*, they have all small leaves, and some of the Chenopodiaceae are practically leafless. In some species all or some of the leaves are shed during summer, and the stems assume the function of assimilating organs (*Alhagi*, *Convolvulus*).

The structure of the leaves is isolateral except in *Frankenia*. The leaves of many species are coated with hairs, some have tracheids, others aqueous tissue.

The year-shoots are almost always branched which is the rule for undershrubs (WARMING 1892).

As already stated all the chamaephytes are late flowering. The structure of the fruit so far as I have observed, presents no general characteristic common to all.

## C. Hemicryptophytes.

The majority of these (see chap. 12, p. 167) are spring-plants the aerial parts of which are dead during the warmest part of summer. So far as I know this is, for instance, the case with all the *Umbelliferae* belonging to this type; and

Fig. 58. *Anabasis eriopoda.* August.

most species of *Astragalus* and *Cousinia*, amongst the larger genera, disappear during summer.

The more important hemicryptophytic summer-plants are some halophytes which will be dealt with below.

### Anabasis eriopoda (C. A. M.).

This species is common in very dry clay- and stone-deserts. It has a very characteristic appearance as will be seen from figures 58 and 59. The year-shoots measure 30 cm. long or even more, and arise from a white woolly cushion which lies in the uppermost crust of soil. The leaves are reduced to small opposite scales, which on older branches terminate in rather long slender spines; in their axils many white woolly hairs occur.

The lower leaf-axils of the year-shoots are branchless. but the upper ones all bear branches. The more vigorous branches give rise to new ones so that a tangle of branches results towards the top (fig. 58). All the aerial shoots are annual.

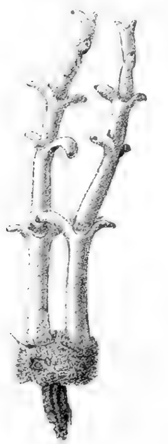

Fig. 59. *Anabasis eriopoda.* Part of a cushion with two shoots. August. Natural size.

The two lowermost leaves of each shoot are embedded in the cushion whence all the shoots issue, they are very short, but have long apical spines (fig. 59), and their leaf-axils are very woolly. The woolly cushion must be formed by the hairs in the lower leaf-axils of successive shoots, and my observations indicate that the shoots arise in these very leaf-axils, though not conclusive enough to prove this positively.

The small inconspicuous flowers open in July, and the fruits which are fleshy and not covered by the perianth ripen during September or October.

The anatomy of the shoots is shown in fig. 60. The epidermis is very thick consisting of three layers; inside it is a thin-walled "crystal layer" which is, however, interrupted in many places. The ordinary layers of palisades are present, likewise a starch-sheath and an aqueous tissue.

### Zygophyllum.

The species of this genus are to some extent at least summer-plants. *Z. Eichwaldii* C. A. M. may be taken as an example. It has long furcate shoots sparsely covered with leaves. These have long stalks and are pinnate with small flat leaflets. The older leaves die off and fall while the apex of the stem is still growing (Translocation of water, comp. above p. 71). The plant flowers in spring (also in summer?), but may still be found with living shoots well into summer.


Fig. 60. *Anabasis eriopoda.* *A*, Part of stem in transverse section: *Phl*, phloëm within which lies wood with vessels. *B*, Details of *A*; *C*, Epidermal tissue with stoma. *A*, × 47; *B* & *C*, × 203.

The leaf is isolateral and in contrast to the species described by Warming 1897 (p. 41) and Volkens (p. 113) it consists of palisade cells throughout. These become larger and more translucent towards the interior, but they all contain chloroplasts, hence there is no aqueous tissue present. The epidermis consists of one layer and seems to be mucilaginous, the stomata are slightly sunk.

In a young stem the pith is a water-storing tissue. The primary cortex includes bundles of bast at regular intervals. Outside is the green outer cortex with its cells slightly palisade-like.

*Zygophyllum Fabago* and *miniatum* both have broader leaves and shorter branches than *Z. Eichwaldii.*

The leaves of *Peganum Harmala* are repeatedly furcate with linear segments. The branches lie prostrate on the ground like those of *Zygophyllum.* It flowers in spring and the shoots wither during the summer. (comp. VOLKENS p. 114.)

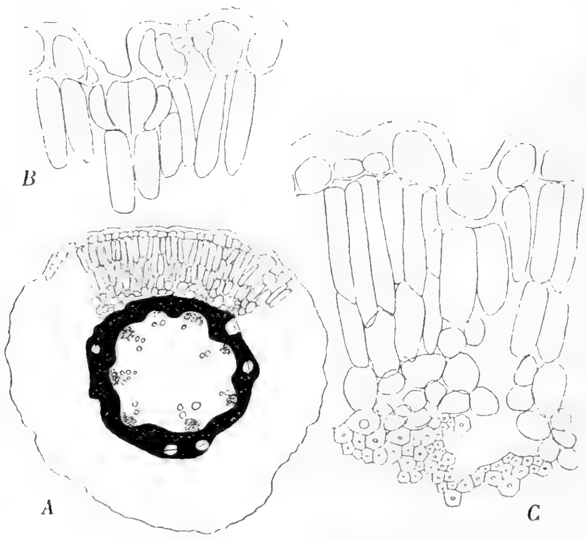


Fig. 61. *Statice otolepis.* *A*, Transverse section of inflorescence-axis. The wood is black, the white holes indicate vascular bundles which are also present within the ring. *B* and *C*, Details of A; *B* shows a gland and a stoma. *A*, × 47; *B* and *C*, × 203.

## Statice otolepis Schrenk.

This species has large broad basal leaves which are dorsiventral with two layers of palisades on the upper side, and spongy tissue with stomata on the lower. These leaves die on the approach of summer. Meanwhile the plant has flowered in May or June and the richly branched floral axes remain green and persistent, and as in *S. cordifolia* (Ross p. 20) they are the assimilating organs for summer. Their structure may be seen in fig. 61: collateral vascular bundles occur in the pith (comp. Solereder 1899 p. 564); the wood forms a solid cylinder of libriform cells; the cortex consists of green tissue, details of which are given in figures *B* & *C*.

Some Summer-Hemicryptophytes occur in the more favourable localities, in depressions near rivers and similar places. These are only slightly xerophytic and have distinct leaves, generally not very large and often hairy. These plants which I have not investigated very closely include, for instance, the following species: *Convolvulus pilosellifolius* and *subhirsutus, Inula caspica, Jurinea derderioides, J. Pollichii, Cousinia triflora, platylepis* and *dissecta* (spiny), *Centaurea iberica, Echium italicum, Lindelofia anchusoides* and *Aster Tripolium*.

### D. Geophytes.

The majority of these are bulbous plants (comp. chap. 12, p. 170), and I have only investigated specimens of three important genera *Dodartia, Heliotropium* and *Aristida*.

Dodartia orientalis L.

This species is a Root-Geophyte which grows in the more favourable localities on clayey soil. Its leafless branched shoots bear purple flowers in May or June. The branches, as illustrated in fig. 62, have a thick epidermis and below

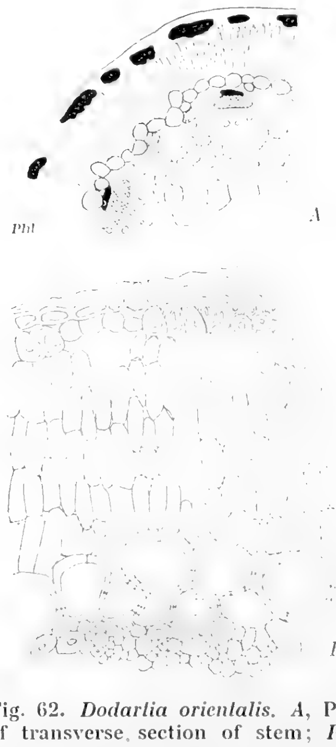


Fig. 62. *Dodartia orientalis*. *A*, Part of transverse section of stem; *Phl*, Phloëm. Sclerenchyma black. *B*, Detail of *A*. *A*, × 47; *B*, × 203).

that a hypoderm in which some cells become bast-cells while others remain thin and ultimately disappear leaving empty spaces between the bast-bundles. There are 4 or 5 layers of palisade cells of which the innermost are bounded by a storage-sheath of large thick-walled lignified cells with numerous pits. Internal to these are vascular bundles with the leptome sheathed by small bundles of bast, while between the vascular bundles is a small-celled tissue. The pith is a large-celled aqueous tissue.

### Heliotropium sogdianum Bge.

This species which has been referred to several times in the preceding chapters (e. g. p. 123, 124), forms long horizontal

Fig. 63. *Heliotropium (Radula?).* Part of a horizontal rhizome with aerial shoots.

subterranean shoots from which aerial shoots arise, sometimes widely apart. A creeping stem of this type is shown (fig. 63) densely covered with shoots. At the base of these shoots, roots are often formed. The aerial shoots are frequently rosette-like. The older light-shoots have a white, glossy cortex covered externally with long stiff protruding hairs. The ovate or ovate-elliptical leaves are also stiff-haired. The length of the leaves is 1—1,5 (— 2) centimetres, the veins are very prominent on the lower surface and the depressions between them appear on the upper surface as convexities, so that the leaf has an embossed appearance.

The hairs on the upper surface are comparatively few, but thick and stiff; they are white and each one occupies a white circular base. On the lower surface these hairs are very numerous. The white flowers are out in May.

*Heliotropium Radula*, so far as it has been possible to determine the frequently sterile light-shoots, seems to have the same mode of growth and the same form of leaf and hair-coating as *H. sogdianum*. The hair-coating is, however, somewhat closer.

The leaf of *H. sogdianum* is isolateral. The epidermis is one-layered, densely hairy (with hair-cystoliths, see *H. dasycarpum* p. 222), and with slightly sunk stomata on both sides. There are about two layers of short, starch-filled palisade cells on each side. The veins are surrounded by translucent cells.

### Aristida pennata Trin.

This sand-binding grass has been already dealt with (p. 81—83). The thick, shrubby growth of the plant and its power of forming lateral shoots, which add to the tufts and when buried by the sand form new ones, makes this plant the "Conqueror of the Sand-desert" (Antonow) and the most valuable of all sand-binders.

It has been already recorded and illustrated (fig. 9) that the roots are encased by a sand-stocking. Within this stocking the root lies loose, "wie das Bein in der Hose oder, besser und ästhetischer ausgedrückt, wie eine Phryganeenlarve in dem selbst gebauten Gehäuse" (Volkens p. 26). Volkens points out that this sand-stocking is formed by the roots-hairs cementing the sand-grains together, and he is of opinion that its function is to protect the roots against evaporation. This is confirmed by the fact that in grasses provided with a sand-stocking, there is no cork or other corresponding means of protection.

My observations show that the root, which sits loose in the sand-stocking, is devoid of cortex. It is enclosed in a thick-walled pericycle consisting of several layers of prosenchymatous cells with numerous pores and containing starch;

outside this is a thin-walled endodermis which on its outward side bears shreds of the cortex.

The stocking itself was originally formed by mucilage secreted by the young root; later on the root-hairs penetrate the sand (R. Price), and long after they are dead, they keep the sand-grains bound together. Root-hairs are found on the epidermis which is still entire and forms the inner wall of the sand-tube. The internal diameter of the stocking

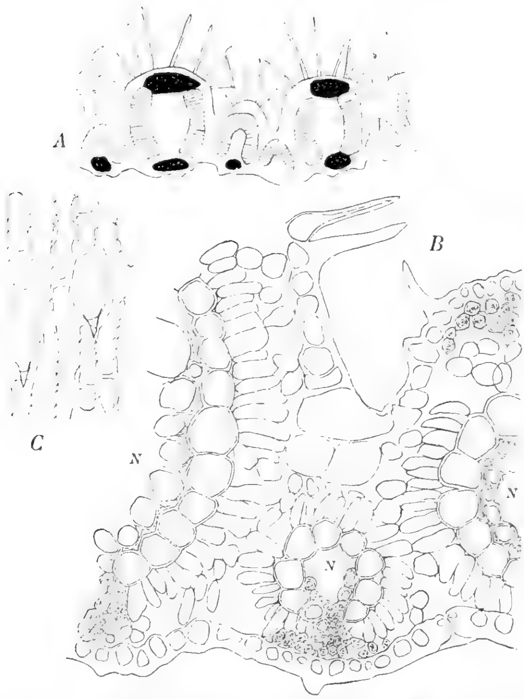


Fig. 64. *Aristida pennata.* *A*, Part of leaf in transverse section, slightly diagrammatic. Sclerenchyma black, green tissue shaded. *B*, Detail of *A*. *N*, Veins; *C*, Epidermis of the lower face with hairs. *A*, × 53; *B* and *C*, × 203).

thus indicates the original thickness of the root, but from the disappearance of the primary cortex the root becomes so thin that is lies loosely in the tube.

The straw or haulm is solid and the vascular bundles lie scattered in a somewhat thick-celled tissue; each of them has 3—4 vessels and a leptome group, while down both sides there is a strand of sclerenchyma.

The anatomy of the leaf has been described in the closely related, perhaps identical species, *Aristida pungens*, by Duval Jouve (tab. 17, fig. 7) and Tschirch (tab. 6, fig. 3). The Transcaspian specimens examined by me agree in their chief features with what has been found by these authors, yet it seems to me that the single cell-layer of the green tissue has a more pronounced palisade-form, and that the whole leaf has larger internal air-cavities than in the figures cited. Some figures of the structure of the leaf are given in fig. 64. The leaf can roll up towards the inner (upper) surface which has long hairs, and the epidermis includes hinge-cells. Like all *Paniceae*, the plant has the veins surrounded by a starch-sheath which is open on the leptome side in the larger veins, while round the smaller ones it is interrupted on both sides; this again is surrounded by a palisade layer. In my specimens the lower surface is also furrowed, though faintly, and in the furrows opposite the air-spaces amongst the green tissue of the "prisms" there are stomata which are slightly sunk; other parts of the epidermis are covered with short, pointed hairs (fig. 64, *B*, *C*).

## E. Therophytes.

It has been repeatedly stated in previous pages that some of the Therophytes are ephemeral spring-plants, while others — the smaller number — are summer-plants which persist through the dry, warm summer. The following includes observations on some of the species belonging to the latter group. The ephemeral species might likewise repay a careful investigation, for instance their variability as to xerophilous structure, depending on the soil and time of development, would be well worth examining. The material available did not, however, permit of such an investigation, particularly as regards anatomy. But the summer-plants seem to me more interesting, and during the journey my attention was chiefly directed towards them and towards collecting material of them.

### Cousinia.

Many Transcaspian species belong to this genus, most of them perennials. They are all rather broad-leaved, thorny, and frequently "cobweb-haired". *C. annua* and *C. dichotoma* were examined as examples of annual species. The former I found flowering in the sand-desert during the hottest time of summer. It was about half a metre high and had broad spiny leaves the axils of which bore rich dense inflorescences. The plant is glabrous, the stem snow-white and glossy.

The leaf is somewhat dorsiventral with two layers of palisade cells on the upper side and one on the lower, and a rather loose spongy paranchyma. The veins have bast-strands, the larger ones projecting as ridges on the lower face. They lie several together, quite separate or connected by a translucent aqueous tissue which merges outwards into a collenchymatous tissue.

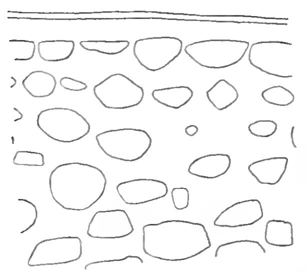

Fig. 65. *Cousinia annua*. Epidermis and collenchyma of stem. (× 203).

The epidermis is rather thin-walled and has stomata on both sides, slightly sunk.

The stem is without green tissue, and has a thick epidermis over a deep thick-walled collenchyma (fig. 65) all the way round.

*Cousinia dichotoma* is a smaller plant which may still be found flowering at the beginning of July, but it begins to wither about this time. The broad, spiny leaves still preserve their form and position because well-provided with sclerenchyma; they are somewhat dorsiventral and have stomata (not sunk) on both faces as in *C. annua*.

### Frankenia pulverulenta L.

A slender plant with decumbent branches. Like *F. hirsuta* (see p. 222) it occurs most frequently on somewhat moist soil. The leaves are small and flat with salt-crystals on both faces; the glands which are figured by Solereder

(p. 121), thus occur on both surfaces, and the same is the case with the stomata (in contrast to the statement made by Volkens l. c. p. 109). On the other hand, the long hairs are only found on the lower side. The leaf otherwise is dorsiventral with two layers of palisade cells on the upper side and a rather loose spongy parenchyma.

### Crozophora gracilis F. & M.

An herbaceous plant with outspread branches and long-stalked ovate-cordate leaves which are covered on both surfaces with a thick felt of stellate hairs. The plant occurs in places where the soil is not too dry, and it is still in flower in the month of July. The leaf is dorsiventral with one layer of long palisade cells on the upper surface, and one layer of short ones on the lower; there is no aqueous tissue. Crystal-cells are present in considerable number. The epidermis consists of one layer and has slightly sunk stomata on both leaf-surfaces.

### Euphorbia Turczaninowii Kar. Kir.
(E. carnosa Pauls.).

A thick-leaved, green, glabrous plant, attaining the height of about 10 centimetres. Like the previous species it occurs in more favourable localities. It is rarely found in flower in July although it frequently has fruits at that time of the year. The sessile, broad leaves are directed obliquely upwards, and are isolateral in structure. There is a thin epidermis with slightly sunk stomata on both surfaces.

### Euphorbia cheirolepis F. & M.

An erect plant with rather long internodes; habitat the sand-desert. The leaves are about one centimetre long, petiolate, obovate, spinose-toothed; the upper surface is shining and cobweb-haired, the lower is almost woolly-haired. They are dorsiventral, yet with stomata (slightly sunk) both above and below. The epidermis is thin. The dorsal side has a layer of long palisade cells over a spongy parenchyma which has its lowest (green) layer of cells slightly palisade-like, and below this is still another palisade-like layer of cells which is colourless and must be designated an aqueous tissue.


Fig. 66. *Ceratocarpus arenarius.* *A*, A young plant with green leaves and a few fruits in the axils. May. (natural size). *B*, An older plant, (reduced one-half). *C*, A branch of *B*, (× 2). The parenchyma has disappeared and the midribs remain as spines. August.

## Ceratocarpus arenarius L.

This very common plant occurs both on sandy and clayey soil; Fig. 66 shows its appearance. In spring the leaves are distinctly linear-lanceolate and bear single flowers in their axils (fig. 66, *A*). The plant is coated with stellate hairs. The leaves are isolateral with about two layers of palisade cells on each side and a number of crystal-cells. The midrib is surrounded by a thick sclerenchyma extending often from epidermis to epidermis. The small veins are surrounded by translucent storage cells. The epidermis consists of one layer, not very thick-walled, and has stomata (not sunk) on both sides.

In August *Ceratocarpus* resembles a spiny ball (fig. 66, *B*, *C*). The leaves are reduced so that only the midrib remains, and even if some still seem to retain their lamina, an anatomical examination shows that all the cells are collapsed and dead. At this season of the year all the leaves are thus reduced to thorns, and the assimilating functions are carried on by the two connate prophylls which form the two-thorned fruit-spathes (see fig. 66 *C*). A section of the wall of the fruit-spathe shows (fig. 67) that the inner surface is formed of two lignified thick-walled layers, the second of which shows no cell-cavities; beyond these skeleton-cell-layers there lies an assimilating parenchyma made up of one layer of short palisade cells and 1 or 2 layers of transverse cells loosely arranged. All the cells are filled with starch. The veins *(N)* are enclosed in bundles of bast above and below, especially the two veins situated near the two margins of the spathe.

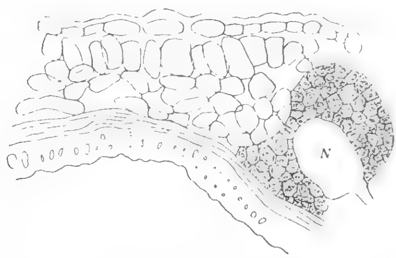

Fig. 67. *Ceratocarpus arenarius.* Transverse section of part of the fruit-spathe (Prophyll). (× 203.)

## Cornulaca Korschinskyi Litw.

An erect sand-desert plant thickly covered with short acicular leaves (fig. 68). Each leaf-axil gives rise to a rosette-shoot bearing many leaf-thorns, and in every leaf-axil, (i. e. on the lower parts of the leaves) there are a great number

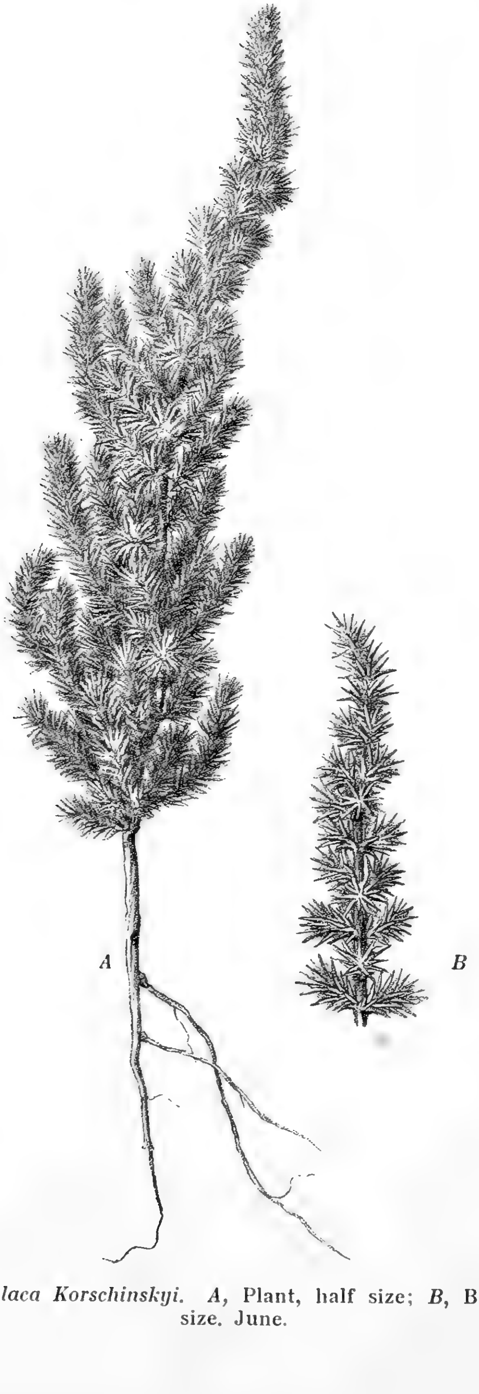


Fig. 68. *Cornulaca Korschinskyi.* *A,* Plant, half size; *B,* Branch, natural size. June.

of white, woolly hairs. These are slightly over 1 mm. long and are arranged in bunches. Each hair consists of one, two or three rows of cells, the thickness decreasing from below upwards (fig. 69).

The leaf is constructed after the ordinary centric type and resembles that of *Horaninowia ulicina* (fig. 71): There is an epidermis of one layer with large papillæ, a crystal-layer, one layer of palisade cells with a starch-sheath, a thin zone of aqueous tissue, and a thick sclerenchyma enclosing the vein.

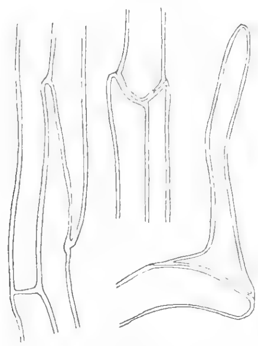

Fig. 69. *Cornulaca Korschinskyi.* Parts of axillary hairs. (× 302).

The small flowers do not open till autumn. The perianth remains round the fruit and bears a spine 4 mm. in length.

## Horaninowia ulicina F. & M.

A sand-desert plant with decumbent branches and acicular leaves. The branches may attain a length of 20—30 centimetres (see fig. 70), with long internodes between the pairs of opposite leaves. In the woolly-haired axils of the more or less cylindrical thornlike leaves, there are either rosette-shoots, or more or less elongated long-shoots, or flowers. The leaves on the main branch die rather early but the axillary shoots remain green.

In favourable localities the leaves may attain a length of a couple of centimetres, and the shoots are erect (*var longifolia.*)

With regard to the structure of the leaf and stem, reference to fig. 71 renders any description unnecessary. The

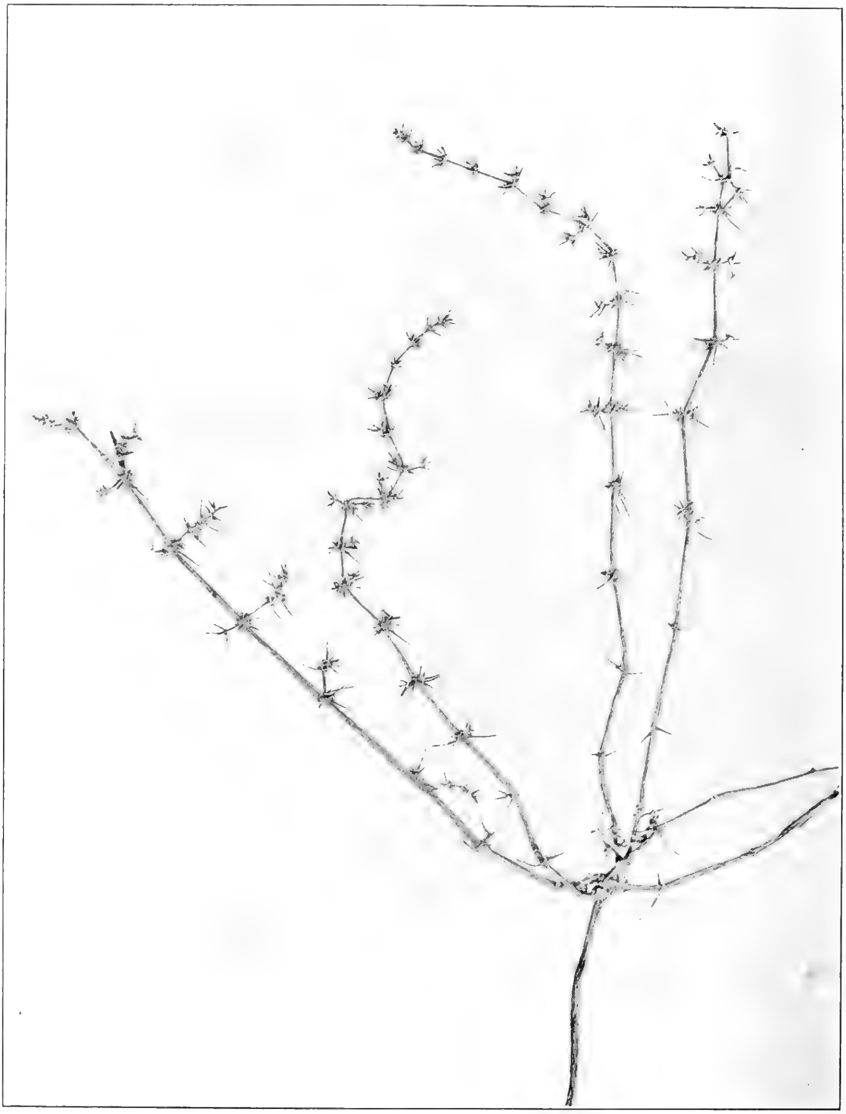

Fig. 70. *Horaninowia ulicina.* Part of a plant. July.

stem has bands of green tissue alternating with bands of collenchyma (fig. 71 *C*).

## Agriophyllum minus F. & M.

A strongly branched, thorny-leaved sand-desert plant which may attain a height of about 30 centimetres: fig. 72 illustrates a small specimen. The leaves are up to 3 cm. long, flat with stellate hairs, hard in texture, parallel-veined and traversed by parallel ribs and furrows, and terminate in a spine. The lower ones are lanceolate, but higher up they become narrower. The leaf-axils bear short-shoots with

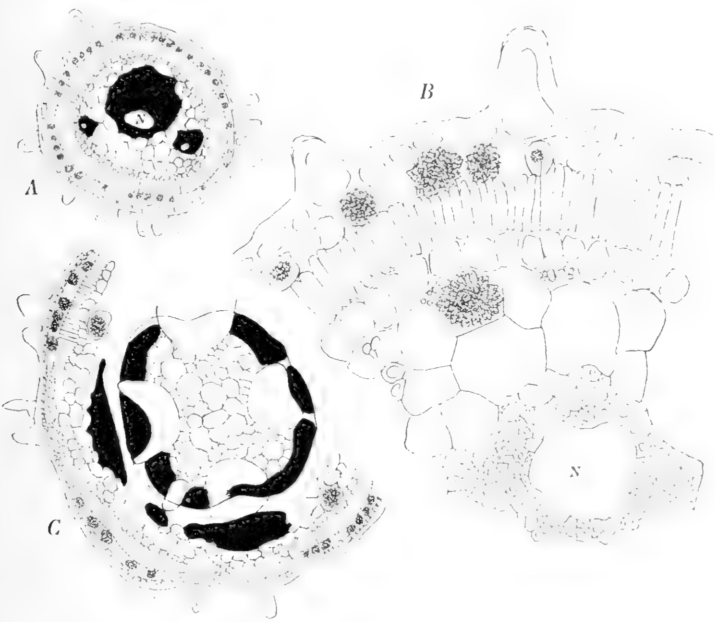


Fig. 71. *Horaninowia ulicina.* *A*, Transverse section of leaf; *N*, Vein. *B*, Detail of *A*. *C*, Part of transverse section of stem. Sclerenchyma black, collenchyma dotted, palisade tissue shaded. (*B*, × 203; *A* and *C*, × 53).

leaves which are quite narrow, acicular and ending in a straw-coloured spine. The flat leaves die away in the course of summer, while the short-shoots remain green.

The structure of the isolateral leaf will be seen from fig. 73. The superficial ribs consist of bands of sclerenchyma. There are one or two layers of palisade cells on each side, and translucent cells with numerous crystal-cells in the middle.

The stem shows bands of collenchyma alternating with bands of green tissue which have about two layers of low palisade cells supported by transverse storage-cells. Where root and stalk merge into one another, the axis is thickened and succulent. No green tissue occurs here but the collenchyma extends all round.

Fig. 72. *Agriophyllum minus.* June.

## Agriophyllum latifolium F. & M.

This resembles the previous species, but the lower leaves, which gradually disappear, are ovate-elliptical to broadly cordate with pinnate venation (fig. 74). They are covered with scattered stellate hairs and end in a spine. Higher up the plant the leaves become narrower with the spine longer; the uppermost leaves as well as the leaves of the rosettes are sessile and acicular as in the previous species. The leaf is not ribbed as in *A. minus* but the structure of the green tissue is almost the same. The veins have a thick bast-


Fig. 73. *Agriophyllum minus.* *A*, Transverse section of leaf, showing the distribution of sclerenchyma (black), palisades (striped) and veins *(N)*. *B*, Detail of *A*; *N*, Veins (*A*, × 53; *B*, × 203).

sheath and a strand of bast runs along the margin. The stem (fig. 75) has thick hypodermal ribs of sclerenchyma and is better provided with green tissue than the previous species. Lying within the palisade tissue there is a layer of storage cells interrupted by the bast-bundles of the leptome.

Salsola.

This genus includes a number of leaf-succulents some of which are thorny (*S. Kali, aperta, sogdiana, Androssowii*) while others (*S. crassa, lanata, clavifolia*) are thornless; also some

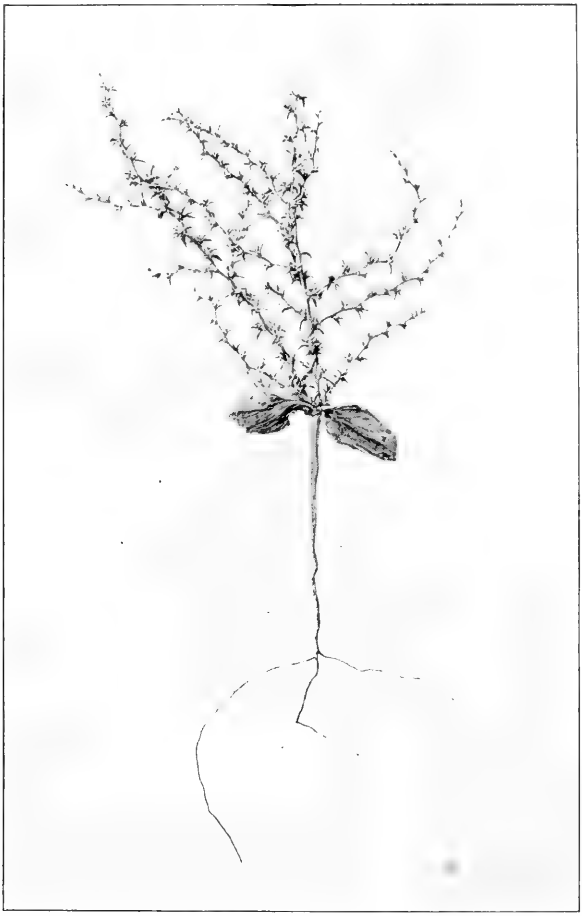

Fig. 74. *Agriophyllum latifolium.* June.

bracteole-succulents (comp. above p. 71), namely, *Salsola spissa* (fig. 8), *incanescens* and *sclerantha.*

I have examined *S. sogdiana* (fig. 76) and *S. aperta* both of which have thorny-pointed, semicircular leaves, and found them to have the ordinary centric structure like *S. Kali* (see

Warming 1897 p. 216). The bracteoles in *S. spissa* and *S. sclerantha* are similar in structure. The latter species is white-haired.

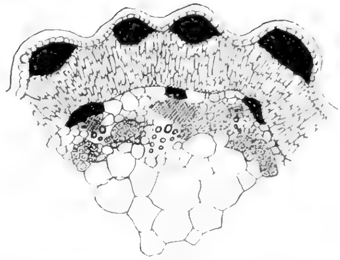

Fig 75. *Agriophyllum latifolium.* Part of a transverse section of stem. Bast in black, leptome cross-hatched. (× 53).

Halocharis hispida C. A. M.

A clay- and salt-plant with stiff hairs which give it a greyish colour. The leaves are more or less cylindrical and long-haired, especially at the apex; they are very closely arranged on short-shoots arising in the leaf-axils. These short-shoots

Fig. 76. *Salsola sogdiana* in fruit. June.

may stand so close at the tips of the branches that the plant becomes almost globular.

The anatomy of the leaf is of the ordinary centric type. There are two sorts of hairs: some are long stiff multicellular hairs, but more abundant are the short, stiff unicellular ones. No hypodermal layer of crystal-cells is present, but these cells are numerous in the green tissue and in the aqueous tissue. The epidermis is one-layered, with stomata slightly sunk.

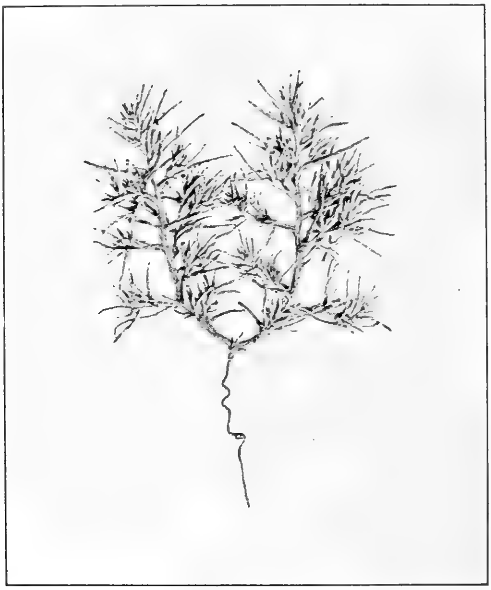

Fig. 77. *Halimocnemis pilosa.* July.

## Halimocnemis.

This genus is characterised by the ripening fruit, the perianth of which developes no wings or other protuberances, whereas the leaves harden and coalesce thus forming a protective cupule in which the fruit is placed. The species are true summer-plants growing on clayey and saline soil.

The habit of *H. pilosa* is illustrated (fig. 77), and related to this we have *H. macranthera* and *H. villosa.* These species have long triangular and hairy leaves, the upper ones subtending the solitary flowers.

*H. villosa* and *macranthera*, probably also *H. pilosa*, have leaves constructed after the ordinary centric type. Since the leaf is thick the aqueous tissue in the middle is large; the midrib has a bast-sheath; the hairs consist of a basal cell and a long filamentous cell; the stomata are not sunk.

The leaves of *H. Karelini* (fig. 78), a bracteole-succulent, are similar in structure; they have very short hairs and the stomata are slightly sunk.

Closely related to the long-leaved species of *Halimocnemis* both in appearance and inner structure we have *Halanthium gamocarpum*, and probably also *Piptoptera turkestana*, the anatomy of which I have not examined.

Fig. 78. Branch of *Halimocnemis Karelini*. July. (Nat. size).

### Suaeda.

The leaves of a number of species of this genus have been examined. As regards leaf-structure these may be divided into three groups.

The leaf-structure of the species of the first group is similar to that already described for *S. maritima* (see for instance Warming 1897, p. 207, 1890, p. 221). Below the thin-walled epidermis there is a green mesophyll of palisade-like cells which become larger and contain less chlorophyll towards the interior; the veins lie in a curve in the middle of the leaf. Other species belonging to this group are: *S. setigera* and *S. Olufsenii* (from Pamir), also *S. linifolia* which differs in having flat leaves with ordinary isolateral green-tissue.

The second group of *Suaeda* has underneath the epidermis a single layer of palisade cells all round and a starch-sheath below this (fig. 79, *B*). Thus far these leaves follow the ordinary centric type of the *Chenopodiaceae*. But those veins, which in other organs of this type run obliquely through the central aqueous tissue and arrange themselves beside the starch-sheath, are here wanting. The aqueous tissue must therefore be capable of translocation and we also find that all its cells contain chlorophyll, though very little.

The veins, like those in the first group, lie in a curve with the concave side upwards (fig. 79, *B*). In longitudinal section they are seen to branch reticulately within the curved plane, the transverse section of which is the curve mentioned, but not outside it. To this second group belong *S. pterantha*, *altissima*, *Lipskii*, *arcuata* and *dendroides*.

*S. microsperma* is the only one of the species examined by me which belongs to the third group. As shown in

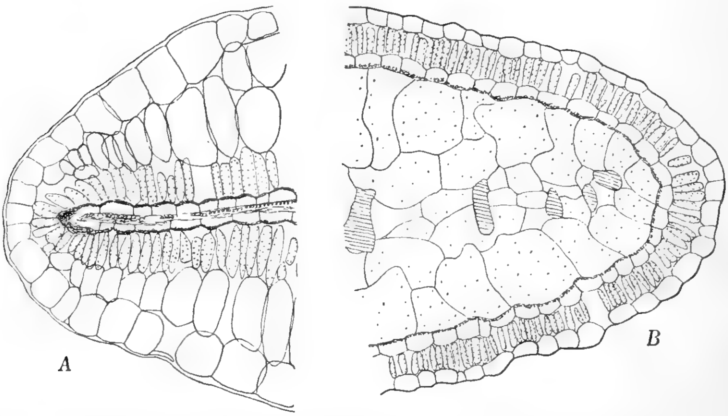


**Fig. 79. Transverse sections of: *A, Suaeda microsperma*; *B, Suaeda Lipskii*. In *B* the veins are indicated by horizontal hatching. (× 203).**

fig. 79, *A*, the palisades and the starch-sheath of this species lie internal to the aqueous tissue which is quite translucent. The starch-sheath immediately adjoins the arc in which the veins run and branch.

## Halopeplis pygmaea (Pall.) Bge.

A halophyte with sheathing and almost globular leaves. The epidermis is not very thick and the stomata are not sunk. About three layers of rather loosely arranged palisade cells are present, abutting internally on the network of finer veins which in turn are linked up with the primary vein by larger branches. Internal to this network of finer veins there is a translucent aqueous tissue. The structure of the leaf thus resembles that of *Halostachys caspica* (see above p. 201).

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Some of the herbaceous plants described under C, D and E, are Halophytes e. g. *Halopeplis, Suaeda, Halimocnemis, Salsola, Halocharis, Anabasis, Statice* and *Zygophyllum.* With the exception of the two last-named they are *Chenopodiaceae* and have thick assimilating organs of the centric type, which is also the case with the vicarious branches of *Statice.* Linked with *Zygophyllum* we have *Euphorbia Turzaninowii*, both being thick-leaved and isolateral. Other representatives of the *Chenopodiaceae* are xerophytic plants *(Cornulaca, Horaninovia, Agriophyllum, Ceratocarpus).* They are spiny, with the assimilating organs thin and not succulent, but in the two first-named the same centric structure is observed, although on the whole they are better provided with sclerenchyma; to the same category belongs *Dodartia.* — *Heliotropium* and *Cousinia* are more nearly related to the hemicryptophytes with a more pronounced mesophytic structure (see p. 237) since they have flat leaves not much modified. Such leaves are as a rule isolateral, but dorsiventral also occur *(Frankenia, Euphorbia, Crozophora).*

The fruits exhibit a variety of types.

The material of herbaceous plants available is however insufficient to furnish a reliable general summary of the conditions of structure. The foregoing must therefore be regarded as a series of examples illustrating the different modes of adaptation to the conditions of life in Transcaspia.

If we endeavour, in conclusion, to summarise the features of all the plants described in this chapter, — keeping, however, *in mente* the Spring-plants — it is possible to formulate under three heads some of the specially characteristic features of Transcaspian desert-plants.

1. The difficulty attending the development of long-lived aerial shoots. In this connection one must consider

the large number of spring-plants with light-shoots which only live a short time, and also the chamaephytes and fanerophytes on which annual shoots are common, but where the persistent shoots of most species lose their distal parts.

2. Reduction of the leaves. It is a well-known feature of deserts that the leaves become small or disappear entirely. As a rule the stem assumes the part of vicar, it may be in some cases where leaves are still present, as assistant vicar, or in other cases, where leaves are entirely wanting, as deputy-vicar (B. Jönsson 1910). Boirivant has proved by experiments a correlation between absence of leaves and formation of assimilating tissue in the stem.

3. The frequency of the centric type of assimilating organs (in and outwith the *Chenopodiaceae*) and of isolateral leaves. Isolateral structure seems to be specially dependent on strong light (Heinricher), and it must promote the process of assimilation. The xerophytic structure of the assimilating organs is likewise a well-known feature in desert plants as recorded in the various text-books on plant-geography; see also Henslow 1893, with whose interpretation, however, I do not agree.

# SECTION IV. THE FLORA OF THE TRANSCASPIAN LOWLANDS.

## CHAPTER 14

### The Elements of the Flora.

When at the beginning of the Quaternary period Transcaspia emerged from the sea which retreated towards the West and North, a change in climatic conditions took place simultaneously in the various parts of Western Asia previously washed by this sea. In this earlier period the climate, which was probably rather moist, had been favourable to the growth of plants and had resulted in a luxuriant and fairly homogenous flora developing over the immense area between the Himalaya and the Pyrenees. When the sea disappeared the climate became dry. The plants came under the influence of a very different environment so that they were compelled to change. Only in the northern part of the Elburs and the western part of the Caucasus, near two great inland seas, are luxuriant forests still found which are regarded as the last, though perhaps somewhat altered, remnants of the old tertiary vegetation of Western Asia. The rest of the plants must either die or adapt themselves to the new conditions. At the same time the Aralocaspian lowlands, left by the sea, were open to immigration from the neighbouring countries. The result of the changes which took place was a new flora, xerophytic and especially adapted to a climate with a short vegetative period, but which was — and is — otherwise closely related to the elements of the flora of the Mediterranean lands with which they have a common origin[1].

If the development took place as indicated here according to ENGLER, it is evident that the flora of Transcaspia must for the most part have originated from that of Western Asia, and that the plants must have descended from the mountainous parts towards the South and East (comp. BORSCZOW, above p. 30). Southern Russia cannot come under consideration as a starting point for the species which populated Transcaspia, because large tracts of it at the beginning of the quaternary period (SJÖGREN, see also KARPINSKI) were covered by water (the Aralocaspian Sea) and this "Caspian Transgression" probably originated in ice-water from the margins of the great European ice-sheet, so that the climate must have been cold. With regard to the climate of Western Siberia at that period there is no information, but it must also have been cold, colder than now, therefore the possibility of immigration from there need not be considered.

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[1]) ENGLER 1879, pp. 57 and following, 184 and following.

If the flora of Transcaspia originated thus from species which at the end of the tertiary period or the beginning of the quaternary period immigrated from the neighbouring mountains, it is natural to expect that many endemic species have developed. For all the factors of the lowlands, cosmic as well as terrestrial, differ from those of the highlands; besides, for many plants Transcaspia has been a closed basin enclosed towards the South and East almost everywhere by mountains — the Balchash basin being included — and barred towards the West by the Caspian, and towards the North by the cold.

A third condition favourable for the evolution of endemic species is the dryness of the climate, and consequently a very scattered plant-covering. There is no internecine struggle among the plants themselves, but always sufficient open ground available; they have only the conditions of the environment to contend with (comp. Engler 1882, pp. 48, 324; Vahl p. 154).

Moreover it is natural that there should be a close floristic relationship between Transcaspia and the surrounding mountainous parts. This relationship must be closest towards the South, since the country towards the East rises to a far greater height than towards the South where the natural conditions must resemble those of Transcaspia more closely.

Utilising the records of distribution given in the plant-list in chap. 12, we shall endeavour to formulate some conclusions which may be of interest with regard to these questions.

The 768 Transcaspian species enumerated in the plant-list (chap. 12) may be assigned with respect to their distribution outside Transcaspia to the following eight groups (comp. p. 138):

1. Endemic species, 169 or 22 p. cent.

2. Species distributed only towards the South (Western Asia), denoted in the list by V: 142 or 18 p. cent.

3. Species distributed only towards the North (Russia) denoted in the list by R: 29 or 4 p. cent.

4. Species distributed towards the East (High-Asia) denoted in the list by H: 83 or 11 p. cent.

5. Species distributed towards the North and South, but not towards the East, denoted in the list by RV: 56 or 7 p. cent.

6. Species distributed towards the East and South, but not towards the North, denoted in the list by HV: 68 or 9 p. cent.

7. Species distributed towards the East and North, but not towards the South, denoted in the list by HR: 52 or 7 p. cent.

8. Species distributed equally towards the East, North and South, denoted in the list by HRV: 169 or 22 p. cent.

From these statistics it follows by addition that 372 species (48 p. cent.) are distributed towards the East, 306 species (40 p. cent.) towards the North, 435 species (57 p. cent.) towards the South, while 169 species (22 p. cent) are endemic.

These figures form the basis of the following conclusions, but their accuracy must only be regarded as more or less comparative. As previously stated, the flora of Transcaspia is insufficiently investigated, and to a still greater extent is this the case with several of the neighbouring countries, especially Persia and Afghanistan. This will naturally involve mistakes in the figures given above. Another source of error is that the species are differently interpreted by the various authors who have described the plants of these countries, and no descriptive floras have been compiled for the countries in question. I have in several cases been obliged to decide according to my own judgment. Of course I believe that I am right in general, but future investigations on the flora of these countries may prove that many species which in this memoir are recorded as common to several territories ought to be divided into more species, each one endemic to its own territory, or that species which are here regarded as endemic to Transcaspia are identical with species in other countries.

The figures given above must therefore be treated with caution, and conclusions drawn from them can only be regarded as rough estimates.

As endemic species I have reckoned not only those occurring within the territory defined in chap. 1, but also species which likewise occur in the Balchash-basin, with natural conditions which to my knowledge are almost identical with those of Transcaspia and without transition. Dsungaria, on the contrary, is left out, and species which are also found there are classed under those with an eastern distribution (denoted H). In my opinion this was necessary, firstly in order to fix a boundary between the eastern and the endemic species; secondly because Dsungaria, though much the same in character as the Balchash-basin, yet for the greater part lies higher and according to BUNGE (1880, No. 26) it also differs to some extent in phytogeographical respects from the countries lying to the west.

Nor are plants occurring in the areas north of the Aral Sea regarded as endemic. It is impossible to fix any natural well-defined boundary between Transcaspia in the south and the Kirghiz-steppe in the north, but the boundary I have selected, the $46^{th\,0}$ northern parallel of latitude, cannot be far wrong as it is confirmed in the recently published work by SAWITCH. This memoir shows that several plants which are common in Central Europe also occur in the desert north of the Aral Sea (see p. 5).

The census shows that there are 169 endemic species in the Transcaspian lowlands, that is 22 p. cent. of the total number of species. If the area had been differently defined so as to be wider in extent and to include for instance the the whole of West-Turkestan inclusive of the mountains, it is possible that the endemic percentage might be increased, but then it could not be regarded as an expression of, or to be connected with, the homogeneous natural conditions which pervade and have pervaded the Transcaspian lowlands. Since the area has been confined within such narrow limits, we must have a certain right to see such a connection, remembering, however, that the endemism is dependent not only on the number of species formed, but also on the faculty of migration and adaptation of these species. The endemism would have been still greater if the northern boundary of our territory had been moved farther north. If the Kirghiz steppe and the eastern part of Ciscaucasia to the Jergeni mountains had been included, a number of Chenopodiaceae (e. g. *Nanophytum, Alexandra, Ofaiston*), *Calligonum* spp. and *Ammodendron* would be regarded as endemic. But as already indicated the natural conditions and the vegetation are rather different in these more northern areas.

The distribution of the endemic species amongst the various growth-forms will be seen from the following table 6:

**Table 6.**

| | F. | Ch. | H | G | HH | Th |
|---|---|---|---|---|---|---|
| Endemic species p. ct...... | 17 | 6 | 32 | 11 | 0 | 34 |
| Transcaspian „ „ ..... | 11 | 7 | 27 | 10 | 5 | 40 |

The endemic species are thus distributed over the growth-forms in about the same proportion as the aggregate flora of the desert. The following variations may be of some interest: 1) There are no endemic aquatics and marsh-plants whatever; 2) The endemic species include comparatively greater numbers of fanerophytes and hemicryptophytes than the aggregate species; 3) The endemic species include comparatively fewer annuals than the aggregate.

The first variation is not surprising since it is well known that aquatics and marsh-plants have a wide distribution (see e. g. Drude p. 317).

The last point, that there are comparatively few endemic therophytes, may be explained thus: the therophytes are as a rule spring-plants, and many of these have a wide distribution because over considerable tracts of regions with winter-rains they find almost the same conditions during the short vegetative period. In accordance with this at least 28 p. cent. of the endemic therophytes are late-flowering, in comparison with 21 p. cent. of the total therophytes of the whole flora (comp. table 4, p. 162). The second point of variation suggests that the natural conditions of Transcaspia have been favourable to the development of fanerophytes and hemicryptophytes. This does not seem unnatural since the fanerophytes are one of the most prominent and apparently one of the best adapted types in the deserts. As regards the hemicryptophytes, about 30 out of 55 endemic species are spring-plants and about 25 are xerophytes (most of which, however, shed their blossoms before July 1. comp. p. 162). Unfortunately I have not been able to draw up sufficiently reliable comparative figures for the whole flora. If what has been stated about the annuals be taken as a starting point, it might be expected that the xerophytic hemicryptophytes were comparatively better represented among the endemic species than the mesophytic ones; but I am unable to decide this question.

The 169 endemic species belong to 83 different genera. Only 7 of these genera are endemic namely:

*Borszcowia* Bunge. (Chenopodiaceae).
*Piptoptera* Bunge. (Chenopodiaceae).
*Chartoloma* Bunge. (Cruciferae).
*Cithareloma* Bunge. (Cruciferae).
*Smirnowia* Bunge. (Papilionaceae).
*Holopleura* Rgl. & Schm. (Umbelliferae).
*Miltianthus* Bunge. (Zygophyllaceae).

These genera are monotypic except *Cithareloma*, which has two species.

Of the two *Chenopodiaceae*, *Borszcowia* is closely allied to *Suaeda* and *Bienertia*, while *Piptoptera* is related to *Halanthium* and other *Anabaseae*. Thus both belong to groups of plants which are widely distributed in Transcaspia and surrounding countries.

The two *Cruciferae* are doubtless well-established genera, but both have some near relatives: *Chartoloma* is closely allied to *Isatis*, *Tauscheria* and *Sameraria*, of which *Tauscheria* is indigenous in the interior of Asia while the other two occur in western Asia and the eastern Mediterranean countries. *Cithareloma* is related to a number of oriental *Hesperideae*, such genera as *Farsetia*, *Eremobium* (N. Africa) and *Malcolmia*.

The validity of the genus *Smirnowia* likewise seems to be well-founded, in fact it stands amongst the endemic genera as one of the most isolated. It is allied to *Sphaerophysa* which likewise belongs to the interior of Asia, and to *Colutea* which is distributed from the south of Europe to the western Himalaya.

*Holopleura*, so far as I can learn, is insufficiently known and there may be some doubt as regards its right to generic rank. Regel says that it is related to *Carum* and *Rumia*. *Miltianthus* is related to *Zygophyllum*.

Among the endemic species scarcely any one stands isolated. Whichever one be named, it is possible to indicate closely related species in the surrounding countries, more especially those towards the South and South-west. Through more intensive systematic studies one could probably enumerate a series of pairs of vicarious species. Studies of this kind have not been undertaken here, as I have restricted myself to the investigation of the distribution of the genera which contain endemic species in the lowlands of Transcaspia. The following genera have their main distribution in the Mediterranean countries, especially in the eastern ones, and in Nearer Asia whence some of them extend right into Central Asia.

| | | |
|---|---|---|
| *Heliotropium* | *Pterotheca* | *Allium* |
| *Lappula* | *Scorzonera* | *Limodorum* |
| *Rochelia* | *Convolvulus* | *Cistanche* |
| *Gypsophila* | *Isatis* | *Hypecoum* |
| *Herniaria* | *Malcolmia* | *Trigonella* |
| *Saponaria* | *Peltaria* | *Crucianella* |
| *Silene* | *Sisymbrium* | *Haplophyllum* |
| *Centaurea* | *Crypsis* | *Scrophularia* |
| *Echinops* | *Lepturus* | *Tamarix* |
| *Jurinea* | *Lagochilus* | *Cachrys* |
| *Rhaponticum* | *Phlomis* | *Ferula* |
| *Matricaria* | *Tulipa* | *Valerianella* |

The following genera seem to have their main distribution more to the East, in the interior of Nearer Asia and in Central Asia:

| | | |
|---|---|---|
| *Eminium* | *Salsola* | *Ammothamnus* |
| *Acanthophyllum* | *Cousinia* | *Oxytropis* |
| *Agriophyllum* | *Lachnophyllum* | *Calligonum* |
| *Anabasis* | *Eremostachys* | *Aphanopleura* |
| *Cornulaca* | *Hypogomphia* | *Cryptodiscus* |
| *Girgensohnia* | *Eremurus* | *Hyalolaena* |
| *Halanthium* | *Rhinopetalum* | *Psammogeton* |
| *Halimocnemis* | *Ammodendron* | *Zygophyllum* |

The following genera have a wide distribution mainly in warm-temperate countries (or tropical):

| | | |
|---|---|---|
| *Cleome* | *Aristida* | *Lactuca* |
| *Cuscuta* | *Iris* | |
| *Euphorbia* | *Astragalus* | |

There still remain some large widely distributed genera:

| | | |
|---|---|---|
| *Artemisia* | *Plantago* | *Ranunculus* |
| *Elymus* | *Delphinium* | *Carum* |

These genera are distributed over so large an area that only a closer study could elucidate where the Transcaspian endemic species of these genera have their nearest relatives.

Leaving out of account the 6 genera last-named which are represented by 9 endemic species, all the rest of the plant genera containing endemic species in Transcaspia have their main distribution towards the South, most of them in the Mediterranean countries and in Western Asia. This is an indication that the flora of Transcaspia is closely allied to the flora of these countries.

The natural orders which contain endemic species can be ascertained by reference to the list of plants (pp. 138—158). More than one example of endemism is to be found in the following families:

| | Number of endemic species | | Percentage of total species |
|---|---|---|---|
| *Papilionaceae* | 31 | (24 *Astragalus*) | 36 p. ct. |
| *Compositae* | 28 | (9 *Cousinia*, 8 *Scorzonera*) | 27 „ |
| *Chenopodiaceae* | 17 | (5 *Salsola*) | 18 „ |
| *Polygonaceae* | 14 | (*Calligonum*) | 54 „ |
| *Umbelliferae* | 10 | | 32 „ |
| *Liliaceae* | 9 | | 37 „ |
| *Caryophyllaceae* | 8 | | 32 „ |
| *Cruciferae* | 8 | | 16 „ |
| *Labiatae* | 6 | | 30 „ |
| *Zygophyllaceae* | 6 | | 44 „ |
| *Gramineae* | 5 | | 11 „ |
| *Orobancheaceae* | 4 | | 66 „ |
| *Convolvulaceae* | 4 | | 36 „ |
| *Borraginaceae* | 3 | | 7 „ |
| *Ranunculaceae* | 3 | | 13 „ |
| *Rutaceae* | 3 | | 50 „ |

Only a few orders contain no endemic species at all, for instance *Cyperaceae*, *Geraniaceae*, *Plumbaginaceae* and none of these orders are rich in species in Transcaspia.

The *Papilionaceae* take first place as regards endemism, and this is especially due to the numerous species of *Astragalus* the majority of which belong to the sub-genus *Cercidothrix* which has bifurcate hairs.

It is characteristic that several of the smaller families are comparatively rich in endemic species, thus half of the *Rutaceae* and two-thirds of the *Orobancheaceae* are endemic likewise one-third of the *Convolvulaceae*, *Liliaceae* etc. The one species of *Araceae* and the only Orchid are both endemic.

Endemism in Transcaspia may according to the preceding be denoted as recent, i. e. it has arisen from the development of species within a period not very remote in the geological sense. There are no forms at all standing quite isolated and showing indications of being relicts, but there are endemic species in almost all the natural orders and in several of the larger genera.

The result we have arrived at does not, therefore, conflict with the theory of the migration of the flora into Transcaspia at the beginning of the quaternary period (see above p. 259). The great number of endemics moreover confirms ENGLER's assertion that dry areas (he also mentions "the Asiatic Steppes") whence a great number of plant types are excluded give rise to endemic species[1]).

Among the non-endemic species of Transcaspia we distinguish between those which have a northerly, those which have an easterly and those which have a southerly distribution (see above p. 260).

Northerly distribution is seen in such species as are distributed from Transcaspia over western Siberia and South Russia. The limit is fixed at about 46° N. Lat. (see above p. 262). Of such plants there are 306 or 40 p. cent. of all the species of Transcaspia; in the plant-list they are the species with the letter R included in the distribution-index. This is no small number, but the importance of the figure is lessened when we remember; (1) that with the exception of 29 of the 306 (9 p. cent.), they are equally distributed towards the east and south; (2) that only 96 species (12 p. cent. of the total number of species) are common to both Transcaspia and the government of Yekaterinoslaw, (these are indicated in the list by R*). The first of the above points emphasises that the species occurring towards the North are on the whole widely distributed. The 29 species referred to (those indicated in the list merely by R) do not even extend far northwards, only one of them *(Erodium Hoefftianum)* is found as far north as Yekaterinoslaw. Most of them occur on the Kirghiz steppe which as already stated is very similar to Transcaspia. Nor do many of the remaining plants with a northern distribution reach the true steppe or forest areas.

As regards the second point (2), the number of species common to Transcaspia and Yekaterinoslaw, it may be remarked that, with the exception a few *Chenopodiaceae* and *Lycium* and *Statice,* the species common to both countries

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[1]) 1879 p. 10, 1882 p. 50.

belong to the mesophytic aspect, and that all except *Erodium Hoefftianam* are species with a wide distribution; only a small number of them have not also an easterly and a southerly distribution in relation to Transcaspia.

Easterly distribution is seen in the plants occurring in the mountainous countries towards the East, i. e. from Hindukush, Badakshan, Hissar, Pamir to Tibet, Tianshan and Dsungaria (comp. p. 262). This category includes 372 plant-species or 48 p. cent. of the total species of Transcaspia (in the list the letter H occurs in their distribution-index). Of these 372 species, 83 or 22 p. cent. are not distributed towards the North and South (indicated in the list by H alone). Many of the 372 species occur only in Dsungaria, (as to the similarity and dissimilarity between this country and the Balchash-basin see p. 262). As a test of the distribution of Transcaspian lowland plants over really high mountains, I have summed up the species this country has in common with the Pamirs (according to the boundaries given by Olga Fedtschenko). Such species are denoted in the list by H*, and there are 41 (5 p. cent. of the total number of species). Only a few of these (*Nitraria* and a few *Chenopodiaceae*) belong to the xerophytic aspect. They are all species of wide distribution, and most of them also occur both towards the North and South.

Southerly distribution is seen in plants which beyond Transcaspia are distributed over larger or smaller parts of Afghanistan (Badakshan, however, being reckoned as part of High-Asia), Persia, Asia Minor, Syria and onwards to the Mediterranean countries, including North Africa.

There are 435 plants or 57 p. cent. with a southerly distribution — their distribution-index in the list contains the letter V — against 40 p. cent. with a northerly and 48 p. cent. with an easterly distribution. Thus more than half the plants of the Transcaspian lowlands have a southerly distribution. Of the 435 species, 142 or 33 p. cent. (18 p. cent. of the total number of species) have no distribution towards the North or East, they are thus Western-Asiatic species which avoid the higher mountains and the higher degrees of latitude. (In the list they are indicated by V alone). Recapitulating the above, we have that the "northerly" plants include only 9 p. cent. which are exclusively northern, the "easterly" ones 22 p. cent. exclusively eastern, while the "southerly" plants include 33 p. cent. exclusively distributed towards the South.

These figures as in the case of the percentage for the total distribution, show that the Transcaspian lowlands are most closely related to the countries lying towards the South and South-West, and most distantly related to the countries lying towards the North. This is the case though the Transcaspian lowlands towards the North are open and without any natural boundary, while in every direction towards the South they are hemmed in by mountains.

This result is further confirmed if we take into consideration the species which the Transcaspian lowlands have in common with Syria and Palestine (166 species, Post, indicated in the list by V*), or with Egypt (91 species, Ascherson & Schweinfurth); that is respectively 22 and 12 p. cent. of the total number of species. About one-third of these (Syria 30, Egypt 29 p. cent.) do not occur either east or north of Transcaspia, and less than half of them (Syria 39, Egypt 41 p. cent.) are widely distributed species which are also found north and east of Transcaspia.

Compare with this what has been stated about species common to Yekaterinoslaw and to Pamir. Here almost all the species in common have a wide distribution; this community therefore indicates a more distant relationship than that between areas with species in common which show a more limited distribution.

Though derived from imperfect and somewhat scanty materials, our figures point in the right direction, as they have shewn us that the Transcaspian lowlands in their floristic as well as their biological aspects (comp. above p. 160) are more closely related to the countries towards the South. This result will probably be further confirmed by future systematic investigations within the individual genera or families. Such investigations are already being carried on, and we may illustrate them by a short summary of Professor Kusnezow's interesting investigations on *Rindera* Pall., a genus of *Borraginaceae.*

As the result of careful morphological and anatomical studies of the species of *Rindera,* it appears that the sub-genus *Mattia* is the "central-type" of the genus, from which the sub-genera *Cyphomattia* and *Eurindera* have developed each in its own way.

Kusnezow presumes that the ancestors of *Rindera* (and *Paracaryum*) at the beginning of the tertiary period were widely distributed over the earth; the last remnants of them are the two existing monotypes: *Tysonia* in south-eastern Africa and *Myositidium* in New Zealand.

During the latter half of the tertiary period *Rindera* must have been widely distributed in the Mediterranean countries (from Spain to Central Asia), and the genus at that period had two sub-genera: *Mattiaria* (now one species) and *Mattia* (now 6 species). These seven species are constant with no intervening transitions, and they have small and well-defined areas of distribution from Algeria to Persia, — they must be regarded as relict forms.

At the end of the tertiary period when the lowlands were drying up, Kusnezow considers that the five species of the sub-genus *Eurindera* were evolved in the mountains of Turkestan; these species are harder to distinguish than those of *Mattia.* One of them, *Rindera tetraspis,* had the faculty of migration so that after the drying-up of the Transcaspian lowlands it was able to propagate here as well as in Western Siberia, South Russia and Ciscaucasia.

Simultaneously with *Eurindera,* there came into existence in Nearer Asia from *Mattia* the two species of the sub-genus *Cyphomattia* of which one, *Rindera lanata,* is very polymorphic and widely distributed.

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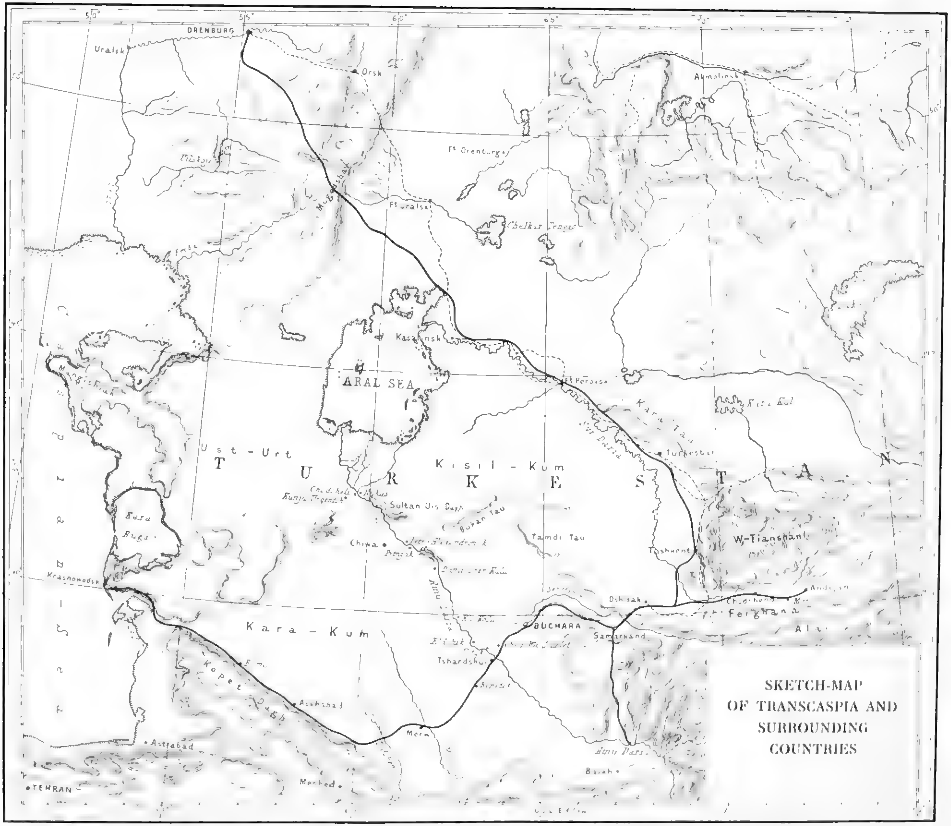


SKETCH-MAP OF TRANSCASPIA AND SURROUNDING COUNTRIES

# THE SECOND DANISH
# PAMIR
# EXPEDITION

CONDUCTED

BY

O. OLUFSEN
Lieutenant of the Danish Army

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## STUDIES IN THE VEGETATION OF PAMIR

BY

OVE PAULSEN
Member of the Expedition

WITH 30 FIGURES AND A MAP

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# OVE PAULSEN

## STUDIES IN THE VEGETATION OF PAMIR

*. . . . . Balaxiam, and direct our way towards Cathay, betwixt the east and north-east. Beyond Balaxiam*[1]*) is a certain river, whereon stand many castles and villages belonging to the king of Balaxiam's brother; and after three days journey is the province Vachan, having in length and breath three days' journey, the inhabitants whereof have a peculiar language, and worship Mohammed . . . If you depart thence betwixt the north-east and east, you must ascend for three whole days together, until you come to an exceedingly high mountain, than which there is said to be none higher in the world. There also between two mountains is a great lake, and through a plain runs a very fine river, near which are excellent pastures, so that in them a lean horse or an ox may be fat in ten days. There are also plenty of wild beasts, especially exceeding great wild sheep, having horns, some of them six spans long, of which they make divers kinds of vessels. The plain contains twelve days' journey in length, and is called Pamer; nor is there any habitation there; and travellers must carry victuals with them. No bird also appears there, by reason of the cold; and it is reported that if fire be kindled there it is not so bright nor so effectual to boil anything as in other places . . . .*

MARCO POLO (Voyages and travels, 1307).

[1]) = *Badakshan.*

# CONTENTS

# INTRODUCTION

The second Danish Pamir Expedition, due to the initiative of Professor O. Olufsen, at that time a lieutenant, and under his leadership, left Copenhagen in March 1898. The route lay across Russia, by steamer over the Caspian Sea, by rail through Transcaspia, stopping at various places underway, to Ferghana. In the little village of Osh which is located in this latter country, our caravan was fitted out, and in the month of June we turned our faces southwards and went over Guldsha, Olgin Lug and the Taldyk Pass to the Alai Plain through which flows the Kisil-Su, a tributary of the Pandsh. South of the Alai Plain the expedition entered Pamir, passed the Sea of Kara-Kul, (about 4,000 mètres above sea level), went over the Ak-Baital Pass and reached the Murghab River on which the Russian fort, Pamirski Post is situated. From this point our way led westward through Tshatir Tash to Alitshur Pamir, and in the neighbourhood of the mighty alpine lake, Jashil Kul, (about 4,000 mètres above sea level), we spent more than a month. This was the most important episode of the period spent in Pamir, especially for a botanist, as leisure was afforded for making excursions far and near. The expedition left this part of the country in September, going South over Tuz Kul and the Chargush Pass (4,240 mètres above sea level), along the Pamir-Daria to Wakhan. The autumn was spent in the southern and western valleys of Pamir, the Wakhan, Goran and Shugnan, and at the end of October we went into winter quarters in Chorock, a little country village situated where the Gund river joins Pandsh. In the beginning of March 1899, we retraced our steps across Pamir, which was now covered with snow, and the first days of April saw us again in Osh.

The summer of 1899 was spent in Transcaspia, September and October in Persia, and in November 1899 the expedition was back in Copenhagen.

The cartographic, topographic and ethnographic results of the expedition have been published by Professor OLUFSEN, while Mr. A. HJULER, senior assistant master at a public school, published the results of measurements of air electricity and studies of the dialects of southern and western Pamir. (See the literature list.) The botanical results have been published by the author of the present article, first in a number of taxonomic papers,[1]) later in a book on the vegetation in the Transcaspian Lowlands. (See the literature list.) The present paper is the last of the articles on the results of the expedition. The manuscript has lain half-completed for a long time and its conclusion has been frequently postponed on account of stress of other work. No one realizes better than the author himself how much this is to be regretted.

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[1]) These publications are located as follows: Videnskabelige Meddelelser fra den naturhistoriske Forening i Kbhvn. 1901 — Caryophyllaceae (by H. WINKLER), Ranunculaceae, Phytoplankton from the Caspian Sea (both by OSTENFELD), in the same periodical for 1903 — Cruciferae, Umbelliferae, Valerianaceae, Compositae (by HOFFMANN), Gramineae (by HACKEL), Potamogetonaceae (by BAAGØE), Chenopodiaceae; Botanisk Tidsskrift Vol 24 — Nouvelle espèce de Riella (by PORSILD); Vol 26 — Pteridophyta, Gnetaceae, Cupressaceae, Lemnaceae, Typhaceae, Juncaginaceae, Alismaceae, Typhaceae, Juncaginaceae, Alismaceae, Liliaceae, Convallariaceae, Amaryllidaceae, Iridaceae, Juncaceae, Lichenes (by WAINIO), Orchidaceae, Salicaceae, Cupuliferae, Urticaceae, Cannabaceae, Polygonaceae; in Botanisk Tidsskrift Vol. 27 — Amarantaceae, Phytolaccaceae, Berberidaceae, Ceratophyllaceae, Papaveraceae, Fumariaceae, Resedaceae, Violaceae, Frankeniaceae, Tamaricaceae, Euphorbiaceae, Oxalidaceae, Linaceae, Geraniaceae, Balsaminaceae, Malvaceae, Rutaceae, Zygophyllaceae, Polygalaceae, Ampelidaceae, Rhamnaceae, Thymelaeaceae, Elaeagnaceae, Saxifragaceae, Ribesiaceae, Hamamelidaceae, Rosaceae, Lythraceae, Oenotheraceae, Haloragidaceae, Myrtaceae, Loranthaceae, Primulaceae, Convolvulaceae, Solanaceae, Plantaginaceae, Bignoniaceae, Apocynaceae, Asclepiadaceae, Rubiaceae, Caprifoliaceae, Dipsacaceae, Scrophulariaceae, Selaginaceae, Gentianaceae, Borraginaceae; Botanisk Tidsskrift Vol. 28 — Fungi (by ROSTRUP), Cyperaceae (by OSTENFELD), Labiatae (by BRIQUET); Bulletin de l'Herbier Boissier VI — Papilionaceae (by FREYN); Botanisk Tidsskrift Vol. 29 — Additions and Corrections. — The Algae are still unpublished.

# PART I. THE ALAI MOUNTAINS

## CHAPTER 1

ALAI is a mountain range lying north of Pamir and stretching from east to west. It is separated from Pamir by the Alai Plain, or the Alai Steppe, as it is often, (incorrectly, it seems to me) called. From an orographical point of view, then, the Alai Range may be considered the northern mountain boundary of Pamir. It slopes toward the north, down to the fertile, densely populated country of Ferghana, at one time the Kingdom of the Khans of Kokan. Ever since olden days important caravan routes have led from this country to western China (Kashgar). These have been enlarged and improved recently by the Russians. Our expedition, after being fitted out at Osh, left that town by one of these routes, going through Gultsha and Sufi Kurgan to the Taldyk Pass, from which we descended to the Alai Plain. This was in the latter half of June, 1898. From richly cultivated country the way now led up into the extreme foothills of the range, fresh green and rounded, covered with a dense carpet of grasses and *Cyperaceae*: *Poa bulbosa*, *Festuca ovina var. sulcata*, *Carex supina*, *C. nitida var. conglobata*, and others, and dotted with flowers in great profusion. Here *Eremurus robustus* bore its crimson clusters two mètres in the air, like burning torches, and the intensely yellow *Eremostachys labiosa* and the white *E. nuda*, large and upright as waxen tapers. The *Trollius*-coloured *Anemone biflora*, *Macrotomia euchromon*, *Erysimum canescens*, and *Euphorbia sub-*

*cordata* all had yellow blossoms, while *Hedysarum songoricum, Onobrychis pulchella, Astragalus platyphyllus, Cousinia microcarpa* and *Thymus serpyllum* had red, *Geranium collinum var. alpinum* and *Viola silvestris* lilac, *Lappula sp.* and *Myosostis arenaria* blue and *Silene brahuica, Astragalus alpinus* and an undetermined lily white

Climbing higher up we entered veritable mountain glens, their sides formed from a blue-black clay-slate and their bottoms filled with the strange conglomerates composed in part of very large stones cemented together with clay, which will be discussed further in Chapter II. Through these conglomerates, which we found in the valleys also in Pamir, the rivers of to-day have forced their beds. High up, at Sufi Kurgan for instance, a little over 2,000 mètres above sea level, we found on the disintegrated surface of the slate mountains, a poor scattered vegetation, with *Ephedra distachya*, green bushes a foot or two high, *Artemisia sp., Umbilicus Lievenii, Lagochilus Paulsenii* and *Oryzopsis holciformis var. songorica* as its most important components. *Stipa barbata var platyphylla* which at great altitudes, (2,400 mètres above sea level), is replaced by *Stipa orientalis var. trichoglossa*, was seen occasionally and also the acicular-leafed *Arenaria Ledebouriana, Polygonum acerosum, Astragalus macrotropis var. robustus, A. tibetanus, Sisymbrium brassiciforme* and *Sedum sp.* I found *Orchis turcestanicus*, and *Primula sibirica* in the marshes, and in a cold mountain stream submerged mosses, *Bryum Schleicheri var. latifolium* and *Philonotis calcarea.*

It was very striking that throughout lower Alai hardly a tree was to be seen. Near Gultsha, at a great distance up in the mountains a few scattered dark evergreens were discernible, presumably *Juniperus excelsa*, which B. FEDTSCHENKO mentions from here, and which he assumes has been driven out by cultivation. Along the valley trails which we followed, single lonely poplars or willows, (*Salix coerulea*), were to be seen, always with tattered fragments of garments hanging on them. There is a belief current among the Kirghiz, who wander with their herds in these regions, to the effect that single trees, standing free, are sacred and capable of effecting a cure, when a rag, which has been in contact with a diseased or injured spot is hung upon them. As a consequence every tree fairly bristled with rags of multi-coloured hues. All the trees remaining are now considered sacred. The reason that so few remain must presumably be sought in the fact that they were not always so reverenced. There is no doubt but that under normal conditions these regions would be densely wooded, — at all events the valleys. The nomadic Kirghiz have chopped down tree in great quantities for fuel, and their grazing herds have prevented the subsequent growth of seedlings. Nor did we see any signs of the trees and bushes, poplars, birches, *Rhododendron*, *Berberis*, *Crataegus*, *Rubus fruticosus*, *Hippophaës*, *etc.*, mentioned by GEIGER as found on Alai's northern slope; the reason too is presumably the same, we followed a much travelled caravan route. Almond bushes, (*Amygdalus communis*), alone, were common.

The climate of Alai must be propitious to trees. To my certain knowledge no meteorological observations on this matter exist, with the exception of those published by OLUFSEN, based on the few days of our sojourn in Alai. The Alai mountains indeed act as a screen for Pamir rendering it rain-poor by intercepting moisture coming from the north and condensing in into rain. We experienced several severe thunder showers in these regions, and from these and the accounts of similar storms given by natives it would seem that much rain falls in Alai. The vegetation, expecially on and near Olgin Lug, bears witness to the same. The woods near Olgin Lug prove to what an extent climatic conditions have favoured their growth, and seem too, to indicate that the Alai Range further down might, in fact, become wooded.

Olgin Lug is a grass grown plain in the Alai Mountains, narrow and about 5 kilomètres in length. It lies about 2700 mètres above sea level with its greatest length running from south to north. High mountains, ab. 3,500 mètres above sea level, some with their summits covered with snow, shut it in on every side. It is watered from south to north by the little stream, Kurshab, which, coming from the Taldyk Pass, flows into the Syr Daria. We spent several days on Olgin Lug and very regretfully left the beautiful spot. In brilliant sunshine, broken by refreshing showers, our excursions on Olgin Lug and up the wooded mountain slopes, where the flora was rich and varied, were a joy.

The plain itself is treeless, but along the banks of the Kurshab a few small junipers, *Juniperus psendosabina*, were growing. It is probable that the plain would by nature be densely forested and that the absence of trees is due to man. Not only is Olgin Lug situated on the caravan route to Kashgar, but it is inhabited as well by a number of Kirghiz. Their dome-shaped Kibitkas may be seen here and there, while their live stock, especially the Yak bulls, graze far and wide. These alone are sufficient to prevent the growth of new forests. They are very amusing, these sturdy diminutive oxen, with their horse's tails and pig-like gruntings. They and their masters, the Kirghiz, the barking dogs and the women, with high turbans, lend to Olgin Lug a populous and picturesque charm, increased by the ever moving caravans on their way to and from China and Pamir. These stop for a night on the plain and are soon off again, a long line of heavily burdened horses and camels, hung with bells and accompanied by drivers, horsemen and dogs. Marmots, *(Arctomys marmotta var. dichroa)* too, were lively. Their burrows were legion, and in riding great care was necessary, lest ones horse should stumble in one of their holes and break a leg. These small animals are both quick and shy, They would squeak as they perched or played about, only to disappear in great haste at one's approach. We saw, too, many small, burrowing rodents, the gray and brownish gray *Arvicola tianschanicus* and the almost tail-less *Ellobius talpinus.*

The plain is covered with grass, but the vegetation, which most closely resembles that of a meadow, as it is principally composed of mesophytic hemicryptophytes, was somewhat trampled down and cropped. I made note of *Atropis convoluta*, *Festuca ovina var. vallesiaca*, *Carex stenophylla var. desertorum* (common), *Avena desertorum*, *Alopecurus pratensis*, as well as *Cerastium falcatum*, *Lepyrodiclis holosteoides* and the little gray annual *Alyssum desertorum* and very tiny specimens of *Erodium cicutarium*, *Rumex sp.*, *Poten-*

*tilla sp., Taraxacum sp.* Along the Kurshab River I found *Kobresia Royleana, Scirpus pauciflorus and compressus, Triglochin palustre, Gentiana leucomelaena, Taphrospermum altaicum, Lappula tenuis, Euphrasia Regelii* and *Funaria microstoma* growing, and in the water, *Ranunculus natans* with floating leaves and *Bryum Schleicheri* were swimming.

However conditions changed as soon as we began to

Fig. 1. Forest of *Juniperus pseudosabina* on Olgin Lug, cowering a slope below a steep rock. Drawing after a photograph.

climb up the mountains. We found ourselves at once in woods of juniper, *Juniperus pseudosabina.* This species extended from the plain all the way up to the summits of the adjacent mountains, to an altitude of about 3,300 mètres above sea level. At this height, though, the junipers were but bushes at most 2 mètres tall, far too scattered to be considered a wood. Below on the other hand, the junipers formed, as I have said, a wood. The trees attained 10—12 mètres in height, and many had mighty trunks; a single one which we measured had three trunks, the largest, a mètre above the ground, was 1,5 mètres in circumference, and at the level of the ground the three together measured about 3 mètres in circumference. *Juniperus pseudosabina* has not a very close crown, the scale-like, or in some cases needle like leaves form foliages far from full or umbrageous. There were many dead limbs, doubtless killed by *Gymnosporangium juniperinum*, for the latter's pale brown spore masses were very common on the branches, which showed swellings on the infected spots.

The wood of the junipers had very narrow annual rings, indicating the great age of the large trees. Unfortunately I had no opportunity to count the rings.

In the lowest, most fertile part of the juniper grove the distance between the trees was 5—7 mètres, thus affording light and room for other plants to grow. The ground was stony, damp and mouldy with fallen branches and needles. It was covered by a somewhat dense herbaceous vegation, while between the junipers various bushes and single small other trees were scattered. Among the latter we saw only one little non-flowering *Sorbus*, under 3 mètres in height, (Fedtschenko mentions *S. thianschanika* from here), while *Berberis*, (Fedtschenko mentions *B. heterophylla* from here), *Rosa*, (both were barren), *Spiraea crenata*, *Ribes triste*, *Lonicera hispida*, *Karelini and microphylla*, all with rather large leaves and growing to an height of 1—3 mètres, and the little fine-leafed *Lonicera Olgae* represented the bushes. I found climbing *Clematis alpina var. sibirica*. There were no other arborescent plants and the species already mentioned were so few and far between that they contributed but little to the general physiognomy of the vegetation.

The herbaceous vegetation was however rich and varied, the profusion of flowers was nothing short of marvelous, dotting a carpet of perennial grasses: *Poa attenuata*, *Festuca ovina var. vallesiaca*, *Koeleria cristata*, the narrow-leafed *Avena desertorum*, the broad-leafed *Poa pratensis*, *Festuca sibirica*, *Carex supina* and *nitida*, and others. Of "flowering" plants the perennials were the most numerous, as a rule 20—30 centimètres tall with broad leaves and large blossoms. To this group belong *Trollius songoricus*, *Ranunculus songoricus*,

(O. Olufsen *fot.*)

Fig. 2.

The northern end of Olgin Lug. The Kurshab river is seen is the foreground, behind is a caravan camp and mountain-slopes with *Juniperus pseudosabina*.

*Anemone albana* and *narcissiflora*, *Onosma Gmelini*, *Gentiana Olivieri*, *Cerastium dahuricum*, (40 cm tall), *Aquilegia sp.*, *Cortusa Matthioli* with its beautiful foliage and handsome purple clusters, *Linum heterosepalum* and *L. perenne*, *Aster alpinus*, *Crepis multicaulis*, a rosette-plant with a long peduncle, *Lamium album*, the two broad-leafed large *Ligularia*-species, *L. robusta* and *L. altaica*, both with great yellow heads, *Parnassia subacaulis, Polygonum rumicifolium and Rheum Webbianum*, *Valeriana caespitosa*, and *Ferula Jaeschkeana*, of which I only saw the leaf-rosettes. The names of these species will give a European reader an idea of the luxuriant growth and abundance of flowers.

The low perennials, 10—20 cm tall, are: *Thymus sp.* (common), *Astragalus alpinus* and *myriophyllus, Carex supina* and *nitida*, *Potentilla bifurca*, with subterranean runners, *Polygala comosa*, *Leontopodium alpinum*, *Psychrogeton turcestanicum*, a rosette plant with yellow blossoms, *Saxifraga cernua, Stellaria graminea*, *Adoxa moschatellina*, the yellow flowering *Viola uniflora, Carum atropurpureum*, *Draba incana* and *media*, the beautiful *Isopyrum anemonoides* and the even more beautiful *I. grandiflorum*, both with low finely pinnatisect foliage and large white or pink blossoms, *Oxytropis humifusa*, *Primula farinosa*, *Botrychium lunaria*, *Cystopteris fragilis*, *Fragaria sp.*, *Pedicularis pycnantha*, *Galium sp.*

Many of the low perennials are more or less cespitose in their growth: the very common *Astragalus pamiro-alaicus*, which has abundant pinnate foliage and yellow stemless blossoms, *Potentilla radiata*, *nivea* and *hypoleuca*, *Androsace villosa*, *Koeleria cristata*, *Festuca ovina var. valesiaca*.

Bulbous plants claim a special place. We found the lovely blue *Ixilirion Pallasii*, *Fritillaria ruthenica*, a common plant, 20—30 cm in height, with narrow leaves and large red and yellow mottled flowers, *Gagea persica*, and the following spring, March 1899, *Crocus alatavicus* was found in blossom.

Finally the juniper woods contained a number of annuals: *Gentiana leucomelaena*, *Lappula tenuis*, *Euphrasia Regelii*, *Valerianella plagiostephana*, *Smelowskia sisymbrioides*, all tiny, small-leaved, slender, soft plants, among which *Lappula* and *Smelowskia* are covered with hairs.

In the juniper wood the following Cryptogams were found: Mosses, *Distichum capillaceum*, *Orthotrichum anomalum*, *Bryum sp.* (?), *Tortula ruralis*, the three latter on stones, *Timmia bavarica*, *Bryum pendulum*, *Tortula fragilis var. pocillum*, and of lichens *Lecidea candida* and *Dermatocarpon miniatum* on stones, *Lecanora mutabilis* and *L. umbrina var. umbrinofusca*, *Placodium aurantiacum*, *Anaptychia ulotrichoides*, *Lecidea goniophila* and *glomerulosa* on branches of the juniper, and finally *Cladonia pyxidata var. pocillum* and *Lecanora bracteata var. alpina* on the ground.

By glancing at the species it is easy so see that this rich herbaceous vegetation is for the most part composed of mesophytic hemicryptophytes, indeed many of them have rather a hygrophytic character, for instance *Trollius*, *Gentiana*, *Parnassia*, *Saxifraga*, *Adoxa*, *Primula*, *Botrychium* and *Pedicularis*. As far as I have been able to judge *Thymus sp.* and *Androsace villosa* are the only chamaephytes and there are only a few annuals.

That this herbaceous flora depends on the trees for its existence is proved by the fact that where the latter are lacking the former is also. It must therefore be called an under-vegetation. Boris Keller has described similar vegetations from the Altai Mountains, open pine, larch or silver fir forests with vigorous or more or less dense herbaceous vegetation, of which he gives analyses. It appears in looking these over that in Altai, too, hemicryptophytes are most common.

*Juniperus pseudosabina* does not form a wood everywhere. In many places the trees are scattered or bushlike in form and then the herbaceous vegetation is far less abundant. However under the bushes there is more green to be seen than between them; it grows in a dense verdant carpet of annuals, including *Veronica cardiocarpa*, *Galium songoricum* and *spurium*, grasses (without flowers), and a tiny Borraginaceous. The mountain slopes were covered with stony gravel dotted here and there with plants: *Lagochilus Paulsenii*, *Ixilirion Pallasii*, *Ephedra distachya* 1,5 mètres tall, various barren grasses, *Artemisia sp.*, *Potentilla bifurca*, *Ferula Jaeschkeana* and a thorny-leaved cushion-plant without blossoms, presumably an *Acantholimon*, *Carex nitida var. conglobata*, the annual *Polygonum acerosum*, *Nepeta satureioides*, *Poa attenuata* and *persica*, *Fumaria Vaillantii*, *Adonis aestivalis var. miniata*, *Callipeltis cucullaria*, *Rhinanthus sp.*, *Arenaria serpyllifolia*, *Asperugo procumbens*, *Bromus tectorum*, *Bromus crinitus*. Nor did this plant community show any signs of xeromorphy. It contained indeed specimens like the labiatous *Lagochilus*, *Artemisia*, and *Ephedra* which are somewhat xerophytic, since *Lagochilus* is thorny and has leathery pinnatisect leaves, while *Artemisia* is silvery haired, and *Ephedra* leafless, yet the majority of the species are tiny, soft, slender annuals, easily destroyed by a short drought. It is possible too, that later in the year they would have been gone, we found them in June. Many of the annuals seem to have been imported, (*Fumaria*, *Adonis*, *Asperugo*, *Bromus*.)

Climbing higher up the mountain side the junipers are more and more bushlike and gradually disappear. Here at an altitude of 3,000—3,300 mètres above sea level, with patches of snow here and there, the vegetation comprises only a few species. I found the lovely borraginaceous *Macrotomia euchromom* with its blue blossoms unfolded and the dainty little *Isopyrum grandiflorum* finding foothold in the cracks of the rocks. The cruciferous *Parrya pinnatifida* and *P. fruticulosa* are also rock plants, as are *Smelowskia calycina* and *Draba fladnizensis*. I found too *Carex macrogyna*, *Lloydia serotina*, *Rhodiola rosea*, *Allium monadelphum*, *Linum perenne* and *Phlomis oreophila*. All these were perennials. The season up here was too short for annuals.

The mountain tops resemble fell fields more closely than anything else, for the vegetation was so sparse that there was more soil bare than covered with plants.

B. Fedtschenko (Pamir i Shugnan) finds 7 formations in Olgin Lug, but in his preliminary articles they are characterized so briefly that it was difficult for me to recognize them. This author states too, that barley fields are to be found on Olgin Lug. In such case it is the highest altitude for the cultivation of cereals.

The forests of Olgin Lug were the only luxuriant forests seen on our expedition in Turkestan, and the sudden transition to the parched, wind-scourged Pamir was striking. Yet of all the 98 species I saw on and near Olgin Lug, about one half (48 %) are also to be found in Pamir, while only 7 % were in common with those of the Transcaspian Lowlands. As both Pamir and Transcaspia have very little rainfall, it must be the conditions on the mountains which are common for Pamir and Alai.

The species common to Olgin Lug and Pamir are the following:

Allium monadelphum
Androsace villosa
Anemone narcissiflora
Aster alpinus
Astragalus pamiro-alaicus
Atropis convoluta
Bromus crinitus
Carex stenophylla
Cortusa Matthioli
Cystopteris fragilis
Draba fladnizensis
— incana
— media
Ephedra distachya
Euphrasia Regelii
Festuca ovina
Gentiana leucomelaena
Isopyrum anemonoides
— grandiflorum
Kobresia Royleana
Leontodon alpinum
Ligularia altaica
Linum perenne
Lloydia serotina
Macrotomia euchromon
Oxytropis humifusa
Parnassia subacaulis
Phlomis oreophila
Poa persica
Polygonum acerosum
— rumicifolium
Potentilla bifurca
— hypoleuca
— nivea
Primula farinosa
Psychrogeton turcestanicum
Ranunculus songoricus
Rhodiola rosea
Saxifraga cernua
Scirpus compressus
Smelowskia calycina
Triglochin palustre
Valeriana caespitosa
Veronica cardiocarpa
Viola uniflora.

The above list is given here because it shows that none of the plant species forming the xerophytic plant communities of Pamir are to be found in Alai at Olgin Lug. The species in the list grow in Pamir all under especially favourable conditions, in marshes or on shady monntain sides.

The Alai Plain, the summer paradise of the Kirghiz, which forms the southern boundary of the Alai mountains, is watered by the river Kisil Su, (the red stream) whose waters like the soil of the plain are rusty red. The plain near Sary Tash (3,270 mètres above sea level) is flat or slightly rolling and furrowed by many small streams flowing into Kisil Ṣu. On June 27 the soil was dry and dusty when dug, yet the vegetation did not impress one as being xerophytic. It is composed of a short green-sward of grasses and *Cyperaceae* dotted with many gay flowers. The main plants are *Festuca ovina var. vallesiaca*, *Carex stenophylla var. desertorum* (both cespitose) and the tiny annuals, *Ceratocephalus orthoceras* and *Alyssum desertorum*. Common too were *Avena desertorum* (cespitose), *Anemone Tschernaewi*, a rather low tuberous species, *Astragalus Danieli Kochi*, *A. tibetanus*, *Pulsatilla albana*, *Carex nitida var. conglobata* and *Leptaleum filifolium*. Of these the latter only is an annual. *Alchimilla sp.*, *Draba media* (annual), *Psychrogeton turcestanicum*, *Chorispora macropoda*, and *Sisymbrium mollisimum* (perennials), were found, as well as the following mosses, *Tortula Paulsenii* on a slope near a stream and *Bryum leptoglyphodon* at the mouth of a marmot burrow. The vegetation both in appearance and species composition resembles closely that of Olgin Lug and may best be compared to a meadow. Here, on the Alai Plateau, the plants are smaller and less well developed than on Olgin Lug, and the absence of trees is natural, as Sary Tash lies above the timber line. Near the river or its tributaries on moist ground we found the delicate little *Ranunculus flexicaulis*, *Taraxacum paludosum*, *Carex Regelii*, *Scirpus alpinus* (= *pumilus*), *Erysimum altaicum*, *Polygonum cognatum* and *Primula algida*.

On the southern side of the Alai Plateau, near Bordo-Ba, there was a little pond with *Hippuris vulgaris* and *Potamogeton gramineus*. Here too, in a stony, dried-out river bed, *Rheum rhizostachum*, a species under a foot tall, was growing.

# PART II. THE HIGHLAND OF PAMIR[1])

## CHAPTER 2

### Structure and Geology.

Pamir, the mighty highland, connecting Hindukush and Karakorum in the south with the Alai Mountains and Thianshan in the north, and forming a sort of natural bridge between these mountain ranges, falls sharply off on the east toward Eastern Turkestan, while toward the west its slope is gradual. The water-shed dividing the rivers flowing east from those flowing west, lies at about the line Rang Kul—Great Kara Kul, so that the larger part of Pamir is watered by streams flowing westward. (See the annexed map).

These conditions, then, determine the eastern border of Pamir, fixing it at the line of the Kashgar chain of mountains, which extend from the north toward the south. The western boundary is not so easily fixed. It may perhaps be most naturally placed where the Pandsh River flows from the north to the south. The northern border is the Alai Plain, which is watered by the Kisil-Su, and the southern, the upper course of the Pandsh and the Hindukush mountains.

Between the rivers, which for the most part flow toward the west, and of which the most important are the Pandsh, the Gund and the Murghab, are high mountain ridges, 5—6,000 mètres above sea level. The greatest altitude is to be found in the East, where Mustagh-ata in the Kashgar chain reaches a height of 8,000 mètres, and in the north-

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[1]) The land is often called »The Pamirs«. This name indicates that there are several »Pamirs«, i. e. flat barren valleys. Hower as the name Pamir is ordinarily used, and as it used here, it designates not only the valleys but the mountains between them as well, including also the western part where no flat valleys exist. Thus, when speaking of »The Pamirs« in this treatise we mean the valleys, Pamirs specifically (in the narrow meaning of the word »Pamir«), while »Pamir« includes the entire district.

west, (Darwas), where there are peaks more than 7,000 mètres high.

From a geographical point of view, the Eastern part alone belongs to "Central Asia" as defined by Richthofen, the drainless water basin of olden days, where all the products of disintegration remain in the land itself. The larger, western section, on the other hand, belongs to Richthofen's peripheral regions, — those having outlets into the ocean or its relics, — and the water of the rivers of Pamir flowing west, does empty into the Aral Sea.

However the whole of Pamir may be included in Mushketow's definition of Asia Media, — that territory with no outlet in the ocean. (See Geiger, Paulsen.)

From an orographical point of view there is a difference between eastern, or Pamir proper and western Pamir. We may characterize the former as a complex of flat plains or broad valleys, now divided by high mountains, now succeeding each other, tract on tract, and often watered by rivers. These valleys, which are from 3—4,000 mètres above sea level have separate names, — Little Pamir, Great Pamir, Alitshur Pamir, Rang Kul Pamir. Toward the west, however, in Lower Pamir, which borders High Pamir at ca. 73° W., the valleys are deep and narrow, the rivers flow more swiftly, there are no plateaus, but mountain ravines.

Geologically considered, Pamir, that is Eastern Pamir, is according to Iwanoff one huge mountain mass on a lodgment of granite and gneiss. These rise to the surface, particularly, in the southern part; toward the north they are largely hidden by the metamorphosed deposits of the paleozoic age (Devon?), — by slate, crystalline lime-stone, dolomites, and sandstone. Of upheavals which have formed the mountain ranges, the most important and the oldest is the one running W. S. W., for it is that upheaval, or rather that series of parallel upheavals, which has formed the principal mountain chains and valleys.

The glacial period attained a very high development in Pamir. Many of its traces are still visible. A thick layer of ice once covered the entire country; from this jagged, precipitous, ice-breaking peaks towered, while the lower mountains were polished smooth. The valleys, everywhere, were filled with deep moraine deposits especially of conglomerates, through which the rivers of our age have worn their way. In Pamir of to-day there are no glaciers except in the north and east on the highest mountains, where, indeed, they are very large.

The glacial period was followed by a lake period, during which many lakes, far greater than those of to-day, came into being. In many places, in Alitshur for instance, water washed out all traces of the glacial period, eating away the moraines and depositing the debris in the bottoms of the valleys.

The glacial period and the lake period together, still according to Iwanoff, have given to High Pamir of to-day its orographical characteristic of plateau.

According to another theory, represented among others by Max Friederichsen, conglomerates, the so-called Hanhai formations, are the results of atmospheric disintegration in an arid climate.

From a tectonic point of view, High Pamir is no mountain plateau, but, as has been stated above, a mighty mountainous mass, with deep valleys partly filled with deposits of conglomerates. The valleys are continually being filled today at a lively pace by the help of the atmospheric disintegration, which is very great, on account of the enormous differences in temperature from season to season, and between day and night. Huge stretches of talus at the base of all the mountains bear witness to this.

The deep valleys of Lower Pamir, with their steep slopes are being filled in a similar way. Here, though, no glacial nor lake period has acted as an auxiliary.

Lower Pamir, as its name indicates, does not lie as high as High Pamir. Chorock, located at the junction of the Gund and Pandsh rivers is about 2,100 mètres above sea level, Pamirski Post in High Pamir about 3,600 mètres. The climates of the two localities are very similar, as the curves on Fig. 3 show, but that of Lower Pamir is much milder and has far more rainfall during the winter season (see below). The valleys of Lower Pamir are cultivated for the most part, and villages are scattered here and there. The population, Iranian by race (Galtshas or Mountain-Tadjiks) has fixed habitations, whereas the population af High Pamir is sparse and of the nomadic Kirghiz. Regular agriculture is practised in the Pandsh valley (Wakhan Daria) to Ssarhad (3,350 mètres above sea level), and in Langarkisht (3,000 mètres), where our expedition made a halt, both cereals and fruit trees (apricots) are grown. Near Shach Daria cultivation extends ud to Sseis (3,160 mètres), along the Gund river up to Ssardym (3,160 mètres), in the Murghab valley to Ssares (3,200 mètres) and on the Alai plateau to 2,740 mètres. (This is according to GEIGER.) In a large part of Lower Pamir then, the valleys are cultivated, and according to GEIGER in early days the cultivation extended even higher up than now. The condition to-day he does not think due to a changed climate, but rather to the lack of energy of the population.

## CHAPTER 3

### The Climate of Pamir.

The climate of Pamir is continental. The winters are cold and the summers, in consideration of the high altitude, hot. The actual summer is short. In High Pamir, July and August are the only summer months in which plants grow and blossom, and even during these months, in which the average temperature is over $13^{0}$, night frosts up to $-4^{0}$ are common. At the end of August the minimum-thermometer of the expedition even registered $-10^{0},_{2}$.

However the days are for the most part bright and hot. The light is so strong that one is obliged to wear coloured glasses, and the sun burns so fiercely in the thin atmosphere that hands and face become blistered. As we rode horseback hour after hour in this scorching sunlight the upper side of the left hand holding the reins was often covered with great burns; and it has happened that the foot exposed to the sun's rays even though protected by a great boot, was so scorched that one was obliged to dismount to avoid keeling over in a faint.

In Pamir one is exposed to great changes in temperature. One afternoon in August the thermometer registered $24^0$ an hour before sunset, a few hours later it showed $10^0$ frost.

The summer days, too, contain other surprises than those of changes in temperature. On July 21 for instance. (it was not the only occasion) a very severe snow storm overtook us. Dense clouds of snow were driven hither and yon by a whistling wind and we were unable to see either behind or ahead.

Such gales are frequent in High Pamir. In the evening the wind would often suddenly begin to howl down the mountain sides, carrying stones and gravel in its path. In a short time however all would be quiet. With the exception of these mountain storms Pamir is a country where gentle breezes or total calm are the natural order of events. See OLUFSEN and FICKER on this point.

The canopy of clouds is light. According to FICKER, Pamirski Post has 116 clear days and 55 cloudy. The remaining 194 partly cloudy days have presumably nearly all been bright with scattered cumulus clouds covering the tops of the mountains, for this is the usual condition of affairs. (Compare OLUFSEN.)

In the summer-time Pamir is practically rainless. Both the amount of rainfall (see the Table) and the number of rainy days are very small. Pamirski Post has a rain-probability (KÖPPEN) for the month of July of $0,_{11}$, for January of $0,_{10}$ and, according to FICKER, three months can pass without a drop of rain falling. The rain-probability for Chorock is $0,_{04}$ in July, $0,_{22}$ in January, and four months can pass totally without rainfall. In High Pamir our expedition experienced rain a few times in the month af July. In some instances only a few drops fell, but on one occasion a soft rain fell 14 hours in succession, turning to snow on the tops of the mountains. Nor do the winter snows of High Pamir amount to much, as may be seen from the figures of the table. In the month of March, leaving

Shugnan and Wakhan (Langarkisht), our expedition crossed Pamir via Chargush. The heaviest snows were encountered in Goran in the Pandsh valley. Even though most of the valleys of High Pamir were filled with deep snow yet nowhere did it lie in such quantities as to impede passage. In many places near Pamir Daria the Kirghiz had gone into

**Table 1.**

(Prepared from FICKER's statements.)

| 1894—1903 | Pamirski Post 38° 11′ N. L. 74° 2′ E. Long. 3640 metres above sea-level | | | | | | Chorock [1] 37° 27′ N.L. 71° 39′ E.L. 2105 m. above sea-level | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Average temperature (centigrade) | Maximum temperature, absolute | Minimum temperature, absolute | Total precipitation, mm. average | Number of days with precipitation (average) | Relative humidity (average) | Average temperature (centigrade) | Maximum temperature, absolute | Total precipitation, mm. average | Number of days with precipitation (average) |
| January | — 18,4 | | — 46,7 | 7,8 | 3,0 | 62 | — 8,4 | | 28,2 | 7,0 |
| February | — 16,6 | | | 2,5 | 1,8 | 49 | — 6,6 | | 20,2 | 4,8 |
| March | — 6,7 | | | 1,6 | 2,4 | 53 | 1,7 | | 27,8 | 6,6 |
| April | 0,2 | | | 3,6 | 2,3 | 47 | 7,9 | | 21,4 | 4,6 |
| May | 7,1 | | | 8,4 | 5,6 | 47 | 14,3 | | 28,6 | 5,6 |
| June | 10,7 | | | 15,4 | 5,4 | 45 | 18,5 | | 14,6 | 4,2 |
| July | 13,9 | 28,0 | | 8,0 | 3,4 | 42 | 22,0 | 35,0 | 5,7 | 1,2 |
| August | 13,6 | | | 4,4 | 2,4 | 42 | 22,0 | | 0,2 | 0,4 |
| September | 7,9 | | | 3,9 | 1,8 | 39 | 18,0 | | 0,2 | 0,2 |
| October | 0,0 | | | 2,5 | 2,0 | 48 | 9,7 | | 13,2 | 2,5 |
| November | — 8,0 | | | 2,1 | 2,0 | 54 | 3,0 | | 43,0 | 5,7 |
| December | — 16,8 | | | 2,1 | 1,4 | 57 | — 2,9 | | 24,8 | 3,7 |
| Year | — 1,1 | | | 62,3 | 33,5 | 49 | 8,4 | | 228,5 | 46,5 |

[1]) OLUFSEN published as a minimum for Chorock ÷ 24°,8 (winter 1898 - 99).

winter quarters at an altitude of about 3,800 mètres above sea-level. The snow here was not thick enough to prevent the numerous herds of yak, fat-tailed sheep, goats and horses from finding pasturage.

In Lower Pamir, where the summers are even dryer than in High Pamir, much more snow falls during the winter, as the table and curve show. During the winter journey referred to above, the worst obstacle to our progress through the Pandsh valley in Goran was the enormous masses of snow lying on the mountain sides, often avalanche-snow, in which our horses stuck fast again and again.

The humidity in the air is slight. The table shows the averages for Pamirski Post, those for Chorock have not been given by FICKER. The records made by the expedition (OLUFSEN), show that the average humidity in July was 38 %, in August 21 % — both from High Pamir. The minima recorded for these months were 5 % and 2 %.

There is, then, less humidity in the air of Pamir than in that of the lowlands of Transcaspia, where Tashkent, for instance, shows a yearly average of 63, Petro Alexandrowsk 57. (FICKER, see PAULSEN as well.)

It was unnecessary to read a record of the dryness of the atmosphere in Pamir to become conscious of that condition. It is the most peculiar characteristic of the country, — the clear air (when not filled with dust) and the scorched and desolate appearance of the earth are always reminding one of the fact. It was noticeable too, how quickly one's clothing dried, and too how often it was necessary to dip or refill ones pen.

I have no data to show the amount of evaporation but it stands to reason that it must be very great.

The temperature of the soil was measured by the expedition at Jashil Kul in High Pamir during July and August and at Chorock in Lower Pamir from November to February. The depths at which measurements were made were from 0,40—1,30 mètres. In High Pamir the temperature at the greatest depth varied between 7—8°, and at the smallest depth between 12—17°, while observations of temperature at the surface of the ground varied between 7—33°,5. All records of soil-temperatures were made on horizontal ground. Slopes with southern exposures presumably show higher temperatures. Near Chorock the temperature at the greatest depth (1,3 mètres) lay between 0,6 and 9°,4, at the smallest depth (0,40 mètres) between — 8°,6 and 3°,9. Whereas night frosts became the rule from the middle of November, no negative temperature was observed at 0,4 mètres below ground

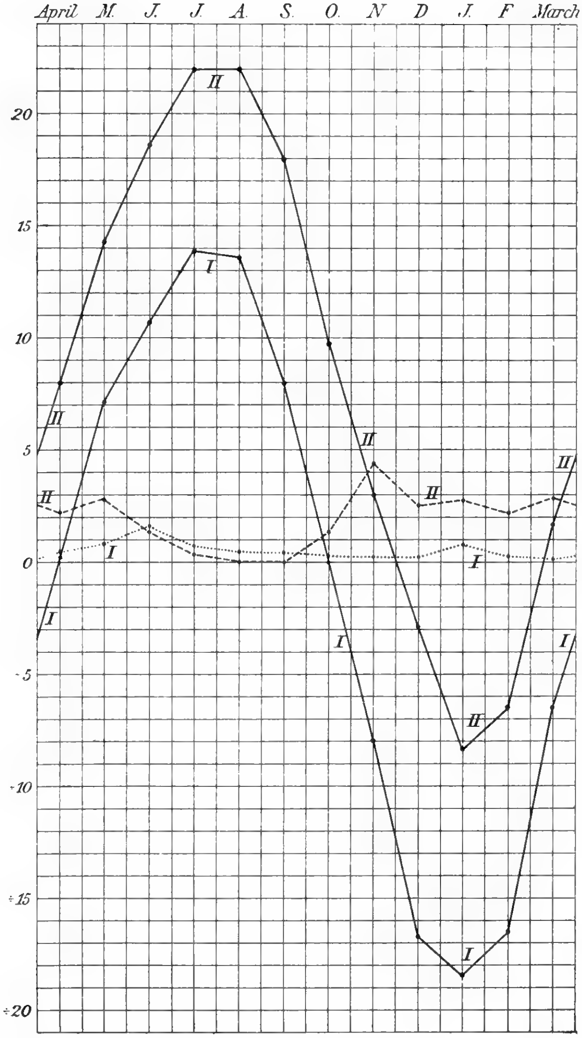


Fig. 3. Hydrothermals for Pamirski Post (I) and Chorock (II). The ordinary lines are temperature-curves, and the figures to the left express degrees Centigrade. The dotted lines give the precipitation in centimeter. (Constructed after the method of RAUNKIAER, 1905, 1907.)

before December 5, at 0,7 mètres before December 23, at 10 mètres before January 6, and, at the end of February at a depth of 1,3 mètres the termometer still showed 1°,1 (OLUFSEN).

Taken all in all, the climate of Pamir is severe but healthy. After an attack of mountain fever, which wakens one at night with a pressure across the chest and a gasping for breath, and after one's skin has become toughened by sun and snow, it is difficult to imagine a healthier place to be in. The sun is always shining, mountains and lakes are bathed in the clearest light. Even though mountain-climbing in this rarified atmosphere is strenuous, the mighty splendours of nature send one sound and rejoicing to the day's work. At night the brezes blow the tent flaps, the candle flickers inside, tired and content we stretch out on the floor and sleep deep and sound. All organs function properly. In Pamir we exuded health and happiness, all three.

## CHAPTER 4

## General Observations on the Vegetation and Flora of Pamir.

While Alai, low-lying and rainy has her forests of mesophytic herbaceous vegetation, High Pamir is dry and treeless. Only in the valleys with running water and special shelter (deep snow during the winter?) and in certain places along the banks of the lakes can scattered low bushes be found. Narrow green stripes of swamp-meadow or of more scattered mesophytes edge the rivers, when these flow through broader valleys, which is often the case in High Pamir. The northern slopes of the mountains, where the sun's rays cannot penetrate are covered, high up near the snow-line, by a fresh, green mesophytic vegetation. Aside from these few particularly favoured spots, by far the larger part of the mountains and valleys of High Pamir are covered with scattered cespitose hemicryptophytes and suffrutescent chamaephytes.

The intervening distance varies according to the localities, — it is less in more horizontal, damper places, which therefore at a distance assume a strange dotted appearance, — greater on parched southern slopes, which seem at first glance to be entirely bare.

On the whole the vegetation of High Pamir lends only a faint greenish hue to the landscape. Seen from a high altitude, brown seems the colour of the entire country; the mountains are brown, brown too the flat bottoms of the broad valleys, while the talus look like darker brown shadows at the base of the mountains. At the bottom of the furrows on the mountain-sides dark green lines may often be seen; they are narrow stripes of vegetation which only serve to make the furrows appear even deeper, accentuating the picture just as an exaggerated retouch may a photograph. Looking toward the north and east nothing green or only the very faintest green tones are visible, because from that point only the slopes with a southern or southwestern exposure are turned toward the spectator, but looking toward the south a greenish shadow seems to rest on those mountain-sides having no western exposure. Exposure, as the following will also prove, plays then a very great part for the vegetation of High Pamir.

I have previously (Paulsen, 1912) given an account of the biological types (growth-forms, based on Raunkiaer's[1]) system), to be found in Pamir. The following statistics give a summary of the facts.

**Table 2.**

| | Number of species | Percentage of species under each growth-form | | | | | |
|---|---|---|---|---|---|---|---|
| | | F | Ch | H | G | HH | Th |
| Pamir............ | 514 | 1 | 12 | 63 | 5 | 5 | 14 |
| Normal spectrum[2]) | 1000 | 46 | 9 | 26 | 4 | 2 | 13 |

[1]) Raunkiaer, 1905, 1908. [2]) Raunkiaer, 1918.

Pamir has, then, a decided hemicryptophytic spectrum with strongly recessive phanerophytes and somewhat pronounced chamaephytes. According to RAUNKIAER the latter are very characteristic for arctic and high alpine districts. In Puschlav, Switzerland, for instance, at an altitude above 2,850 mètres the vegetation contains 35 % chamaephytes[1]. It would seem reasonable, then, to expect to find a larger percentage of chamaephytes in Pamir. However a large number of the Pamir species show a tendency toward chamaephytic growth; they are cespitose and curve upwards more or less. The determinations were made here in Copenhagen, — for when the expedition was in Pamir, RAUNKIAER'S system was not yet published — and even so they have shown a percentage of chamaephytes which is higher than the standard spectrum. Chamaephytes are very unevenly distributed among the various vegetation formations. This fact will be discussed later.

Although several Russian botanists had been in Pamir prior to our visit, and although the Englishman, J. F. DUTHIE had published a list of the plants found in those regions, yet previous to our expedition to Asia knowledge of Pamir's flora was but fragmentary. From that time on, however, knowledge of the flora of the country increased rapidly. In 1901 Mme OLGA FEDTSCHENKO made a trip to Pamir and published in 1903 in Acta horti Petropolitani, "Flore du Pamir" in which were included all the specimens from Pamir then known. Supplements appeared in 1904, 1905, 1907 and 1909. Here we have a working synopsis of the plants of Pamir, even though the limits of the district could have been better fixed, and even though the interpretation of species and particularly nomenclature may be open to criticism. The main article is illustrated by 8 plates, with characteristic pictures of the landscape, and a map. There is, too, a comparative table showing the distribution of the plants of Pamir in other localities. These other localities are 1.) Tianshan, 2.) Tshungai-Alatan, and Tarbagatai, 3.) Afghanistan, Hindukush and Himalaya, 4.) Thibet, 5.) Chinese

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[1]) Counted after BROCKMANN-JEROSCH.

Turkestan and Mongolia, 6.) China, Japan, Korea, 7.) Northern Asia, 8.) The remainder of Turkestan, 9.) Persia, Asia Minor, Caucasus, 10.) Europe and the Ural, 11.) Other countries.

Later, in 1907, M^me^ FEDTSCHENKO published a key for the determination of the plants of Pamir, in Russian. That, as well as the other publications, with which I am familiar, are given in the literature list.

The following description of the vegetation of High Pamir is based in part on notes made on the trip from Transalai to Jashil Kul, and in part on a more complete study of the vegetation near Jashil Kul, where the expedition went into camp from July 19—August 30 1898. Plant growth on a horizontal plain is taken as a starting-point for the description of the vegetation, and we find that that type, the vegetation of the Pamirs i. e. the flat horizontal valleys, is widespread and characteristic. We may call it the Trigonella formation. Next, the vegetation on the mountain slopes with various exposures is described, the Eurotia formation on dry slopes with a southern exposure, Arenaria-Meyeri formation on the northern slopes near the base of the mountains, Poa attenuata formations ("Alpine meadows", of B. FEDTSCHENKO) higher up on the northern slopes watered by melting snow, and finally Talus formations on the mountain sides cowered with great loose rocks. Last of all the hygrophilous formations are mentioned:

Swamp-meadow formation, hot-spring formation, submerged formation, stony river-bed formation, river-bank formation.

Let me explain briefly what is meant by the term "formation" as used in this paper, — an expression applied nowadays to many and various phenomena. The formations to be described here are regarded as plant-communities, belonging to certain growth-forms, — always the same within the same formation, — and these are determined by and adapted to common conditions. I used the same definition in my book on the Lowlands of Transcaspia. WARMING (1909, p. 140, 1918, p. 336) uses the word in the same sense.

du Rietz, Fries und Tengwall let agreement, (between associations composing the formations) in regard to the dominant growth-forms be the determining factor. I agree with these scientists in believing that inductive research must be based on the vegetation itself and its growth-forms, not on the conditions for growth. The growth-forms used here, are, as has already been stated, the growth-forms of Raunkiaer's system, and in this book the formations will be characterized according to the growth-forms of the constituent species, based on Raunkiaer's conception. Unfortunately it has been impossible to give any formation-statistics based on the valence[1]) of species, as this method was unknown when the observations were made.

In a high, arid country like Pamir, conditions of growth are as a rule so plain and the differences in plant-growth of the various localities so distinct, that it seems natural to regard the different plant-communities as formations, and the result shows that most of them are rightly regarded as formation. The idea of association, — species-list, to use a single word, — is of less importance in such a country. This is especially true in extensive investigations, where the point in question is to see large tracts of country, and to characterize in general. Of course species-lists have been made from many localities, (they form indeed the basis for our investigations), and many of these lists are given later on to illustrate the formations. The vegetation divisions are based on them.

B. Fedtschenko (1902?) gives the following synopsis of the most characteristic plant formations of Pamir.

1. Aquatic vegetation in fresh water lakes, river-windings, and puddles, composed of very common species, *Caulinia fragilis, Ranunculus aquatilis, Utricularia vulgaris* (?) and *Ranunculus natans.*

2. Near the river-banks groups of bushes, *Myricaria germanica*, and between these, *Oxytropis glabra, Artemisia sp.* etc., are found on sandbanks.

3. On the terrace nearest the rivers there is usually a

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[1]) Raunkiaer, 1909, 1918.

tufted (cespitose) meadow, formed by herbaceous plants, among which *Carex* and poor grasses dominate. Here, too, may be found the white blossoms of *Gentiana leucomelaena* and the red of *Primula sibirica* and others.

4. On the steep slope leading up to the second terrace, which is composed of conglomerates, a very special and characteristic flora is often to be found. Here we may see *Clematis tangutica, Comarum Salessowi, Dracocephalum stamineum*, etc.

5. Terrace No. 2 and the largest part of Pamir, as well, is covered by desert vegetation, scattered low bushes of "Terskén" (*Eurotia ceratoides* C. A. M.), *Artemisia*, species of *Astragalus* and *Oxytropis* (*A. Mushketowi* and others, *O. chiliophilia, Poncinsii* and others).

6. Along the banks of brooks, with their source in the perpetual snows, there is usually a narrow strip of alpine meadow, with a vegetation high-alpine in character.

7. These same alpine meadows are developed on the mountain ridges encircling Pamir. The author has seen them on Kisil-art and Koi-tesek, and there are many other places where they may be found.

8. Finally, in the ravine of Karasu in Jaman-Tal, which is sheltered on all sides, thickets or small groves of willow (*Salix sp.*) are to be found. The trees, however, are not more than 4 mètres high.

To the above detailed report of Fedtschenko's system, (all his statements are included,) his German brief may be added in extenso, as it includes in part new information. (However it does not include all the formations given in the Russian text.)

"Die Vegetation des inneren Pamir ist äusserst arm, (aus etwa 300—350 Pflanzenarten bestehend) und wird folgendermassen gegliedet:

A. Wiesen:

I. Alpenmatten (13—17,000′);

II. Feuchte Wiesen;

III. Salzmoorwiesen längs den Flussufern und um den Seen (10—14,000′).

B. Steinige Wüste:
IV. Eurotia-Wüste;
V. Abhänge u. s. w.

C. Gehölzformationen:
VI. Myricaria-Gebüsche;
VII. Salix-Gebüsche (im Dschamantal)."

A comparison between FEDTSCHENKO's formations and those described in this article will show that

Alpine meadows = Poa attenuata formation.
Damp meadows
Salt-marsch meadows } = Swamp-meadow.
Eurotia-desert = Trigonella formation (?).
"Abhänge u. s. w." = Eurotia formation (?).
"Myricaria-Gebüsche" belong to the river-bank formation, and "Salix-Gebüsche" to the stony river-bed formation.

As will be shown in further detail, later, *Eurotia* vegetation should presumably not be classified as desert vegetation.

## CHAPTER 5

## Notes on vegetation made on the way from Alai to Jashil Kul.

From the fresh and charming Olgin Lug our way leads southwards. It is very steep, and our panting horses crawl slowly zigzagging up over the Taldyk Pass, where in shady places snow lies unmelted on the twenty-sixth of June. Once on the other side, the south side, one may see far across the wide green plain of Alai, stretching from east to west, and forming the boundary between Alai and Pamir.

There lies Pamir! We see a mighty snow covered mountain range, glittering and remote; it is the Trans Alai Chain, — called Katman Tagh by the natives — the northern mountain boundary of Pamir. Over those mountains lies our path, behind them our goal.

A few days later we rode slowly up over the Kisil Art Pass and found ourselves in Pamir. There we remained nine months. Half of this time, or there abouts, we were snow-bound in our winter quarters in Chorock in Shugnan, while the summer of 1898 was our actual working period in High Pamir.

To attempt to give a general description of our journeyings would lead me too far astray from the matter in hand. In Olufsen's book "Gennem Pamir" experiences and localities are described. Hedin's book "En Færd gennem Asien" may likewise be recommended. However, in order to give the reader a general impression of the scenery I will describe very briefly a few of the places which we visited, adding at the same time a short account of the plants found.

Kisil Kul lies at an altitude of 4,000 mètres above sea-level. The name means "red lake". However, there is no lake to be found there to-day, only an arid depression in the landscape. Through this depression the little stream, Markan Su, flows, pouring into the eastern Kisil Su, which in turn empties its waters into the Tarim River. Kisil Kul was the first Pamir landscape seen, and our minds were still filled with the memory of the fertile luxuriance of the Alai Mountains. The contrast was striking. Here at Kisil Kul a cold, dry, biting wind was sweeping over the naked mountains and plains A snow storm followed in its path, but the snow did not remain where in fell, but was whirled away to cracks and corners where it melted until overtaken by night frosts.

The slate mountains here abouts were in an advanced stage of disintegration, those nearest were merely rounded hillocks covered with fragments of slate. Strange hues appeared in th[illegible] process of decay, red, gray, and poisonous copper green[illegible] seen at a distance a wonderfully beautiful play of colour, re[illegible]ding one weirdly of changeable silk, curious simile indee[illegible] this dry, lifeless landscape. Far away in the north a[illegible] he stony slopes tower up to the snow-covered peak[illegible] Tagh again, seen from the south now, — bet[illegible] tiny mountain strem glistens, there a little [illegible]wish vegetation is visible, otherwise barren desolation as far as the eye can pierce, not a tree nor a bush, anywhere. On approaching the stony slopes, however, low green tufts appear about 20—30 steps apart. They have long, thick, perpendicular roots and the withered remains of leaves and stalks cling like close tunics below the green. Several have beautiful bright flowers, *Parrya eriocalyx* pink, *Hedysarum pumilum* crimson, *Oxytropis vermicularis* violet, *Smelowskia calycina*, *Sisymbrium Korolkowi* and *pamiricum* and *Chorispora macropoda* yellowish-white or yellow. We found, too, the cushion plant *Androsace villosa var. congesta*. Other species than those mentioned here were not found.

Below, in the river valley, where there is rich black clay between the stones, *Dilophia salsa*, *Primula sibirica*, *Gymnandra Korolkowi*, *Calamagrostis anthoxanthoides*, *Colpodium altaicum*, *Carex pseudofoetida*, *Kobresia stenocarpa* and *Oxygraphis glacialis* are growing. Of these the most common are *Calamagrostis*, *Carex*, and *Kobresia*, and they lend the yellow hue to the river valley.

The lake Kara Kul is situated in northern Pamir south of Kisil Kul, at an altitude of about 4,000 mètres. It is a large lake with colours like the ocean, clear green and deep blue. Promontories of low, dark, rounded mountains put out into its waters at both the northern and southern ends. Its shores are curving and emphasized by a broad margin of snow-white salt, extending the entire circumference of the lake. Absolute quiet and desolation reign, enhanced, perhaps, by the presence of a few small white gulls with brown heads circling above the blue waters. A broad barren plain encompasses the lake, surrounded in turn on all sides by snow-covered mountains. On a clear day, with great white cumulus clouds drifting over the white mountains, Kara Kul possesses a strange weird beauty. Th[illegible] deserted lake in this dry silent country surr[illegible] mountains forms a picture lacking perha[illegible]a picture of greatness and death, — an impression once [illegible] never effaced.

Fig. 4. A view of Kara Kul. The sea is fringed by salt. (O. Olufsen *phot.*)

The plain surrounding the lake is both clayey and sandy with stones everywhere. In many hollows salt has crystallized out on the surface. Skeletons and wind-dried carcasses of scores of horses whiten the ground. There are great stretches where not a single plant is to be seen, but here and there groups of non-flowering cespitose grasses grow stiffly. Otherwise I saw only *Sisymbrium Korolkowii* and the ill-smelling *Oxytropis tibetica* which formed great sand-catching tufts, growing outward in circles and dying in the centre like fairy circles.

The northern peninsula is composed of a gray, glistening argillaceous slate, whose surface is rendered dark, almost black, by disintegration. Fragments of this slate mixed with grayish yellow clay form the soil. In many places plant growth was absolutely lacking, one could search about for hundreds of mètres without finding a plant, not even a lichen. However, after much wandering, 3 species, *Ephedra Fedtschenkoi*, *Christolea crassifolia* and *Acantholimon diapensioides* were revealed. The first is a creeper with long subterranean shoots and small clusters of slender green stems, the second forms fresh green tufts with many leaves and the third is a typical cushion plant; its cushions were up to 1 mètre in diameter and so hard and firm as to be practically unyielding even when trod upon. *Christolea* and *Acantholimon* were common in the bed of a dried-out mountain stream in which the cushion plant formed natural steps. *Ephedra* was apparently best able to endure drought of the three.

In the salt beds along the banks of Kara Kul, yellow *Carex pseudofoetida* and *Polygonum pamiricum* were growing in great masses. Algae and meter-long pieces of *Potamogeton pamiricus* were washed up on the beach. Gazing into the lake from above, the latter was seen forming dense forests of sea-weed on the bottom.

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The countries about Kisil Kul and Kara Kul are the most barren I have seen in Pamir. However, a few day's journey further south the landscape sinks slightly and the vegetation becomes richer. Near Sary Mullah lies a stony gravel plain, surrounded by steep slate mountains. Here plants are growing, separately it is true, so that the ground is visible between, yet abundantly enough that the plain seen from above looks green with only here and there a bare brown spot of hard cracked clay surrounded by white saline crystals. On this plain I found *Artemisia sp.*, *Stipa orientalis var. trichoglossa*, forming tiny fairy circles, *Carex stenophylla*, *Hordeum secalinum var. brevisubulatum*, *Macrotomia euchromon*, *Solenanthus stylosus*, *Oxytropis tibetica*, *Astragalus Muschketowii*, *Eurotia ceratoides*, *Sisymbrium Korolkowii*, *Christolea crassifolia*, *Arnebia guttata*, *Psychrogeton turcestanicum*. In a single locality there was a great mass of *Chenopodium vulvaria*, presumably brought thither by a caravan. *Lappula Myosotis* and *Acantholimon diapensioides* were growing in a dried-up stream.

The vegetation of the plain extends up the lower part of the base of the mountains, (eastern exposure), without great change. *Eurotia ceratoides* becomes common here, and we find *Oxytropis humifusa*, *Hedysarum cephalotes*, *Poa attenuata*, and *Veronica biloba*.

Many of the species have gaily coloured blossoms. This quite rich and varied vegetation is made up of cespitose hemicryptophytes and suffrutices, and belongs to the Trigonella-formation which will be discussed further later on.

The Russian fortress, Pamirski Post, lies at the upper course of the Murghab River. This river flows through a valley far broader than itself and composed for the most part of swamp-meadows. North of the river valley is a rather broad rolling plain, its soil of stony clay or sand stained here and there by patches of white salt. Looking at the cliff down to the river with its 4—6 mètres perpendicular drop, we see that the foundation of the plain is a conglomerate. The binding substance is sand or clay and most of the stones are about the size of hens' eggs with occasional great boulders several mètres in diameter. Flat stones lie almost always with their flat surface upwards, and there are strata of sand and gravel.

Fifteen kilomètres towards the west the same plain is watered by Kara Su, a little river flowing into the Murghab on the left. Here the Kara Su valley is called Jaman Tal. Its sides, 30 mètres high, are perpendicular walls of conglomerate with strata of sand and gravel. 20—30 cm below its surface there is a layer of sand about a mètre thick. Jaman Tal has many lateral valleys, through which an approach to the plain is possible; these are quite dry now. With its perpendicular walls, regular lateral valleys, strata and drought, Jaman Tal resembles the famous Grand Canyon of the Colorado in Arizona. In point of size, however, no resemblance is possible. A photograph of Jaman Tal has been published by M$^{me}$ Olga Fedtschenko in Flore du Pamir (Table 5).

The landscape about Pamirski Post is desolate. The barren, stony, rolling plain is encircled by rounded slate mountains, brown and naked like the plain itself. A clear blue sky arches overhead and the sun beats down on the dry silent country.

On a horizontal section of the plain the vegetation is extremely scattered: *Christolea crassifolia*, dwarf *Ephedra*, *Artemisia*, *Eurotia ceratoides*, *Crepis flexuosa*, *Zygophyllum Fabago*, and a grass with terete slender leaves, are all found in separate tufts. In the direction of some low-lying hills the vegetation becomes somewhat richer with only 1—5 mètres between each plant. Here, in addition to the species already mentioned, we find the hemicryptophyte *Arnebia guttata* and the suffrutex *Sympegma Regelii*.

Westward towards Shatshan, the plain slopes a little and has an eastern exposure. Here the vegetation is relatively rich: *Eurotia ceratoides, Stipa orientalis, Astragalus Muschketowii, Astragalus ophiocarpus, Crepis flexuosa, Christolea crassifolia, Zygophyllum Fabago, Arnebia guttata, Oxytropis tibetica* (single specimens) and, strangely enough, a smooth little annual *Senecio* (*S. coronopifolius var. parvulus*). With the exception of the latter and of *Crepis* all the plants are short compressed tufts. The same species are to be found on the mountain-sides sloping towards the east. Further up, another tiny, aromatic and arachnoid hairy labiate (*Nepeta spathulifera*), appears, and still higher *Dracocephalum heterophyllum*, growing in patches on account of its long horizontal rhizomes, *Linaria hepatica* and *Solenanthus stylosus.* The ground of the mountain-slope is of dry gravel with jingling bits of slate and here and there boulders of slate fast embedded. Occasional patches of white salt are visible. At a depth of 10—20 cm the ground is slightly damp.

The vegetation of Jaman Tal is unusual. Here there is a thicket, 4—5 mètres high, of *Salix oxycarpa*, and *Myricaria davurica* and besides *Clematis orientalis* and great tufts of *Scrophularia incisa*, *Calamagrostis compacta*, *Elymus sibiricus* and *Potentilla dealbata.* This vegetation, very little characteristic of Pamir, is presumably due to the sheltered warmth of the deep valley.

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Shatyr Tash is situated in the eastern end of Alitshur Pamir at an altitude of about 4,100 mètres. It is a nearly horizontal plain extending on either side of the Alitshur River, which flows westward into the Jashil Kul. Many Kirghiz had pitched their tents on Shatyr Tash and quantities of sheep and yak oxen were grazing on the plain. Mountains tower high into the air on the north and south, and small scattered knolls of rock penetrate here and there the soil of the plain. In some places the ground is dry and covered with fine gravel. Here the vegetation is poor and sparse, composed of *Poa attenuata var. pygmaea*, *Calamagrostis compacta*, *Carex stenophylla*, *Sisymbrium Korolkowii*, *Oxytropis Poncinsii*, *Polygonum paronychioides* and *Chrysanthemum pamiricum.* In a locality with the above flora the ground water was found at a depth of 71 cm. In other places the soil of the plain appeared brown and moist, generally covered with a very thin layer of salt. The dry and wet spots alternate at the same altitude, indicating plainly that they depend on certain subterranean conditions. The surface of the soil in wet places is often rough or lumpy, with quantities of low irregular flat mounds, 1—2 mètres in diameter and up to 30 cm high. These are either cracked and covered with salt or moist and brown with a surface that is wetter than the ground beneath, but with no salt except on occasional protuberances, like tufts of grass. The cause of these eminences is unknown to me, perhaps it is the action of frost. In any case, the soil in them has apparently considerable capillarity and is able to retain salt water. These mounds are as a rule bare of plants. The salty part of Shatyr Tash is somewhat richer in vegetation than the gravelly part, but mostly the same plants grow in both soils: *Poa, Calamagrostis, Potentilla polyschista, Elymus dasystachys, Alopecurus mucronatus* and *Acantholimon diapensioides* are the most important. In some spots the first three named form a thin carpet, and in others, *Acantholimon* usurps all the room there is.

There are swamps too on Statyr Tash; there the soil was very moist but there were no puddles or pools, and practically no change in the vegetation. However in these localities *Alopecurus mucronatus* and the lovely red-flowering *Pedicularis uliginosa* grow.

Mountain-slopes with a southern exposure were extremely dry and there were great spaces between the plants.

Here we found *Eurotia ceratöides, Artemisia* and an undetermined grass. On a slope exposed to the northeast and with a subsoil of clay, mixed with small stones, the vegetation was richer and closer: *Artemisia, Acantholimon diapensioides, Poa attenuata, Nepeta daënensis* and *kokanica, Erysimum sisymbrioides.* Of these *Nepeta daënensis* and *Erysimum* are annuals. There were stripes and patches of green near the streams coming from melting snow. Here *Bromus crinitus, Braya Kizil Arti, Ranunculus Aucheri* and *rufosepalus*, a little annual *Veronica, Primula sibirica,* and *Pottia latifolia* were growing. The lowest great snow mass lay at an altitude of 4,300 mètres. Just below it was the moss *Eucalypta leptodon*, twenty mètres further down the first phanerogams appeared, and another twenty mètres below them were flowering plants: *Chorispora macropoda, Smelowskia calycina, Papaver radicatum, Poa attenuata,* and *Dracocephalum discolor.*

In Alitshur-Pamir, southeast of the eastern end of Jashil Kul, at an altitude of 4,100 mètres is the little lake, Tuz Kul (the name means salt lake). It is grouped with other tiny lakes on a wide plain which is nearly as barren and desolate as that near Kara Kul. The surface of this plain, brown in colour, and either very stony and gravelly, or clayey, undulates gently and is so destitute of plant life that seen from a neighbouring mountain it appears quite bare. Portions are white with salt. In many places one can go 200 steps without finding a single plant. Vegetation is practically only found in the flat hollows and consists of groups of *Eurotia ceratoides*, *Stipa orientalis*, and *Oxytropis Poncinsii*. Only in the deepest hollows into which sand has drifted are other species to be found; *Solenanthus stylosus*, *Polygonum paronychioides*. *Paracaryum himalayense* (?), *Halogeton glomeratus*, *Christolea crassifolia* (one of the most common), flowering *Linaria hepatica*, *Silene caucasica*, *Atriplex sp.*, *Serratula procumbens*, *Crepis flexuosa*, single specimens of *Acantholimon diapensioides*, *Cousinia rava*, and the little annual, *Senecio coronopifolius*. *Halogeton*, *Christolea* and *Atriplex* would indicate salt in the soil. The plants grow in recesses especially in those on slopes having a northeastern and northern exposure, presumably a question of shade or in any case of shelter, for here sand has formed drifts grayish white and glistening with mica. The plain is swept clean; only stones and gravel remain, or clay in the clayey parts, seeming to indicate that wind is the hindering factor.

In the country about Tuz Kul there were many features of great interest even though they were not of a botanical nature. As the author is no geologist he will not enter into details about these matters but briefly describe conditions as they are.

In a hollow, white with salt, there were pools of water, from these a stripe of damp soil free from salt extended downhill. In a couple of places water oozed slowly up from the ground, which in a circumference of 20—30 cm was a veritable mud-pie. Probably the pools were caused by water oozing up, there is most likely a layer containing water deep down, from which water rises to the surface as in an artesian spring.

A similar condition on a larger scale was observed south of Tuz Kul, on a clayey plain, lying about 1 mètre below the stony plain described above. On this clayey plain there were twenty-odd unevenly formed clay hillocks, 2 mètres high at the outset. They were quite dry now, but it was easy to see that water had previously flowed out of their tops, where craters 5—10 cm in diameter sealed with clay were formed. The water had poured down the sides forming deep furrows, which radiated from the top forming a star. The rivulets then flowed together into brooks, these in their turn into one larger brook which has worn its way at 2 mètres depth through the clay, flowing at last into Tuz Kul. Here and there the brooks formed small pools which are now dried up and covered on the bottom with white salt.

The clay of which the hills were composed was very hard and firm and free from pebbles; single stones as large as one's fist lay helter skelter on the surface of the ground, looking as if they had been thrown there.

The water must have transported the clay which forms the hills up from the ground; for, inasmuch as the hills are far more worn away by the action of the streams than the outlying plain, they cannot be remains of clay that is washed away everywhere else, but the plain must be the original level. We are thus dealing with mud volcanoes under one form or another.

## CHAPTER 6.

### Jashil Kul and the Plain near Mardjanaj. (Trigonella-Formation).

Lake Jashil Kul, (the green lake), lies at the western end of Alitshur Pamir, a little less than 4,000 mètres above sea-level. The lake is long drawn-out, being 25 kilomètres at its greatest length, main direction west-east, $3^1/_2$ kilomètres at it's greatest breadth, and about 40 mètres at it's greatest depth. The Alitshur River, which flows into the eastern end, is its most important inlet. An outlet from the neigbouring lake Bulung Kul also flows into the eastern end. On the north Jashil Kul receives water from Great and Little Mardjanaj, while from the south countless small streams of minor importance pour into the lake. Jashil Kul has its outlet on the western end. Here the river Gund whirls the waters of

(O. Olufsen *fot.*)

Fig. 5.
Jashil Kul as seen from a mountain-top on its North-Side, east of the Mardjanaj river which is seen running out into the lake. Between the mountain whereupon we stand and the river is seen the plain, whose vegetation is described below.

the lake rapidly down to the Pandsh River. A chain of high mountains lie north of Jashil Kul; their almost naked talus slopes drop precipitously down to the lake. A ride along the western part of the northern shore is a difficult matter; the horse has trouble in picking its way in the loose stony masses, which are apt to glide, carrying both horse and rider with them. A strip along the western edge of the lake is perfectly impassible. Huge piles of gneiss have crashed into the water and lie in a chaos of great boulders.

However almost everywhere from great Mardjanaj toward the east, one may trot if one likes, for here between the lake and the steep mountains, lies an even, horizontal plain, — the remains of one of the usual Pamir plains, — formed by the filling-in of former eroded valleys. The same plain is also to be found at the eastern end of the lake; it is a direct continuation of the plain of Alitshur-Pamir, whose upper portion is Shatyr Tash.

(O. Olufsen *fot.*)

Fig. 6.
The western end of Jashil Kul. In the foreground willows are seen, piles of boulders behind.

The southern shore of Jashil Kul is quite different from the northern shore. Here partially green mountain-sides, with almost no loose talus, slope gradually down to the lake.

The soundings made by the expedition and published by Olufsen in Geografisk Tidsskrift, 1900, Table IV, show that the bottom of the lake drops more precipitously on the south than on the north side. Only 2 of the cuts, (there are 10 in all), are at variance with this and may be explained on topographical grounds, (mouth of a brook on the south side).

The fact that the bottom of the lake slopes more precipitously on the south than on the north side is presumably due to the same causes as the differences in the acclivity and vegetation of the mountains. The slopes with a southern exposure are heated by the sun. This causes great disintegration and lack of vegetation, (the latter may also in part be due to disintegration), and from these barren disintegrated mountain slopes great masses slide down into the lake. Thus the mountains become constantly steeper while the bottom of the lake slopes. The mountain sides with a northern exposure disintegrate far more slowly, and furnish a good locality for plant growth. Practically no landslides occur here and the bottom of the lake is comparatively precipitous, while the mountains slope more gently.

These south-coast mountains are higher than those on the north, their snow-covered summits tower 5—6000 mètres high, and the torrents rushing down to Jashil Kul seem never to dry up.

South of the eastern end of Jashil Kul lies the little shallow lake, Bulung Kul. It is located in a plain sloping gently toward the north, which is watered by the little stream Koi tesek.

Our expedition spent about a month at Jashil Kul. We camped first east of the mouth of the great Mardjanaj on the northern shore of the lake; later on on the eastern shore, and finally near Bulung Kul (see the map).

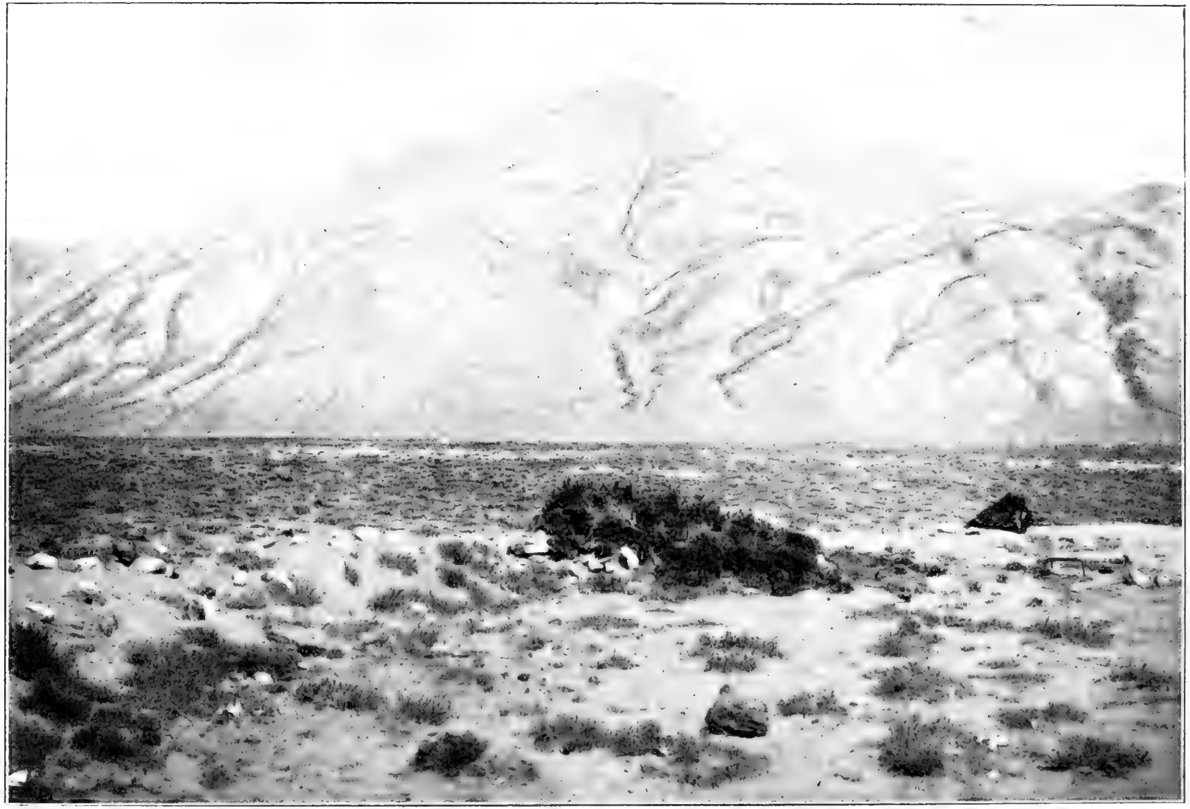
It was a marvellous experience, a constant succession of sunny days in majestic surroundings which we learned to love. When, after climbing high, high up, one's gaze roamed over this huge silent landscape, — the long, yellowish-green sheet of water nestling shining and still among the lofty brown mountains, crowned with summits of snow, — it seemed as if life no longer existed. Yet nature here was far from dead. The vegetation which I shall soon describe was both beautiful and characteristic. Animal life abounded. A strange tickling sensation comes over one, when for the first time and alone on an excursion, one sees the den of a bear, even though the bear is absent. We had indeed one vain bear-hunt after a huge yellowish-white specimen. There are great mountain-sheep too; *Ovis poli*, whose skulls are scattered by the thousand all over Pamir is one of them. They are very timid and seek refuge on the highest mountains. Besides these we saw goats, *Capra sibirica*, and wolves. Many birds are to be seen near the lakes, doves, sea-swallows, *(Sterna hirudo)*, black cormorants, reddish-brown ducks, *(Tadorna casarea)* while great brown eagles *(Haliaetus leucoryphus)* perch on stones near the shore, darting out into the water after fish, with which the lakes abound. Near the mouths of rivers are snipe, (*Totanus callidris, glareola, glottis*) and wagtails (*Motacilla citreola* and *flava* (?)).

There were many mouse-holes on the flat plains, (*Cricetus arenarius, Arvicola tianschanicus*), but the marmot, so common on Shatyr Tash, was not to be seen.

I have chosen the plain near Mardjanaj as a point of departure for a description of the vegetation about Jashil Kul. Located more exactly this plain lies east of the lower branch of the great Mardjanaj. This river and several tiny, now dry streams, which lead from the east down to the green valley of Mardjanaj, have worn deep into the plain. The plain is bounded on the east by high mountains, on the south east by a low mountain ridge behind which a similar plain stretches. The plain is about 70 mètres above the surface of the lake.

It is horizontal and slightly rolling. As no glacial brooks from the mountains flow through it, the vegetation is forced to depend on precipitation alone. The soil is reddish gray, dry sand, somewhat finer in the hollows, prone to crack on the surface, and mixed here and there with salt. At a depth of 17—20 cm dampness renders it recognizably darker.

The vegetation consists of isolated tufts and cushions. It may be said in general to belong to a poor type, — apparently most nearly a semi-desert type of scattered xerophytic, cespitose plants, with an appendix of cushion plants, — but it is a richly developed form of this poor type.



(O. Olufsen *fot.*)

Fig. 7.

The plain east of Mardjanaj, seen from our camp. In the foregroud a heap of fuel, tufts and stems especially of *Artemisia*, *Eurotia* and *Chrysanthemum pamiricum*. The mountain behind, the same from wich the plain was photographed (Fig. 5) shows dark vegetation-lines in furrows of dry water-courses.

The distance between the plants varies from one to some footsteps. As the tufts are often large, up to a mètre in diameter, at least half of the ground is covered with vegetation.

The vegetation covering this plain is both characteristic, interesting and beautiful into the bargain, for, as will appear later, many of the flowers are very gaily coloured. There

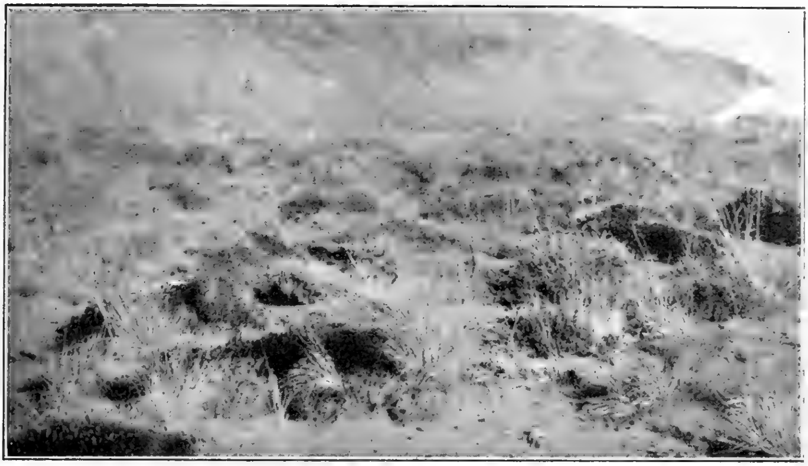


Fig. 8. The plain at Mardjanaj. The large cushions are *Acantholimon alatavicus.*

are many insects: bees, bumble-bees, butterflies, tiny beetles, grasshoppers and quantities of flies.

Below follows a list of the plant species found on the plain and information as to their growth-forms.

Common, appearing everywhere, were the following species:

*Hedysarum cephalotes* (Franch). A hemicryptophytic rosette-plant forming large tufts. Among the largest specimens I saw, was one 120 cm in diameter, and another, almost rectangular in form, 2 mètres long and 1 mètre broad. The tufts were usually dead in the centre. The branches were everywhere fastened to the ground by roots. The pinnate leaves, 6—7 cm long, were silver-haired, the leaflets, (about 9—11), as a rule less than 1 cm long, lanceolate, sulcate and pointed slantingly upward. Peduncles about 12 cm long. Beautiful red flowers.

*Oryzopsis molinioides* Hack. A hemicryptophytic, cespitose

Fig. 9. *Hedysarum cephalotes* Franch. *subsp. shugnanicum* B. Fedtsch. (ab. 1/2).

grass with close tunics around the base. The leaves convolute, filiform, only 4—6 cm long. Straw about 20 cm long.

*Chrysanthemum pamiricum* O. Hoffm. A chamaephytic

Fig. 10. *Chrysanthemum pamiricum* O. Hoffm. (ab. 1/2).

suffrutex, about 15 cm tall, filled with dead and dried sticks, former shoots. Forms tufts up to 70 cm in diameter, (2 mètre in circumference). Leaves small, about 1 cm long, pinnatisect, stiff, hairy, turned upwards, the lobes revolute. Flowers,

Fig. 11. *Silene caucasica* Bois. *var. pamirensis* H. Winkl. (ab. 1/2).

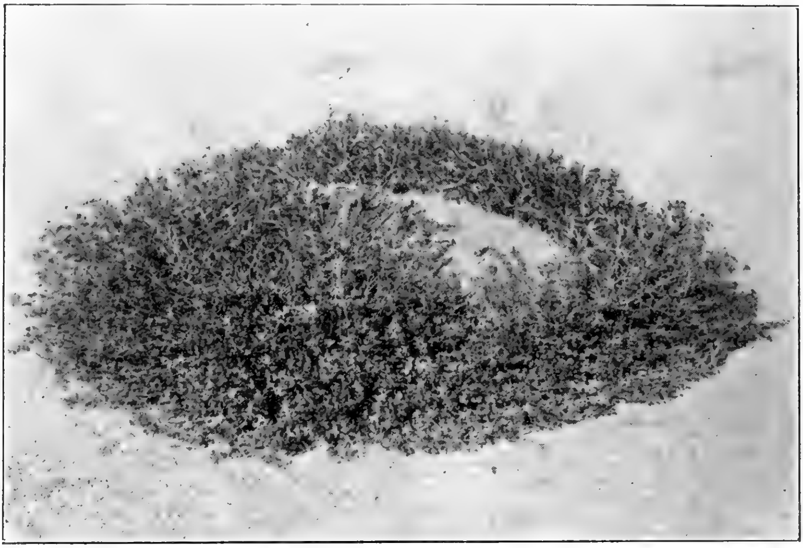
yellow, blossom first on the north side of the tuft. They are not more than 10 cm from the surface of the ground.

*Silene caucasica* Bois. A hemicryptophyte with a large

Fig. 12. *Oxytropis bella* B. Fedtsch. (ab. 1/2).

"radix multiceps" and many buds on the lower parts. Forms small tufts, up to 25 cm in diameter, often dying away in the centre. The leaves which have the same size on the top and bottom of the stem (a "protohemicryptophyte") are oblong-lanceolate, densely hairy, turned-upwards, about 2 cm long. Flowers, white, with red-striped glandular-hairy calyx, about 15 cm above the ground.

*Oxytropis bella* B. Fedtsch. A hemicryptophytic rosette



(*Fot. by* O. Olufsen.)

Fig. 13.
A big tuft of *Trigonella Emodi* Benth. on the plain at Mardjanaj.

plant, forming small tufts 10—20 cm in diameter. (Circumference 40—50 cm). Leaves pinnate, almost vertical, 2—3 cm long, have 4—5 pairs of silvery-hairy, lanceolate leaflets about 7 mm long Flowers, violet, growing 6—8 cm above the surface of the ground. (Fig. 12).

*Trigonella Emodi* Benth. A hemicryptophyte forming large tufts, up to 1 mètre in diameter, on a single thick root. In many cases the entire centre of the tuft is dead and only a circle, 10—15 cm wide, living. Leaves, ternate, with movable leaflets hardly a centimetre long, dentate at the tip, smooth, but with glands secreting an odorous substance. Flowers, yellow, blossoming first on the north side of the tuft. The flower-stalk is about 30 cm long. (Fig. 13, 14).

*Ephedra Fedtschenkoi Pauls.* (?) (possibly *E. monosperma*

Fig. 14. *Trigonella Emodi* Benth., part of a tuft. (ab. 1/2.)

Gmel.) A hemicryptophyte with long, horizontal, subterranean rhizomes and light-shoots only 1—3 cm long, cylindrical and leafless. The rhizomes cause many light-shoots to be

Fig. 15. *Astragalus Alitschuri* B. Fedtsch. (ab. 1/2).

found together, but they never form a close growth. The leaves are small scales.

*Astragalus Alitschuri* B. Fedtsch. A hemicryptophyte with

Fig. 16. *Polygonum paronychioides* C. A. M. (ab. 1/1).

a large "radix multiceps", forming small tufts. Rosette-plant. Leaves, pinnate with about 5 silvery-haired pairs of leaves about 1—2 cm long. The leaflets are elliptical, 4—5 mm long. The peduncles grows slantingly outwards. The flowers are yellow and only 15 cm above the ground. (Fig. 15).

*Polygonum paronychioides* C. A. M. A chamaephyte, suffrutex characterized by the whitish sheen emanating from the large membraneous ochreae. A large vertical tap-root bears horizontal woody branches, 5—10 cm long, whose herbaceous tips turn upwards. The whole forms a flat disc resting on the ground; large portions are dead. The revolute

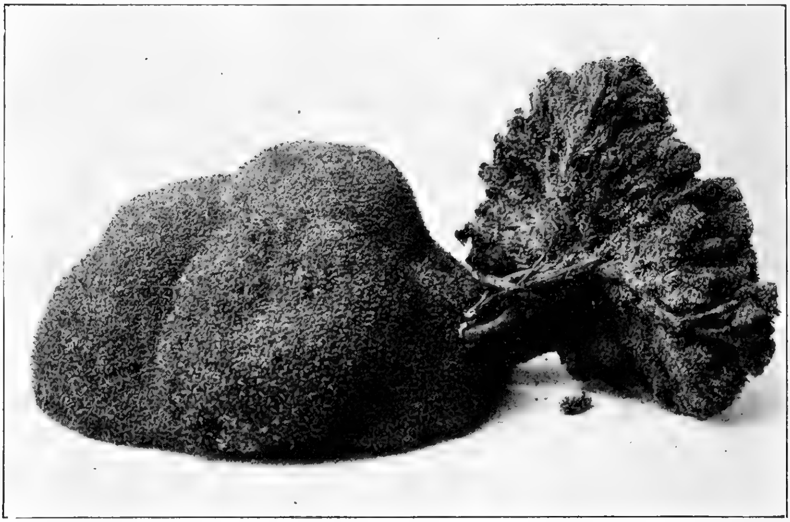


Fig. 17. Two specimens of *Acantholimon diapensioides* Bois., a convex cushion seen from above, and a flat cushion seen from below. (ab. $^1/_2$.)

leaves, a few mm long, are almost hidden among the ochreae. Flowers, small, red. (Fig. 16).

*Acantholimon diapensioides* Bois. A chamaephyte, cushion plant, which can attain a diameter of more than 1 mètre. ("Radial flach Polster", Hauri-Schröter). When young it is only attached by the main-root, later many adventitious roots are formed. The cushions are flat as a rule, on the level of the ground, but occasionally (on clay soil?) high bulging specimens are found; these contain air; ("Luftkugelkissen", Hauri-Schröter), otherwise they are solid, filled with twigs and dead leaves and so firm that one can step on them without injury. In large old specimens the centre is generally dead, and the growth continues in a fairy ring. The leaves are about 2 mm long, very close together and do not prick. The beautiful sessile pale pink flowers are often seen edging the cushion. (Fig. 17).

Fig. 18. Fasciated stem of *Eurotia ceratoides* C. A. M. (ab. 1/2).

*Acantholimon alatavicum* Bge. A chamaephyte, cushion-plant belonging to HAURI and SCHRÖTER's "Kugelsträucher" as it is penetrated by both light and air. The cushions can be more than 1 mètre across and may bulge as high as 18 cm over the ground. It rests lightly on the ground only fastened by a single main-root. The cushion is often higher on the south than on the north side.

Fig. 19. *Astragalus lasiosemius* Bois. Leaflets for the most part fallen off. (ab. $^1/_1$).

It is filled with remains of leaves. The leaves are acicular, 1—1,5 cm long. The beautiful sessile flowers blossom earlier on the north side of the cushion than on the south side. The fruit has a winged calyx.

*Eurotia ceratoides* C. A. M. A chamaephyte, suffrutex. It has a single large main-root with horizontal lateral roots, bearing many woody stems; these are nearly always flat, firmly fasciated, and on top bear living and dead twigs. The tuft can attain a diameter of 120 cm, when they are so large, the centre is generally dead. The tufts have been figured by SCHIMPER fig. 453, p. 791. The leaves are lanceolate about 1 cm long, stellate-hairy with revolute edges. The plant is 15—20 cm tall. Flowers inconspicuous. (Fig 18).

*Solenanthus stylosus* (Kar. Kir.) Lipsky, (Lindelofia stylosa). A hemicryptophyte, forming tufts, without centrifugal growth but surrounded by many withered leaves. The ground leaves are about 10—20 cm long, lanceolate, sulcate and velvety-hairy. The stem-leaves are narrow, and about 5 cm long. The flowers, dark-purple, are at the utmost 50 cm above the ground.

*Astragalus lasiosemius* Bois. A suffrutescent chamaephyte, with a single thick main-root bearing large tufts (one specimen was 90 cm in diameter, another 65 cm long, 35 broad), often dead in the centre; the leaves are pinnate with 3—5 pairs densely sericeous leaflets, 5 mm long. The rachis remains upright like a long pointed thorn. (Fig. 19). Rich florescence of yellow blossoms, not more than 10 cm above the ground.

*Serratula procumbens* Rgl. A hemicryptophyte with procumbent herbaceous branches of which the older part is covered with remnants of leaves. The leaves are 4—7 cm long, lanceolate-elliptic, glabrous. The great red heads blossom in August.

*Artemisia* (*herba alba* Asso?). A suffrutescent chamaephyte, having a single vertical root with many lateral roots. The branches diverge on all sides and upwards, and may form great plates, about 1 mètre in diameter. The leaves are bipinnatisect and sericeous. The small yellow flowers blossom in early September.

*Stipa orientalis* Trin. A hemicryptophyte forming close tufts, which, when old, often wither in the centre and form rings, up to 10 cm in diameter. It is very tunicate. The filiform leaves are up to 8 cm long; the straw up to 20 cm.

In addition to these species found almost everywhere on the plain, many others are found mixed with the above or growing in single localities:

*Macrotomia euchromon* (Royle) Pauls. This plant, when young, is a cespitose hemicryptophyte, but will here be considered chamaephyte, because the vertical rhizome grows up over the surface of the ground like a cushion; it can attain

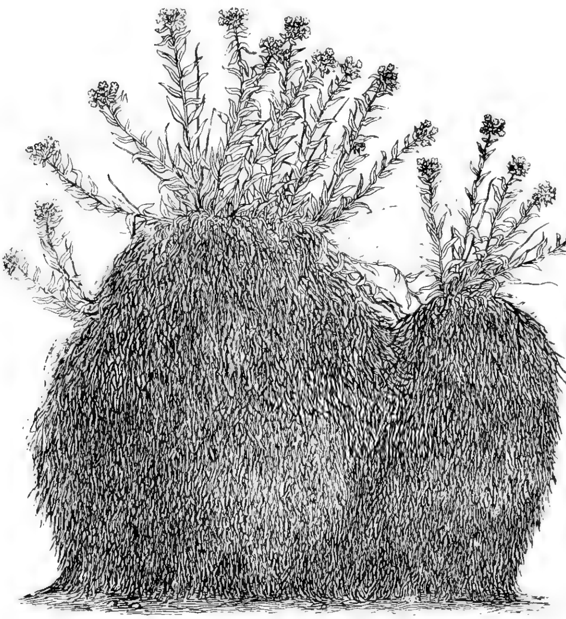


Fig. 20. *Macrotomia euchromon* (Royle) Pauls. Old specimen, which has formed a 30 cm high pillar covered by dead stems, on the top of which fresh shoots appear; they are now flowering. South-side of Jashil Kul. (Drawing after a sketch and measurements by the author). (Ab. $^{1}/_{6}$.)

a height of 30 cm, and is closely covered with dead stems (see Fig. 20). This is a phenomen known to us from arctic regions where some species, (*Lesquerella arctica*, *Potentilla pulchella*) form in open places, the so-called "pillars", covered with remains of dead leaves, and bearing a few green leaves on their top (pictured by Ostenfeld and Lundager). In the case of *Macrotomia* both the pillar and the living portions attain greater dimensions than the arctic plants, which are only a few centimètres high. — The leaves, 5—8 cm long, are ovate-lanceolate, coarsely hispid and covered with many fine hairs, sulcate; the lower leaves are sloping, the stem-leaves horizontal. The flowers at first red and visited by bumble-bees, and later yellowish-white; on specimens born up on large cushions they may be raised up to 70 cm above the ground; on young specimens 30—40 cm.

*Astragalus dolichopodus* Freyn. A hemicryptophyte with a "radix multiceps". By degrees small tufts are formed about 30 cm in diameter, sometimes ring-shaped. Rosette plant. The leaves are 2—3 cm long, and have 4—5 pairs of leaflets, which are cuneate, 7—9 mm long, sericeous and in the day-time when the sun shines turn their profile to the sunlight. The red flowers are only raised 15 cm from the ground.

*Cousinia rava* C. Winkl. A hemicryptophyte with "radix multiceps", forming small tufts. The white, prickly-edged, white-villose leaves, which grow all along the stem, are 5—12 cm long; the red heads are about 30 cm above the ground.

*Oxytropis Poncinsii* Frch. A chamaephyte with a thick "radix multiceps" bearing small very thick tufts of short shoots. The tufts are arched like cushions, and the plant approaches a cushion-plant. The leaves have 4 pairs of lanceolate, densely sericeous leaflets, about 5 mm long placed very close together. The flowers are purple, almost sessile. The swollen, hairy, green or rosy-red pods often encircle the tuft like a hoop. The centre is formed by the many closely packed silvery leaves. The entire effect is strange. (Fig. 21).

*Astragalus oophorus* Freyn. A hemicryptophyte with thick "radix multiceps" bearing small tufts. The light-shoots are very short, only 2—4 cm long, the leaves are 2—3 cm long and have 2—4 pairs of densely hirsute leaflets, which are obovate and about 7 mm long. The flesh-coloured flowers are only a few cm from the ground.

*Carex stenophylla* Wahlenb. A hemicryptophyte with subterranean horizontal rhizomes, and tunics of dead leaves about the shoots. The spikes are 7—10 cm above the surface of the ground.

*Scorzonera mollis* M. B. (*var. cano-velutina* Beauv.) and *Scorzonera pusilla* Pall. are both hemicryptophytes, semi-rosette-plants with long, narrow more or less villose leaves and yellow flowers which are not more than 8 cm above the ground.

*Lappula stricta* (Ldb.) Gürke. A therophyte 10—15 cm tall or, as it has a ground-rosette of dead leaves, perhaps better determined as a biennial hemicryptophyte. The leaves

Fig. 21. *Oxytropis Poncinsii.* Frch. (ab. 1/2). Flowers on the left side.

are narrow and hirsute, flowers small and blue. The fruit has hong-looked thorns.

*Nepeta daënensis* Bois. A therophyte, 5—10 cm tall, slender, upright and for the most part without ramifications, with 2—3 pairs of almost smooth, linear, or linear-lanceolate leaves. Small red flowers. It grows in crevices or similar localities, never, or very rarely, on the flat, arid plain. (Fig. 22).

*Polygonum molliaeforme* Bois. A therophyte with delicate filiform decumbent stems, and 3—4 mm long, smooth, linear leaves, half hidden in great white ochreae. Small, red flowers. In crevices and similar favourable places. (Fig. 23).

*Elymus dasystachys* Trin. (*var. aristatus* Rgl.). A hemi-cryptophyte, with long, subterranean rhizomes (?), and thick tunics around the base of the light-shoots. The leaves are up to 25 cm long, coarse and convolute. The straw up to 35 cm long.

*Halogeton glomeratus.* A therophyte with ascending branches, bearing cylindrical, succulent, blunt leaves, 0,5—0,8 cm long. Flower-clusters in almost all the axils. Found only in the hollows of the plain, preferably where there is a little salt.

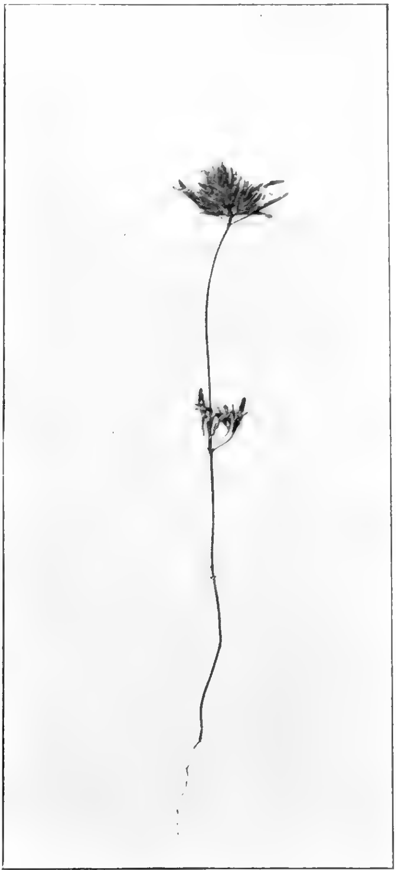


Fig. 22. *Nepeta daënensis* Bois. (ab 1/1).

*Arenaria Meyeri* Fzl. A suffrutescent chamaephyte, forming tufts. The largest I saw was 75 cm long, 70 cm wide. The light-shoots emanate not only above ground, from the lower parts of the stems, but also as far as 10 cm underground; some of them are subterranean runners. It is a semi-rosette-plant in that the majority of the leaves are below on the light-shoots. The leaves are acicular, 1 cm long. The white flowers are about 20 cm above the ground. This species is not common on the plain. It is found almost exclusively in hollows and there, together with *Carex stenophylla*, *Hedysarum cephalotes*, and *Acantholimon diapensioides* and others, forms what may be considered a special formation, the Arenaria-Meyeri-formation. (Fig. 24).

As long as the various parts of the plain are horizontal the vegetation found is, in the main, the same. That *Eurotia* and *Acantholimon diapensioides* form associations in some places, *Artemisia* and *Stipa* in others, is presumably due to chance causes; in any case I have no theory as to how it comes about.

The plants growing on the plain do not represent many different growth-forms. Of the total 31 species, 17 are

Fig. 23. *Polygonum molliaeforme* Bois. (ab. $^1/_1$))

hemicryptophytes, 10 chamaephytes and 4 therophytes. — Let us first consider the chamaephytes. They belong to two groups, cushion-plants and suffrutices. To the former belong only the two *Acantholimon*-species, of which one, *A. diapensioides* is a true cushion-plant, according to Hauri and Schröter's definiton of the term, that is to say, its shoots are so closely packed together, that light and air cannot penetrate between; the leaves are very small and stubby. *A. alatavicum* on the other hand is a "spherical bush", "Kugelkissen", far more open in its construction and with long (spinescent) leaves.

There are 6 suffrutices: *Chrysanthemum pamiricum, Po-*

*lygonum paronychioides* (?), *Eurotia ceratoides*, *Astragalus lasiosemius*, *Artemisia* (*herba alba*?) and *Arenaria Meyeri*. Of these *Polygonum* has short horizontal procumbent shoots, the

Fig. 24. *Arenaria Meyeri* Fzl. (ab. $^1/_3$).

others have upright shoots, of which the lower parts are permanent. Especially characteristic are *Eurotia* with its broad flat stems, and the spinous *Astragalus lasiosemius.*

The 17 hemicryptophytes belong to two types, spot-bound species, and species having elongated, subterrannean rhizomes. To the latter type belong *Ephedra, Carex stenophylla* and *Elymus* (?). The 14 spot-bound species need no repetition here. *Stipa orientalis* is the only monocotyledonous plant among them, and, like most of the others, it forms large close tufts which are born by a huge main-root; radix multiceps. As seen by the figures, the tufts attain great size, and must be very old. Many of them become by degrees so compact and so tall that they approach cushion-plants in form. In the case of others the rhizomes gradually grow high above the ground so that the plants become indubitable chamaephytes. (*Macrotomia*). *Cousinia rava* and the two *Scorzonera* species are the only ones not forming large tufts.

There are only three Therophytes, as *Halogeton* is very rare and confined to single hollows. *Lappula* is, if I may use the expression, a tempered type, upright with rather large leaf-surfaces, while *Nepeta* and *Polygonum* are delicate small-leafed plants mostly found in favourable localities.

Based on the above we may characterize the vegetation of the plain as a richly developed vegetation consisting for the most part of spot-bound hemicryptophytes and chamaephytes, which often form very broad tufts. The plants have no great height as the flowers are usually 20—30 cm from the ground, single exceptions being 1/2 mètre. Among the cespitose plants, the chamaephytes, though the number of the species is few, play a very important part. This is also true of the two species of cushion-plants. Hemicryptophytes with horizontal subterranean shoots are found sporadically. Therophytes are few and of no importance.

This vegetation, or one that is similar, is very common throughout Pamir, especially in the broad flat valleys, called "Pamirs" in the narrow meaning of the term. It is here considered a special plant-formation, named after one of the most important species, Trigonella-formation.

In localities resembling the plain near Mardjanaj there is a vegetation, similar to that on the plain itself, and the same is the case on many slopes having an eastern exposure. Of these more will be told later. Let me here give two examples of Trigonella-formation on flat soil. On the top of the peninsula lying between the two eastern arms of Jashil Kul there is a horizontal flat or slightly rolling plateau, with many stones and occasional embedded boulders. A scattered vegetation of *Eurotia ceratoides, Kochia prostrata* (?) — in some places these two are the only species, — *Stipa orientalis, Acantholimon diapensioides* and *alatavicum, Ephedra, Oxytropis bella, Trigonella Emodi*, and *Silene caucasica* are growing on the fine, sandy, brown soil.

A little to the south, east of the outlet of Bulung Kul, on a plain sloping gently toward the north, grow many specimens of *Solenanthus stylosus, Oxytropis Poncinsii, Cousinia rava, Hedysarum cephalotes* besides the same species as are found on the plain near Mardjanaj, with the exception of *Astragalus lasiosemius* and *Alitschuri*.

Reference may also be made to the descriptions, given above, of the plains near Sary Mullah (page 34), Pamirski Post (page 35) and Shatyr Tash (page 36), where similar vegetation is to be found, composed in part of the same species, among which *Eurotia ceratoides* is always found. The plains near Kisil Kul and Kara Kul had a slightly different character; they were almost bare of plants, and those found were of other species. This difference is presumably due to the fact that the climate of northern Pamir is more severe than that of southern Pamir.

### Sub-formations and Associations caused by moisture or exposure.

As mentioned before, the plain near Mardjanaj though slightly rolling is practically horizontal, and I have also stated that certain species seek out the depressions between the mounds. These depressions naturally enough have a finer, more clayey bottom than the surrounding plain. This bottom is often cracked by drought, and sometimes a little salt may be found crystallized out. Most of the plant species, characteristic of the plain, shun these depressions, — however the following are to be found there: *Acantholimon diapensioides*, whose cushions are here often looser and more rounded than on sandy soil, *Solenanthus stylosus* and *Hedysarum cephalotes* of which there were many low, weakly developed specimens with small, scanty flowers. These species are found just as frequently between the depressions, as in them. On the other hand *Carex stenophylla* prefers the depressions, and *Arenaria Meyeri* (and the annual, *Halogeton glomeratus*, which was only found a single time), grows there exclusively. The case of *Arenaria* was very striking. It made a strong impression of not belonging to the Trigonella-formation, but of being fragments forced in from another plant-community. This other plant-community was found later, south of Jashil Kul, — the Arenaria-Meyeri-formation, covering the rather moist northern slopes of the mountains. The *Arenaria-Meyeri* depressions near Jashil Kul are, then, the forced in fragments of this. The vegetation of the plain cannot then then be rightly considered a single association of the Trigonella-formation, but as a "Complex of associations" (DU RIETZ, FRIES und TENGWALL).

The following may be said in regard to the importance of exposure for the vegetation of the Pamirs. On a gently sloping plain east of a low line of hills, and again east of Bulung Kul, I found *Cousinia rava* dominating, a beautiful luxuriant growth, and of other species: *Stipa orientalis, Chrysanthemum pamiricum, Trigonella Emodi, Hedysarum cephalotes* and *Linaria sp.* The latter were scarce. There was far more soil than plants to be seen.

Where this vegetation is to be found, the plain slopes toward E. S. E. Further south the declivity becomes sharper, and the exposure by degrees N. E. At the turning point, where the exposure changes from south to north, *Cousinia*, *Chrysanthemum* and their accompanying plants disappear almost wholly, and a new association of *Acantholimon diapensi-*

*oides* and *Artemisia* appear. A little further south *Acantholimon alatavicum* appears, *Stipa orientalis* diminishes in quantity and we find large numbers of *Oryzopsis molinioides.* There are single specimens of *Silene caucasica* and *Arenaria Meyeri.*

As the plain forms long flat billows, there is soon a stretch parallel to the first, and here again we find *Cousinia rava* and *Chrysanthemum pamiricum,* but at a new swell of the ground they have once more vanished. We now pass flat stretches with varying exposures and vegetations.

N. W. exposure: Scattered *Eurotia ceratoides,* a few *Acantholimon alatavicum.*

N. E. exposure (decline greater): many *Acantholimon alatavicum* and *Artemisia,* a few *Trigonella Emodi* and *Arenaria Meyeri.*

N. W. exposure: *Eurotia ceratoides, Cousinia rava, Acantholimon diapensioides* (only a few), *Stipa orientalis, Hedysarum cephalotes.*

S. W. exposure: *Cicer pungens, Cousinia rava, Eurotia ceratoides.*

Paying no attention to north and south, but grouping the species just mentioned by eastern and western exposures we find: western exposure, (the dryest localities), *Eurotia ceratoides, Cicer pungens;* both eastern and western exposures: both *Acantholimon* species, *Hedysarum cephalotes, Stipa orientalis* and *Cousinia rava;* eastern exposure alone, (the least dry localities); *Artemisia, Chrysanthemum pamiricum, Linaria, Trigonella Emodi, Oryzopsis molinioides, Silene caucasica, Arenaria Meyeri.* This grouping, in any case the first and last group, corresponds to my own observations of the species most resistant and least resistant to drought. The grouping seems to show how the species are assorted in the various associations. Under definite conditions, (horizontal plains), the species can grow in common, but they are divided into various associations as soon as they are subjected to even a slight degree more or less, of the warmth of the sun and attendant moisture. The differences discussed here are very small; — the slopes are so slight that one cannot feel them when walking. The adjustment between the varieties and their surrounding must be extraordinarily fine.

With what may the Trigonella-formation be most closely compared? In many places its physiognomy resembles a semi-desert, an Artemisia-desert, for instance, or one formed by suffrutescent *Salsola* species, (see Paulsen, page 69); — and Schimper, who, however, only knew the vegetation of Pamir from photographs (fig. 449—455 in his book), says, (page 792), that the flat valleys have the character of deserts, just as does Fedtschenko, (see above, page 28). Compared with the Transcaspian deserts these differ physiognomically by containing the many large cushions of the two *Acantholimon*-species. Cushion-plants (*Anabasis aretioides*) are, though, to be found in the Sahara. Perhaps another difference is to be found in the fact that hemicryptophytes, and not chamaephytes, play the leading part, in any case in quantity of species, that thus woody shoots are less conspicuous here than in deserts. However this difference is not vital, as Transcaspia has a considerable quantity of xerophytic hemicryptophytes, even though their importance is less than in Pamir.

A third difference is that there are no vernal-flowering species here, while in low deserts the majority of the species flower in the spring; the lateness and coldness of the spring is the reason for this.

A fourth, and in my opinion conclusive difference, is the fact that the Trigonella-formation is poor in therophytes, annual species, while low-lying deserts are characterized just by the large numbers of therophytes found there. Salt-deserts are the single exception; this is due to a special edaphic cause, the soil's content of salt, while in Pamir the cause is doubtless climatic. Warming, too, (1909, page 251), emphasizes this, and, quoting various authors, shows that the percentage of annuals diminishes with the increased altitude, (also with the geographical latitude), and remarks that the cause of this lies in the shortness of the vegetation-period, and the low temperature, only permitting a few annuals to complete their development and set ripe seed.

The small number of therophytes present is the main reason why the Trigonella-formation may not be considered a desert-formation. When f. inst. Semenow says the vegetation of Pamir has steppe-character, and Warming (1909, page 260) speaks of "mountain-steppe" or "alpine steppe" on the mountains of High Asia, as "a type of fell-field that approximates to steppe in many respects" he places the vegetation between fell-field and steppe, but gives it the latter name. What WARMING here calls "steppe", is, what I call[1]) semi-desert, and, as has been said before, if plant communities are to be

**Table 3.**

| | Number of species | Percentage of species under each growth-form | | | | | |
|---|---|---|---|---|---|---|---|
| | | F | Ch | H | G | HH | Th |
| East Greenland. Fell-field[1] ........ | 72 | | 25 | 74 | 1 | | |
| Disco. Fell-field[2] ................. | 25 | | 36 | 56 | 4 | | 4 |
| South-Greenland. Fell-field[3] ...... | 61 | | 36 | 56 | 3 | | 5 |
| Iceland. Fell-field[4] ............... | 71 | | 31 | 65 | 1 | | 3 |
| Bernina. "Schuttflur"[5] (ab. 3000 m.) | 61 | | 23 | 71 | 3 | | 3 |
| Trigonella-Formation ............. | 49 | | 29 | 57 | 2 | | 12 |
| Transcaspian lowlands[6] ........... | 768 | 11 | 7 | 27 | 9 | 5 | 41 |

[1] N. HARTZ. [2] PORSILD. [3] ROSENVINGE. [4] JÓNSSON, STEFANSSON, OSTENFELD. [5] RÜBEL. [6] PAULSEN.

named according to their growth-forms, it is hardly permissible to give the Trigonella-formation the name of desert. However, as the most important forms are hemicryptophytes and chamaephytes, there seems to be nothing to prevent placing it under the category of fell-fields. In the Table 3 given here the biological spectrum[2]), (after RAUNKIAER), of the

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[1]) See PAULSEN, 1912.

[2]) The species-list given above, for the Mardjanaj-plain, + following species from other similar localities: **Ch:** *Astragalus Muschketowii, Cicer pungens, Sympegma Regelii, Kochia prostrata* (?). **H:** *Psychrogeton turcestanicum, Arnebia guttata, Oxytropis tibetica* and *humifusa, Christolea crassifolia, Zygophyllum fabaqo, Poa attenuta, Hordeum secalinum, Sisymbrium Korolkowii, Crepis glauca, Calamagrostis compacta.* **G:** *Linaria sp.* **Th:** *Astragalus ophiocarpus, Veronica biloba.*

Trigonella-formation is seen, in the line before the last, and in the remaining lines the spectra, (arranged by me after the lists of the named authors), of various arctic and alpine fell-fields, and finally, (last of all), a desert spectrum. The fact might be emphasized that the fell-field spectrum may not specially express the vegetation natural to fell-field formations, but to that of arctic and alpine nature; for, as RAUNKIAER has shown, hemicryptophytes and chamaephytes dominate in just that nature, — the latter thriving the better the poorer the conditions, i. e. the greater the altitude, or the further north. However, this reservation in no way alters the main point that all the spectra given, agree in having a large percentage of hemicryptophytes and chamaephytes, and from this we may conclude that the spectrum both of the Trigonella-formation and of the others is an expression for alpine nature.

In other words the ability of the plants of Pamir to adapt themselves to their surroundings, in so far as this regards the relation of the surviving apices to the crust of the earth, is an adaptation to cold and snow, rather than to heat and drought.

A further comparison between the Trigonella-formation and fell-fields[1]) reveals the following similarities and differences.

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[1]) According to WARMING, 1909, the characteristic of fell-field is the fact that all vegetation is low, and that plants are so far separated from each other that the bare ground is visible between. In arctic fell-fields there are often many mosses and lichens which are either rare or totally wanting in alpine fields from lower latitudes. Fell-fields are to be found on almost all high mountains. "Warming's description of fell-field, (1909, page 256), might have been written on a New Zealand dry mountain". (SPEIGHT & COCKAYNE, 1911.) The conception fell-field includes many various formations, from the arctic fell-field, which is closely related to "Tundra", to the "Gesteinsfluren" of the Alps (SCHRÖTER) and the xerophytic vegetations in the mountains of Pamir, New Zealand, and many other places. They are all rich in chamaephytes, poor in therophytes, and wanting in fanerophytes, however different they may be in other respects. To give them the common name "fell-field", is at present just as permissible as to group many different formations under the term "forest".

1. The vegetation is scattered, does not cover the ground. I have an idea that it is less scattered in the Pamirs than in the fell-field of the Alps and Greenland, where the nudity of the ground is an important character-mark. The poverty of the soil in humus is characteristic for both.

2. An important difference is the fact that the arctic fell-fields are rich in lichens, while these are wanting in the Pamirs (and in the Alps).

3. Shoots are short, and the leaves therefore grow close to the ground, which WARMING, 1888, denotes as a characteristic of fell-field plants. Rosettes of leaves which are common in the Greenland fell-fields are more rare in Pamir (*Scorzonera*, *Astragalus Alitschuri*, *Oxytropis Poncinsii*), but the shoots are generally short, so that the leaves are as a rule close to the ground.

4. Cespitose growth, "radix multiceps" is common to both localities.

5. Cushion-plants are common, perhaps not in number of species, but in the number of individuals. (*Silene acaulis*, *Acantholimon diapensioides*.) These two species belong to the same group of cushion-plants (HAURI u. SCHRÖTER). *Silene*, just like *Acantholimon*, has adventitious roots on the under side of its branches.

6. In arctic fell-fields many procumbent small bushes are found, *Dryas*, *Arctostaphylos alpina*, *Cassiope*, *Rhododendron lapponicum*, *Salix herbacea*, and *Betula nana*. They are woody chamaephytes, with horizontal branches. There is only one representative for this type in "the Pamirs", *Polygonum paronychioides*, and it is far from attaining the same size and compactness as many of the arctic specimens do.

7. Species having subterranean runners are found in both places, even though their importance is small. *Carex stenophylla* and *Ephedra* in Pamir, *Carex rupestris*, *rigida* and others in Greenland are examples.

8. As far as I know, no synopsis of the adaptation of arctic fell-fields in respect to xerophytic structure exists. WARMING, KIHLMANN, WAGNER, BONNIER and others have published facta in regard, to the hairiness, leaf-structure etc., of arctic and alpine plants; and the biology of arctic plants

has formed the subject of a special series of articles published by Warming under the common title "Biology of arctic plants". We see from these studies that arctic plants are generally low in growth, have small leaves which are often evergreen and in that case either leathery or thick and stiff, or hairy, or pinoid, juncoid or cupressoid, or convolute, and that the stomata are either submerged or concealed in some other way.

Warming (1909, page 254) adds, however, "deciduous foliage shows this xerophytic structure to little or no extent". It seems to me, that in studying a list of fell-field plants, the one from East Greenland given by Hartz for instance, many species are found, which, externally at all events, do not show xerophytic structure: *Chamaenerium latifolium*, *Pyrola grandiflora*, *Campanula rotundifolia*, *Erigeron*, *Arnica*, *Oxyria* and others, even though these plants hardly belong to the very typical fell-field plants.

However their xerophytic structure seems to me less definitely characterized than in the plants of the Pamirs, which have smaller leaves and are more hairy. There are probably no other evergreen plants among these than the two *Acantholimon* species and *Arenaria Meyeri*; the remainder, which either are, (or appear to be), deciduous, seem to have just as little xerophytic structure, — as what follows will show, — as the arctic deciduous plants.

In order to give as concrete an idea as possible of the xerophytic adaptation of species composing the Trigonella-formation, I have attempted to classify their leaves in the various groups shown below.

There are 11 Astragaleae, with small pinnate, always hairy, often sericeous leaves. 6 other species have pinnatifid or pinnate leaves. To these belong *Zygophyllum Fabago;* (a chance guest!), with smooth succulent leaves, *Trigonella Emodi* with smooth ternate leaves, and *Sisymbrium Korolkowii* with scattered hairy leaves of an almost mesophytic type. *Chrysanthemum pamiricum* and *Artemisia* are very hairy, *Cicer pungens* very glandular-hairy.

There are 7 species with small, (under 2 cm in length) undivided, hairy leaves, which are generally narrow. To these belong *Eurotia ceratoides*, stellate-hairy, *Silene caucasica* and *Sympegma Regelii*.

There are, too, 7 grasses and cyperaceae, of which the majority have convolute leaves. Among these *Stipa orientalis* is the most important;

5 species with small, narrow, smooth leaves, to which belong the annuals *Veronica biloba* and *Nepeta daënensis;*

6 species with undivided, comparatively large leaves, in any case more than 2 cm long and not linear. The leaves are hairy, (*Solenanthus, Scorzonera* with the exception of the glabrous *Serratula procumbens.*

There are 3 evergreen species with very small (0,2 cm) or acicular leaves, the two *Acantholimon*-species, and *Arenaria-Meyeri*;

2 Polygonum-species with small leaves, for the most part hidden in the large ochreae;

1 hairy succulent, *Halogeton* (a chance guest!), and

1 leafless species, *Ephedra.*

We see from the above, first that the leaves are as a rule small; in the pinnate species the leaflets are small, their measurements are given above. The majority of the leaves are hairy, as a rule closely. Of glabrous-leafed species, not annuals, or having acicular leaves, there are only *Trigonella Emodi* which has movable leaflets, *Serratula procumbens*, whose leaves are sulcate, the *Polygonum*-species, whose leaves are concealed in ochreae, the augusti-foliate *Linaria sp.* and the succulent *Zygophyllum Fabago.*

In order to obtain an idea of the internal structure of the leaves of the plants of the Pamirs, I have dissected several leaves which were brought home in alcohol. They belonged to the following species: *Astragalus Alitschuri*, *Macrotomia euchromon*, *Silene caucasica*, *Acantholimon alatavicum*, *Oxytropis Poncinsii*, *O. bella*, *O. tibetica*, *Trigonella Emodi*, *Scorzonera mollis*, *Serratula procumbens*, *Sisymbrium Korolkowii*, *Solenanthus stylosus*, *Eurotia ceratoides*, *Arenaria Meyeri*, and *Acantholimon diapensioides.* Other species should have been examined but the necessary material was lacking.

The majority of the species examined, show in the main the same structure. The leaves are isolateral, with 2—3 layers of palisade-cells on each side and a thin spongy parenchyma in the centre. In some cases there is a band of sclerenchyma over the nerves, but this is by no means always the case. The epidermis has never more than a single layer, is not thick, nor thick walled; there are always stomata on both leaf-surfaces, they are on a level with the epidermis except in the *Oxytropis*-species, where they are depressed to the inner line of the epidermis. *Oxytropis tibetica* has epidermis cells filled with mucus.

The following species have a deviating structure:

*Sisymbrium Korolkowii's* leaves are dorsiventral with 4 palisade-layers on the upper surface, loose spongy tissue, thin epidermis with stomata on both sides.

*Trigonella Emodi* has likewise a dorsiventral leaf, yet with palisades on both surfaces. The mesophyllum is loose on the whole; the cells of the epidermis are papillose-curved, very thin walled, and filled with mucus; there are bi-cellular glands and slightly depressed stomata on both sides.

Finally, the winter-green species, *Acantholimon alatavicum* and *diapensioides* and *Arenaria Meyeri* have acicular or scaly leaves with many sclerenchyma-bands and 2—3 layers of palisade-cells the entire way round. The epidermis consists of one layer with a thick outer wall and slightly or non-depressed stomata. In *Acantholimon diapensioides* the cells of the epidermis are papillosely protuberant, in *Arenaria* they have thick walls all the way round.

The leaf anatomy of the majority of the plants of Pamir agrees in the main points with that described by Wagner and by Bonnier as typical for alpine plants. The great development of palisade-cells is especially striking, and one is apt to assume that the plants of Pamir, like the european alpine plants, are adapted to a powerful assimilation of carbonic acid (cf. Bonnier). In any case the majority of species of deciduous plants in the Pamirs seem to be in coincidence with their surroundings, when they have small, hairy, isolateral leaves with well-developed palisade tissue, thin epidermis and stomata on both sides.

We know from HEINRICHER that isolateral leaf-structure seems to be especially dependent on strong light, and according to BONNIER the characteristic features of alpine plants, — short, hairy stems, small, hairy and relatively thick leaves, well-developed palisade tissue and a large number of stomata — seem to be determined by strong light and dry air, as each of these factors alone can transform a lowland plant in such a way that it is able to assume these characteristics to a greater or lesser extent (A. LOTHELIER). Strong light has, though, a greater effect than dry air.

We may then explain the structure of the plants of the Pamirs as directly or indirectly dependent on the strong light and the dry air.

But even though the dryness of the air is one of the factors influencing the structure of the plants, the latter does not necessarily express a xerophytic adaptation. We know that the summers in Pamir are dry, and the plants must naturally be adapted to drought as well as to other conditions, — otherwise they could not live, — but we find only a few expressions of this adaptation to drought.

We can only point to the small size of the leaves and their almost unfailing hairiness as frequent xerophytic characteristics. The latter is especially striking and important, for both in the Alps, and in arctic fell-fields, many glabrous species are to be found, (the few indigenous to the Pamirs are named above), so that we here presumably have the expression of the growth-forms for the particularly dry climate of Pamir. Added to this is the structure of the evergreen species, which, as mentioned above, are of a different and far more xerophilous type than that of the deciduous plants. Aside from this the plants do not seem to be xerophytically constructed, but both in regard to hibernation, and to the structure of the shoots and to the anatomy of the leaves, to agree in the main with alpine fell-field plants. The arctic species have as a rule, as shown by BÖRGESEN and by BONNIER, weakly developed palisade tissue in the leaves, and in this respect differ from the alpine species.

The supposition emphasized above that the Trigonella-formation is rather to be considered a fell-field than a desert form, is strengthened by the fact that the species in their outer and inner structure agree most closely with alpine plants, in other words they are more strongly influenced by the altitude above sea-level, than by the dryness of the climate.

## CHAPTER 7

### The Vegetation of the Mountain-Slopes.

(Eurotia-formation, Arenaria Meyeri-formation, and Poa attenuta-formation.)

In writing of the vegetation (Trigonella-formation) of horizontal flats, attention was called to the fact that other plant species than those of the flats are to be found in depressions, even though these are quite small and shallow. *Arenaria Meyeri* is characteristic of such depressions and is only found there (on flats). An example was given of the vegetation on a flat, mainly horizontal, yet slightly billowed, and we found that the species change according to the different exposures, even though the angle of declivity is extremely small. (Above, page 66.) Thus the adaptability of the plants on flats to the conditions of moisture or of exposure is very great. Exposure should presumably merely be considered as another expression for conditions of moisture, in that it determines the angle at which the sun's rays strike the surface of the ground during the different hours of the day, and the length of the period during which the locality is sunny.

Climbing a mountain in Pamir and going down on the other side, very soon reveals to one the enormous importance of exposure, and one quickly realizes that exposure is, in general, the determining factor for plant growth on a mountain slope. Roughly speaking, a northern and eastern exposure are favourable, a southern and western unfavourable for the appearance of a luxuriant vegetation rich in species; plants on a southern and western exposure are xerophytic, while those on an eastern, and especially a northern exposure are more or less mesophytic.

Exposure, while paramount in importance, is not the only factor to be considered. The nature of the soil plays a part, and is of particular importance when the slopes are covered by talus, — masses of great stones or boulders hurled down the mountain-side, — for these cover the surface of the ground and protect is against the rays of the sun, and it is safe to surmise that much moisture is to be found beneath them. The unusual vegetation characteristic of such places indicates the same. (More of this matter below page 93.) The talus of small stones or gravel, which I have seen in a few places, were either nearly or totally barren, probably because the bottom is constantly changing: the continual great variations in temperature bring about a rapid denudation, followed by a constant supply of new gravel and small stones rolled down from above. On account of the fineness of the material the masses are easily set in motion. In Switzerland such localities have their "Schluttpflanzen", as we know from SCHRÖTER and others.

The importance of exposures may be seen at a distance. On account of the vegetation the bottom of the dry stream clefts appear like dark lines (see fig. 7) on the mountain-sides. On looking more closely, but still a good way off, we see that on a slope with an eastern or western exposure, the dark line of vegetation lies south of the bottom of the cleft and along the southern shore of the bed of the stream; i. e. on the side with a northern exposure, — and, on approaching more closely, we find that not only the bottom of the cleft but the slopes as well have a different vegetation on the north and south side; everywhere the localities with a northern exposure have more luxuriant plant growth, than those exposed to the south. A few examples illustrating this are given below.

Going north on the Mardjanaj-plain, described earlier, along the Mardjanaj River, one finds many larger and smaller clefts cut by small streams now dry, and leading into the river; their main direction is east-west.

The slope toward the north of one of these, was closely grown with *Artemisia sp.*, *Solenanthus stylosus*, *Trigonella Emodi*, *Carex stenophylla*, *Oryzopsis molinioides*, as well as a few specimens of *Acantholimon diapensioides, Hedysarum cephalotes* and *Eurotia ceratoides.* The slope exposed to the south was almost bare; there were only a few scattered specimens of *Eurotia* and *Ephedra Fedtschenkoi*, a very few of *Trigonella, Stipa orientalis*, and *Serratula procumbens.* Of these few species, *Ephedra, Stipa*, and *Serratula* were lacking on the slope exposed to the north.

Only the lower part of the slope toward the south was more densely covered with species from the other side. In the bottom of the cleft the species from the slope exposed to the north were growing as well as *Arenaria Meyeri*, which was only found here.

Another parallel cleft revealed similar conditions. The slope toward the north has a fine cespitose growth with yellow and red flowers; here were quantities of *Hedysarum cephalotes, Trigonella Emodi, Oryzopsis molinioides, Agropyrum longearistatum, Eurotia, Solenanthus stylosus*, and further down *Artemisia.* The slope toward the south is rather bare, at the upper part we found only *Eurotia* and *Ephedra*, lower down, in addition to these two, *Stipa orientalis, Artemisia sp., Astragalus dolichopodus*, and *Nepeta daënensis.* The bottom of the cleft was broad and flat in some places and has the same vegetation as on the plain above.

The species included in these examples nearly all grow on the above-named plain, but they are distributed in another way, and in the clefts reveal their varying grades of hardiness to drought, *Eurotia, Ephedra*, and *Stipa* are the most hardy, *Arenaria Meyeri* the least.

*Eurotia* and *Stipa* are the chief plants in what I propose calling the Eurotia-formation, which is widely found in Pamir on all mountain slopes with a southern exposure. Although all its species are to be found in the Trigonella-formation, yet the selection is so restricted and so characteristic that it seems to deserve consideration as a separate formation. This will be discussed further, later on.

The most hardy species named occur again and again on the arid slopes exposed to the south or west. Often in such places *Eurotia* is the only plant-species found, and it has a scattered growth. *Stipa* is likewise common, *Cicer* *pungens,* a spinous, largely cespitose plant, or *Christolea crassifolia* more rare.

These hardy species, particularly *Eurotia* and *Stipa* are also common on slopes with a western exposure, which, presumably on account of the prevalent western winds, (see Olufsen, Met. Obs.), are almost as barren and dry as the slopes exposed to the north. The following is an example illustrating the difference between slopes with an eastern and a western exposure. In a cleft lying N. S. there is a green slope on the western side having an eastern exposure. Here we find *Nepeta podostachya, Acantholimon alatavicum, Artemisia* (*maritima aff.*), *A. pamirica* and many large tufts of *Arenaria Meyeri.* The slope with a western exposure, however, is bare with green patches formed by *Eurotia, Trigonella Emodi* and a few *Cicer pungens.*

On slopes with a northern exposure many different species are to be found, and not always the same. Below are examples taken from different places in Pamir.

1. Plentiful growth of *Chrysanthemum pamiricum* with *Cousinia rava* and large tufts of *Macrotomia euchromon.*

2. A rather steep slope, green in patches, with *Poa attenuata var. versicolor,* in other places covered with many *Eurotia ceratoides,* which do not here shun advantageous localities.

3. A slope with a north-eastern exposure, almost green. There were many large cushions of *Acantholimon diapensioides* and besides *Artemisia herba alba, Poa attenuata var. versicolor, Solenanthus stylosus, Trigonella Emodi,* and *Paracaryum himalayense* (?).

4. South of Jashil Kul. There is an astonishing change when, leaving the gray parched slopes of the north shore, poor in plant growth as they are, one crosses over to the southern shore. Here the slope is quite green, I might say grassy, extending down to the lake (A "Li" in Danish). The soil is the usual rather fine sand, often cracked or lumpy with many pebbles. On the surface were many large disintegrating crumbling boulders. A large, much ramified dwarf-bush, *Ephedra,* (*E. nebrodensis*), is common, and *Arenaria Meyeri,* which on the north side creeps into hollows,

covers the ground here in many places with its fine fresh green acicular foliage and its many white flowers whose odour is plainly detected. There is a profusion of *Astragalus alatavicus*, multipinnate and green-leafed and mostly without blossoms. *Astragalus Alitshuri, Stipa orientalis, Psychrogeton turcestanicum, Trachydium sp.* are common species, and *Festuca ovina var. valesiaca, Parrya nudicaulis,* (lo[illegible] vines hanging down a steep slope), *Nepeta kokanica, Macrotomia euchromon, Cousinia rava, Crepis flexuosa, Kochia prostrata,* (in places very abundant.), *Artemisia* (*maritima aff.*) *Veronica Hjuleri, Sisymbrium heteromallum, Bromus crinitus, Ligusticum alpinum, Geranium collinum,* are likewise found. *Eurotia* is scarce, but on a few slopes exposed to the west or south, that and *Stipa orientalis* are the only plants found. *Acantholimon diapensioides,* one of the most common of the plants of Pamir, is lacking here, but the spinous *A. alatavicum* is common. The lovely red-flowered *Pedicularis pulchra* grows in small, dampish depressions.

Of the last four examples named, — to which many others could have been added, — the first three show a striking resemblance to the vegetation on the horizontal flats, (Trigonella-formation); their species are almost all indigenous to these, which is likewise true of the species characteristic for slopes with a southern exposure.

The last named species, and especially *Eurotia ceratoides*, are characteristic both for the short slopes of clefts and similar places, and for the long mountain declivities exposed to the south, which the strong insolation quickly rids of the dampness coming down from the summits of the mountains.

This is not the case with the species, which from horizontal flats creep up the slopes with a northern exposure, and to which reference was made above. These species seem to be the characteristic for the short slopes of clefts etc. or for the base of the mountains, whereas, on the long main slopes of the mountains exposed to the north, which are shady and watered from above, they resign in favour of communities of other mesophytic plants, (Poa attenuata-formation).

The last of the examples given (4), the one from the southern shore of Jashil Kul belongs to the first category. The vegetation is mostly composed of the species of the Trigonella-formation, very luxuriantly developed. However there are some species, not seen in "the Pamirs", which belong to a more mesophytic type than these plants. *Ephedra nebrodensis, Astragalus alatavicus, Trachydium sp., Festuca ovina var. valesiaca, Parrya nudicaulis, Pedicularis pulchra* are species showing that this slope is more moist than the others mentioned above. This slope was indeed the end of the main slope of the mountain, exposed to the north; and many rushing torrents indicated how much water came from the summit.

The vegetation south of Jashil Kul forms a transition between the Trigonella-formation, and the mesophytic formation on the mountain-slopes exposed to the north. Yet, differing from them both in the combination of species and conditions of adaptability, it seems to claim consideration as a special formation, with a name borrowed from the dominating species, — Arenaria Meyeri-formation. A typical development of this was seen nowhere else.

I have seen the mesophytic vegetation of mountain slopes, or the Poa attenuata-formation especially well developed in three places in Pamir, — on the two mountains lying east and west of the lower course of the Mardjanaj, (on Olufsen's map in "Geografisk Tidsskrift", the western peak is called "Hens"), and in the Chargush Pass.

The finest development of Poa attenuata-formation was on the north-eastern and northern side of Mt. Hens. Before describing it, I will for the purposes of comparison relate a few facts concerning the vegetation of the adjacent slopes. On the south-western slope, on the ridges between ravines, the usual poor *Eurotia* vegetation, with *Stipa, Cicer pungens, Acantholimon alatavicum, Silene caucasica* and *Astragalus lasiosemius,* was found. In the clefts, which are green, *Arenaria Meyeri, Oryzopsis molinioides* and *Hedysarum cephalotes* dominate. Near the summit the last mentioned species becomes common, and many *Elymus lanatus var. canus* and *Senecio Paulsenii* appear.

Seen from a distance the eastern slope looks green, but on approaching it, the ground becomes visible between the tufts, which are formed of *Artemisia aff. maritima*, *Trigonella Emodi* *Acantholimon alatavicum*, *Astragalus lasiosemius*, *Stipa*

Fig. 25. *Poa attenuata* Trin. (ab. 1/2)

*orientalis* and *Astragalus Alitschuri*, and in clefts and hollows *Arenaria Meyeri*, — on the whole a less xerophytic vegetation than on the slope with a S.W.-exposure, and corresponding to the Trigonella-formation. The large clefts open to the east bear on the slopes exposed to the north-east an entirely different and totally mesophytic vegetation, in some places dense in others somewhat marshy, growing on moist soil rich in humus. Here we find the Poa attenuata-formation in an association comprising *Carex macrogyna* and *Kobresia schoenoides*, *Gypsophila cephalotes*, *Geranium collinum var. saxatile*, *Myosotis silvatica*, *Primula nivalis*, with beautiful, large, purple blossoms, the white-flowering bulbous plant *Lloydia serotina*, in large quantities, succulent Ranunculi, (*R. rufosepalus* and *rubrocalyx*), *Saxifraga cernua* and *flagellaris*, *Cerastium trigynum var. glandulosum*, *Leontopodium alpinum*, *Sedum gelidum*, *Swertia sp.* Not a single one of these species belongs to the Trigonella-formation.

On the north slope of the mountain a similar vegetation is found on similar soil. In a single locality were included: *Astragalus alatavicus* (mentioned above from the south side of Jashil Kul), *Draba turcestanica*, *Pedicularis dubia*, *P. pulchra*, *P. sp.*, *Isopyrum anemonoides*, a tiny, fine-leafed ranunculacea with white blossoms, *Gypsophila cephalotes*, *Dracocephalum discolor*, and *Nepeta kokanica*, gray-leafed, aromatic labiates with blue flowers, *Artemisia minor*, *Oryzopsis purpurascens*, *Poa attenuata*, *Elymus lanatus*, for the most part without blossoms, *Acantholimon alatavicum*, *Hedysarum cephalotes* and a few barren cushions of mosses. These last named species do not seem to rightly belong in this plant community, and the same is true of *Nepeta* and *Dracocephalum*, which appear to represent another and more xerophytic type, than *Pedicularis* and the others with which, however, they always appear. I have made no notes on this.

On another part of the north slope the vegetation grew in vertical stripes of various combinations. The most xerophytic were represented by low ridges, with a somewhat western exposure, on which *Eurotia ceratoides* was scattered. The slope was dry, and at a depth of 12—14 cm the soil was a little moist. The intervening degree of moisture was represented by stripes in which *Nepeta kokanica*, and two grasses, *Bromus Paulsenii*, and *Poa attenuata var. versicolor* dominated. Besides these, *Acantholimon alatavicum*, *Psychrogeton turcestanicum*, *Arenaria Meyeri* and *Artemisia minor* were seen. These plants, forming a rather mesophytic community, yet with xerophytic traces, (*Acantholimon*, *Nepeta*), grow on stony brown soil rich in humus, which at a depth of 10—30 cm is dark with moisture. I consider it an association of the Poa attenuata-formation.

The third kind of stripe (another association of Poa attenuata-formation), is the most luxuriant, and the soil is dark with moisture a few centimètres below the surface. The vegetation is green and dense and formed by *Geranium collinum*, *Cerastium trigynum*, *Swertia marginata*, a white-flowering Gentianacea, *Pedicularis*, *Kobresia schoenoides*, *Isopyrum anemonoides*, and *Nepeta kokanica*.

These vertical stripes alternate with each other many times; *Eurotia*-stripes are always on the dry ridges, and *Geranium*-stripes in the flat furrows. In one of these was a spring now dry. Water wearing down through a subterranean $^1/_2$ mètre thick layer of stones about as large as one's fist, had washed away the plant-bearing layer of soil (about 30 cm thick) lying on top, and then continued its course carrying stones, plants and soil in its way. At the mouth of the spring there was a hollow in the mountain-side about 7 mètres broad with a perpendicular wall about 1 mètre high. The soil strata were visible in this wall. Highest up the brown soil in which plants grow, then a layer of stones, from which most of the soil was washed out, and where there were many fine well-rinsed roots, and lowest a very moist, soft, brown layer of soil. This profile is interesting, showing that the mesophytic vegetation is apparently due to the stony layer containing water close below the surface of the ground. The moist soil, rich in humus, above the stones seemed to contain much nourishment.

This vegetation, somewhat dense and surprisingly abundant in a country like Pamir, must then be due to glacial water, which from above oozes through the layer of stones and is here protected from evaporation by the overlying stratum of soil and the vegetation.

On the mountain lying east of Mardjanaj a similar condition to that on Mt. Hens was found. The vegetation on the north slope was rather dense, in some places close, and comprised *Dracocephalum discolor*, *Nepeta kokanica*, *Oryzopzis purpurascens*, *Draba turcestanica*, *D. fladnizensis aff.*, *Astragalus alatavicus*, *Isopyrum anemonoides*, *Potentilla sericea*, *Oxytropis immersa*, *Psychrogeton turcestanicum*, *Elymus sibiricus*, *Chrysanthemum Richteria*, *Gagea stipitata*, *Festuca ovina var. valesiaca*, *Poa attenuata*, *Artemisia macrocephala*, *Hedysarum cephalotes*, and *Sedum Rhodiola*. Of these species only *Psychrogeton* and *Hedysarum* grew on the south side of the mountain too; they are moreover to be found in "the Pamirs" (the flats). This north-side vegetation does not cover the entire north side of the mountain, but apparently only those places where the exposure is somewhat eastern. — Only here are marmots found, which was likewise the case on the mountain described above. There were also places with a slight western exposure and which were covered with Eurotia-formation *(Eurotia* and *Stipa orientalis)*.

On the summit of the mountain, about 4,300 mètres above sea-level, in the pass between too peaks lying east and west of each other, the following characteristic plants were gathered.

On the south side of the pass, widely separated, *Hedysarum cephalotes* and *Oxytropis Poncinsii.*

On the north side, *Sedum Rhodiola*, *Nepeta kokanica*, *Draba fladnizensis aff.*, *Hedysarum cephalotes*, grasses and single specimens of *Solenanthus stylosus*, forming a luxuriant if not close vegetation.

Under the boulders lying on the summit of the mountain, large tufts of the interesting cruciferous *Didymophysa Fedtschenkoana*, with fresh, succulent leaves, small white flowers, and puffy bladder-shaped fruits were growing. *Smelowskia annua* was likewise found here.

For the sake of comparison with the vegetation of the northern slopes, lists of plants from the eastern and southern slopes are given. Trigonella-formation dominated on the eastern slope. Here *Stipa orientalis, Eurotia, Astragalus lasiosemius, Artemisia aff. maritima, Acantholimon alatavicum, Polygonum paronychioides, Chrysanthemum pamiricum* were common; *Trigonella Emodi, Cicer pungens, Crepis flexuosa* more rare, while *Arenaria Meyeri* was to be found in clefts. These plants formed a very dense vegetation, from a distance lending a greenish hue to the mountain-side.

On the southern slope the following species were noted: *Stipa orientalis, Hedysarum cephalotes, Lappula microcarpa* (very scattered), and *Psychrogeton turcestanicum.* The plants were so far apart that from a distance the slope looked quite brown.

We see, then, that the vegetation on both the eastern and southern slopes is formed by the species of the Trigonella-formation, while on the northern slopes these were almost totally wanting.

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West of the Chargush Pass (height of the pass, about 4,200 mètres), two totally green slopes with a northern exposure were examined. They were both bounded on the south by steep talus slopes, under whose stones, the water poured down from the mountain tops. From the talus it sifts in under the green slopes, presumably flowing under the ground through a layer of stones as described above. The soil is humous, almost black, and moist a few centimètres under the surface. I did not see the substratum of stones, but its presence must be inferred from the fact that not a particle of water flows on the surface of the slopes. On these was a close vegetation of the following species: *Ranunculus sp., Cerastium trigynum, Saxifraga hirculus, Swertia marginata, Primula nivalis var. macrocarpa, Carex sp., Aster flaccidus (= tibeticus), Delphinium cachemirianum, Lagotis borealis, Parnassia subacaulis, Myosotis silvatica, Isopyrum anemonoides, Papaver radicatum, Gentiana falcata, Hymenolaena Lindleyana var. bucharica, Melandrium triste, Draba alpina* and *media, Astragalus tianschanicus var. pamiricus, Poa persica var. alpina, P.*

*attenuata var. versicolor, Tragopogon parvifolium, Calamagrostis anthoxanthoides, Bromus erectus f.*

As on the northern slopes near Jashil Kul, described earlier, this is a close or nearly close vegetation composed almost entirely of hemicryptophytes. The remaining plants are a few therophytes, chamaephytes and a geophyte (*Gagea*).

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As a main result of the above descriptions we may conclude that mountain slopes of Pamir with a northern exposure have a vegetation more os less dense, often close, formed of mesophytically adapted species, while the slopes with a southern exposure have an open, poor vegetation of xerophytes. To obtain a synopsis of the ecology of these vegetations, lists are given of the species on slopes with a northern and southern exposure and information of their biological types (growth-forms), — just as was done in the case of the horizontal flats.

List of plants growing on slopes with northern or northeastern exposure (Poa attenuata-Formation).

**Cyperaceae.**

Carex macrogyna H
— sp. H
Kobresia schoenoides H

**Gramineae.**

Agropyrum longearistatum H
Bromus erectus H
— Paulsenii H
Calamagrostis anthoxanthoides H
Elymus lanatus H
— sibiricus H
Festuca ovina H
Oryzopsis purpurascens H
Poa attenuata H
— persica H

**Liliaceae.**

Gagea stipitata G
Lloydia serotina G

**Borraginaceae.**

Myosotis silvatica H
Paracaryum himalayense H

**Caryophyllaceae.**

Arenaria Meyeri Ch

Cerastium trigynum H
Gypsophila cephalotes H
Melandrium triste H

### Compositae.

Artemisia macrocephala Th
— minor H
— rupestris Ch
Aster flaccidus H
Chrysanthemum Richteria H
Leontodon alpinus H
Psychrogeton turcestanicum H
Senecio Paulsenii H
Tragopogon parvifolium H

### Crassulaceae.

Sedum gelidum H
— Rhodiola H

### Cruciferae.

Draba alpina H
— fladnizensis Ch
— media Th
— turcestanica Ch

### Gentianaceae.

Gentiana falcata H
Swertia marginata H

### Geraniaceae.

Geranium collinum H

### Labiatae.

Dracocephalum discolor H
Nepeta kokanica H

### Papaveraceae.

Papaver radicatum H

### Papilionaceae.

Astragalus alatavicus H
— nivalis Ch
— tianschanicus H
Hedysarum cephalotes H
Oxytropis immersa H

### Plumbaginaceae.

Acantholimon alatavicum Ch

### Primulaceae.

Primula nivalis H

### Ranuculaceae.

Delphinium cachemirianum H
Ranunculus rubrocalyx H
— rufosepalus H
— sp. H?
Isopyrum anemonoides H

### Rosaceae.

Potentilla sericea H

### Saxifragaceae.

Parnassia subacaulis H
Saxifraga cernua H
— flagellaris Ch
— hirculus H

### Scrophulariaceae.

Pedicularis dubia H
— pulchra H
— sp. H

### Selaginaceae.

Lagotis borealis H

### Umbelliferae.

Hymenolaena Lindleyana H
Trachydium sp. H

Of these 65 species 54 are hemicryptophytes (H), 7 chamaephytes (Ch), 2 geophytes (G), and 2 therophytes (Th). The percentages are given in table 4. Compared with the plants of "the Pamirs" those of the northern slopes show a greater preponderance of hemicryptophytes and much fewer chamaephytes (11 % compared with 29 %).

List of plants growing on slopes with southern or southeastern exposure (Eurotia Formation).

**Gnetaceae.**

Ephedra Fedtschenkoi H

**Gramineae.**

Elymus sp. H
Stipa orientalis H

**Borraginaceae.**

Lappula microcarpa H

**Chenopodiaceae.**

Eurotia ceratoides Ch.

**Compositae.**

Artemisia maritima aff. Ch
Chrysanthemum pamiricum Ch
Crepis flexuosa H
Psychrogeton turcestanicum H
Serratula procumbens H

**Cruciferae.**

Sisymbrium brassiciforme Th

**Papilionaceae.**

Astragalus dolichopodus H
— lasiosemius Ch
Cicer pungens H
Hedysarum cephalotes H
Oxytropis Poncinsii Ch
Trigonella Emodi H

**Plumbaginaceae.**

Acantholimon alatavicum Ch

**Polygonaceae.**

Polygonum paronychioides Ch

**Table 4.**

| | Number of species | Percentage of species under each growth-form | | | |
|---|---|---|---|---|---|
| | | Ch | H | G | Th |
| Northern exposure (Poa att. Formation) | 65 | 11 | 83 | 3 | 3 |
| Horizontal (Trigonella Format.)...... | 49 | 29 | 57 | 2 | 12 |
| Southern Exposure (Eurotia Format.) | 19 | 37 | 58 | | 5 |

Of the 19 species listed, 11 are hemicryptophytes, 7 chamaephytes and 1 therophyte. The percentages are given in table 4.

Leaving out of consideration the one therophyte, (*Sisymbrium brassiforme*) which was found only a single time, and is not characteristic for these localities, this last spectrum is remarkable for the number of chamaephytes it contains, even more than in the horizontal flats of "the Pamirs".

From the above we see, first that exposure influences the number of the species. This is greatest on slopes with a northern exposure, (65), smaller on horizontal flats, (49) and smallest on slopes with a southern exposure (19). That is to say, that under increasing insolation and resulting drought, fewer and fewer species can exist. We may expect, then, to find xerophytic adaptation least developed on the slopes with northern exposure, and best developed on those with southern exposure.

Next, in regard to the growth-forms, I regret that I have not been able on the spot to make a formation-statistical examination with a computation of the valence of the species. (compare Raunkiaer.) Instead I must repeat what was stated above, namely, that *Eurotia ceratoides* is by far the most common species to be found on slopes with a southern exposure, and *Stipa orientalis* next. In many instances these two are the only species to be found. If we consider them equally common, we obtain (as valence of growth-form) 50 % chamaephytes and 50 % hemicryptophytes. As a matter of a fact *Eurotia* should have a higher number than *Stipa*.

On slopes with a northern exposure the most common species are hemicryptophytes: *Poa*, *Kobresia*, *Astragalus alatavicus*, *Oryzopsis*, *Isopyrum* etc. *Arenaria Meyeri* is however a chamaephyte.

Table 4 shows that when all species are considered equally common the number of chamaephytes increases with the amount of insolation, but according to what I have just stated, if the species, and thereby the growth-forms, had frequency-valences, the figures would show still greater differences.

In any case, according to the above, we may consider it a fact that in Pamir the localities with a southern exposure, (the driest), have the greatest number of chamaephytes, those with a northern exposure the smallest number; while horizontal flats lie between the two, both in regard to insolation and to number of chamaephytes.

How the species on the southern slopes adapt themselves in other respects to their surroundings, may be judged by comparing them with the flats described above. The species on slopes with a southern exposure are no other than a selection of the species growing on the flat "Pamirs", a selection made by nature herself. If we try to catalogue them according to leaves and covering, as was done with the plants of the flats, we find among these plants growing on slopes with a southern exposure, 5 pinnate Astragaleae as compared with 11 on the flats, — 3 other species with pinnate or pinnatifid leaves, as compared with 6 on the flats, — 3 species with undivided small, hairy leaves, as compared with 7, — 2 Gramineae and Cyperaceae, as compared with 7, — 2 species with small, narrow, glabrous leaves, as compared with 5, — 1 species with large entire, glabrous leaves, as compared with 6, — 1 evergreen as compared with 3, — 1 Polygonacea as compared with 2, — and 1 leafless Ephedra as compared with 1.

The reduction has, as we see, especially hit the groups Gramineae + Cyperaceae, and the two groups with entire and glabrous leaves. These 3 groups contain, I suppose, the least xerophytic plants. The plants on southern exposures in the remaining larger groups number about the half or a little less, of the species of the same groups on the flats, corresponding to some extent to the total number of species in the two localities: 19—49.

That the least xerophytic species of the flats are preferably the ones wanting on the southern slopes confirms that the former are drier than the latter.

The plants on slopes with a northern exposure do not, as so often stated, belong to the xerophytic type. A glance at the list, page 87, will confirm the impression that the species are, on the average, mesophytic in their structure. Only a few species (*Psychrogeton*, *Hedysarum*, *Acantholimon*) are found again on the slopes with a southern exposure, and with these are a very few, especially *Dracocephalum* and *Nepeta* which, on account of their xerophytic character (small, hairy leaves) seem strangers to the plant community in which they are found.

Among mesophytic traits we may mention that the grasses, except *Festuca ovina* and *Poa attenuata*, are broad-leafed, as are Liliaceae, that there are many glabrous species, (*Gypsophila, Melandrium, Senecio, Gentiana, Swertia, Geranium, Primula, Ranunculus, Parnassia, Saxifraga, Pedicularis, Lagotis, Hymenolaena*; *Trachydium*) and that these species have also brittle leaves, — that is to say the mechanical tissue is slightly developed. More or less hairy species are also found: *Myosotis, Paracargum, Artemisia, Chrysanthemum, Leontodon, Draba, Dracocephalum, Nepeta, Papaver, Astragalus*, and *Potentilla* belong here, but these can not be called xerophytic. *Papaver radicatum* and *Myosotis silvatica* are mesophytically adapted; the same is perhaps true of the others. Cyperaceae and the bulbiferous Liliaceae, of which there are respectively 3 and 2 species, are not usually found in very dry localities. This is likewise the case with species with horizontal and rootstriking shoots of which *Leontodon, Draba fladnizensis* and *turcestanica,* as well as *Saxifraga flagellaris,* were found on slopes with a northern exposure. Only the few species mentioned above, which are also found on slopes with a southern exposure, and perhaps to some extent *Arenaria Meyeri* can be called xerophytes.

On the whole, one may be justified in calling the vegetation on the slopes with a northern exposure, mesophytic, and, as a comparison with what is to follow will show, this vegetation is most closely related to the vegetation of the river-banks.

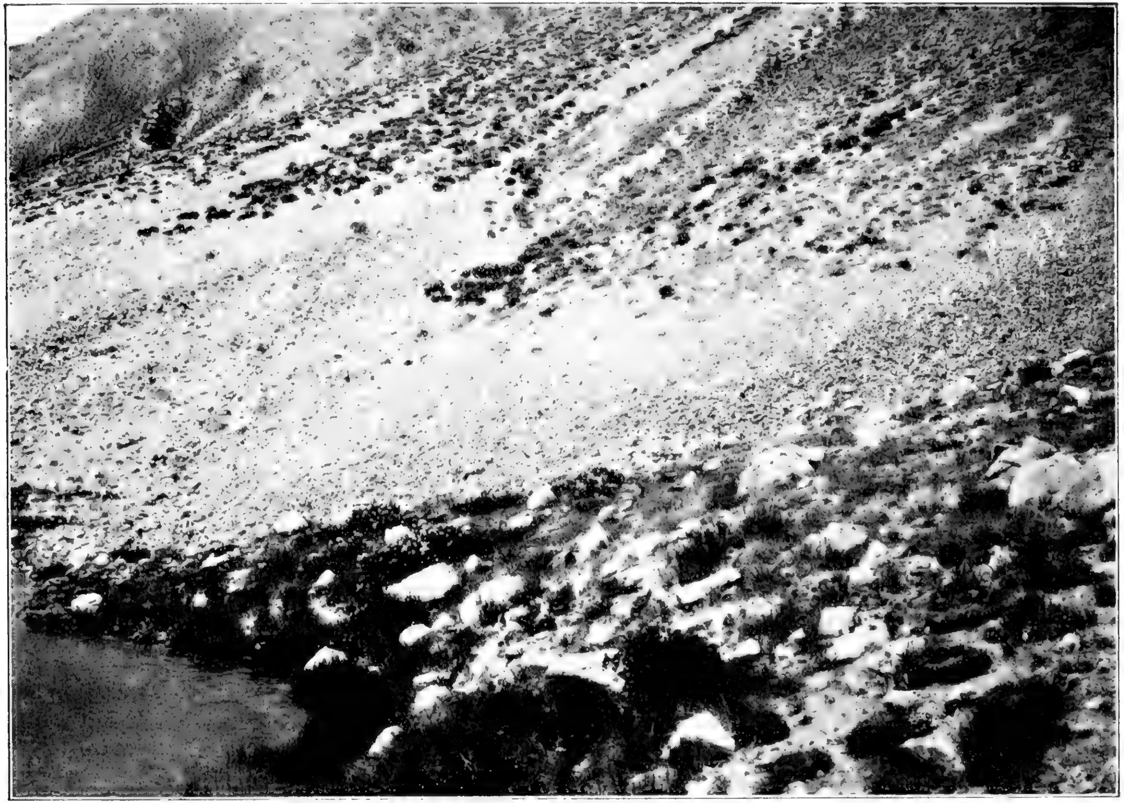
CHAPTER 8

## The Formation on the Talus Slopes.

As was stated on page 77 talus with large stones reveal other conditions than those usually found on mountain-sides. The great stones and boulders cover protectingly the finer soil beneath, so that even on slopes exposed to the south it does not dry totally out. The vegetation is influenced by this condition, as will be shown in the following.

The western part of the northern shore of Jashil Kul is formed, as described on page 40, by a talus slope stretching, from the almost perpendicular wall of the mountain, straight down to the lake. This slope is continued along the west shore as well.

In many places the talus of the north shore is totally without plant life; seen from a distance no green is visible, only gray-brown stones. Even in the most fertile spots there is a distance of at least a mètre, and some time many mètres, between each plant. The common species are: *Eurotia ceratoides*, *Cicer pungens*, *Lagochilus diacanthophyllus*, *Ligusticum alpinum*, *Nepeta podostachys*, *Elymus lanatus var. canus*, *Artemisia maritima aff.*, *Astragalus lasiosemius*, huge cushions of *Acantholimon alatavicum*, *Zozimia tragioides*, *Rubia tibetica*, *Heracleum Olgae var. virens*. The latter is very noticeable, even though most of the specimens have only rosettes of leaves. The leaves are green and about ½ mètre long; yet high inflorescences both green and dry are to be seen also in quantities. We found too, *Erigeron acer var. droebachensis*, *Sisymbrium Sophia var. nana*, *Astragalus tibetanus*, *Linaria sp.*, *Silene caucasica*, and on the western part, with partly eastern exposure, were *Artemisia pamirica*, *Allium sp. Trigonella Emodi*, *Crepis flexuosa*, *Cousinia rava*, *Astragalus Alitschuri*, *Ephedra distachya*, *Chrysanthemum Richteria*, *Stipa orientalis* (scanty), *Elymus sibiricus*, *Agropyrum longearistatum*, *Polygonum alpinum* with its large white spiraea-like flowers, in great quantities; *Arenaria Meyeri*, *Ziziphora clinopodioides var. dasyantha*, *Hymenolaena darvasica*, *Sedum Rhodiola*, *S. sp.*, *Ribes heterotri-*



(O. OLUFSEN *fot.*)

Fig. 26. Talus slope with vegetation, at the western end of Jashil Kul.

*chum* with long crooked stems clambering between the stones, while growing sporadically on the lower part of the talus was a large quantity of *Chamaenerium angustifolium*, and single low bushes of *Hippophaës rhamnoides*.

At the western end of Jashil Kul the talus vegetation was strikingly abundant; particularly on slopes with an eastern exposure. The illustration fig. 26 shows this. It is so unusually rich for conditions in Pamir that M^me^ Olga Fedtschenko has omitted the western end of Jashil Kul from "the true Pamir" (Flóre du Pamir, map) On the slope with an eastern exposure the vegetation is most abundant, but there is no qualitative difference of importance between that and the vegetation on the neighbouring talus slope with a southern exposure. *Polygonum alpinum*, *Chamaenerium* and *Hippophaës* are found only on the western part of the lake (on both shores), I have in fact never found them in any other places in High Pamir. M^me^ Fedtschenko does not mention them from Pamir. Later on, I found *Polygonum* and *Hippophaës* in Goran, in the valley of the river Pändsh, and it is reasonable to surmise that they have migrated from the west toward the east along the Gund river, and have not yet come further in their journeyings. However there is no information at hand at present as to whether they are to be found in the valley of the Gund. It is possible that they are only to be found at the western end of Jashil Kul, because only there are conditions sufficiently favourable, — the place is comparatively warm and sheltered. Yet *Polygonum* was so luxuriant and abundant in its growth that it did not appear to be at its extreme boundaries. This might be true of *Hippophaës*. The latter has juicy fruit and might have been transported by birds; the former has rather heavy nuts.

# CHAPTER 9

## Formations Confined to Water

(Hygrophilous and mesophilous).

### A. The Formation of swamp-meadows.

Along the shores of lakes, and in particular in many places along the banks of slowly flowing rivers, and in deltas, stretch green flats, which, at a distance, look like meadows but which are better described as marshes or swamp-meadows. Their most characteristic feature is the great cyperacea-tufts, broad, and up to almost a mètre in height, and doubtlessly very old. They are formed by the species, *Kobresia Bellardi, Royleana, schoenoides, stenocarpa, Carex orbicularis* and often *Triglochin maritimum. Carex pseudofoetida*, which is a subterranean runner, is also common. Between the tufts, there are either open pools, of gently moving or stagnant water, or bare, water-sooked, stinking mire. In these stagnant pools, and where the water moves but gently, salt is crystallized out, lying like hoar frost on the tufts, or, — when the water has evaporated, forming centimeter-thick crusts between them, and looking like solid frozen pools. Some marshes are quite white with salt.

In regard to vegetation non-saline marshes resemble in the main salt-marshes, if the amount of salt in these is not particularly great, as is the case near Tuz Kul. The cyperaceous tufts in particular are the same. In regard to the other flora, many species are found here, which I never found in salt-marshes, others which only seem to appear in non-saline marshes, and a third group, which is common to both localities.

Among halophilous species *Saussurea crassifolia* and *Polygonum pamiricum* occupy the first rank, in the second are *Potentilla dealbata*, which was common in some localities, *Atriplex crassa* and *rosea, Suaeda setigera* each of which, however, was only found in a single locality, *Carex pseudofoetida* and *microglochin, Alopecurus mucronatus, Calamagrostis stricta*, and *Scirpus compressus*, all with subterranean or ground-runners, *Calamagrostis compacta* and *Atropis tenuiflora* in tufts, and lastly *Taraxacum bicolor* and *T. officinalis var. Steveni, Oxytropis glabra var. pamiricum, Capsella draboides, Erysimum pamiricum*, the latter having only been seen a single time in Pamir, and then in a salt marsh. *Atropis convoluta*, a cespitose grass, and *Elymus dasystachys*, with runners, belong most nearly to salt-marshes, though I have seen them in other localities. *Carex vesicaria var. alpigena, Triglochin maritimum* and *palustre, Poa pratensis, Hordeum secalinum var. brevisubulatum, Pedicularis uliginosa* and *Primula sibirica*, both with beautiful red blossoms, *Swertia marginata*, and *Gentiana prostrata* have all been found both in non-saline and very salty swamp-meadows. I saw *Heleocharis palustris* and barren *Phragmites* a single time in a salt marsh with an inlet of warm, sulphurous water.

The following species are only seen in non-saline marshes: *Polygonum viviparum* which here is a substitute for *P. pamiricum, Ranunculus pulchellus var. pseudohirculus, Astragalus brachytropis, Gentiana leucomelaena*, and *barbata, Pleurogyne carinthiaca, Plantago major, Pedicularis rhinanthoides, Saxifraga hirculus, Euphrasia hirta, Melandrium triste, Capsella procumbens, Rheum spiciforme, Juncus triglumis, Carex parva, Stellaria brachypetata*, and *Salix repens var. rosmarinifolia*, which is sometimes seen on the edge of the swamp-meadows as low bushes.

As a rule the species found in swamp-meadows are hemicryptophytes and, as one might expect, they have no xerophytic traits; a few, (*Saussurea* and the Chenopodiaceae), are thick-leafed halophytes. The majority and the dominating species are cespitose plants or spot-bound species, yet a few species with runners are also found. There are hardly any other annuals than *Atriplex* and *Suaeda*. There are several plants with beautiful blossoms, as the following examples will show:

Examples of Marsh-Vegetation.

1. The little lake, Bulung Kul, is shallow, its shores flat and almost encircled by a rather broad belt of marsh-vegetation. Salt is present nearly everywhere, and on mounds

or other protuberances, especially old cyperaceae-tufts, is crystallized out. These latter are formed by *Carex orbicularis var. bulungensis* and *Kobresia schoenoides; Carex pseudofoetida* is especially halophilous. In very moist places *Carex vesicaria var. alpigena* with runners and the cespitose *Calamagrostis compacta* are seen. *Atropis convoluta var. subscariosa* colours some spots with its crimsom panicles, in others, *Alopecurus mucronatus* and *Atropis tenuiflora* are found. Between the tufts in the most saline places are the red-flowering *Saussurea crassifolia*, and *Polygonum pamiricum; Pedicularis uliginosa* flaunts its flaming red clusters of flowers, while the slender, graceful little *Primula sibirica* often finds fast ground on the large cyperaceae-tufts. Here and there, where there is not too much moisture, the greenish white blossom of *Swertia marginata* alternate with the tiny *Gentiana prostrata*, and, as occasional guests, we notice *Mulgedium tataricum*, *Taraxacum officinale var. Steveni*, *Lepidium latifolium*, *Capsella draboides*, *Erysimum pamiricum*, and *Oxytropis glabra var. pamirica*. *Potamogeton Friesii* is seen in the pools of water, with *Batrachium paucistamineum* f. *Drouetii*, as white islands.

On the southwestern shore of the lake the vegetation is somewhat different. Here, a 3—4 mètre high slope confines the lake-basin. At the foot, numerous small springs gush forth, and their fresh water slowly oozes over a narrow beach. Here too, are cyperaceae-tufts, with *Desmatodon cernuus* and *Pottia Heimii* growing on top, and between them sterile moss-cushions and spikeless grasses. We find, too, *Cerastium trigynum*, *Ranunculus pulchellus var. pseudohirculus*, *Saxifraga hirculus* and *Pleurogyne carinthiaca*.

2. In the valley of the Murghab near Pamirski Post broad green swamp-meadows[1]) stretched away on either side of the river. Great tufts were formed by *Carex orbicularis*, *Kobresia Royleana* and *Bellardi* and *Triglochin maritima*. Between the tufts was shallow water, stagnant, near the edge of the marsh, running, further out. On the tufts and along the edge were *Taraxacum bicolor*, *Pedicularis uliginosa*, *Ra-*

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[1]) Pictured by Mme FEDTSCHENKO, Flore du Pamir, Table 3.

*nunculus pulchellus*, *Carex microglochin*, *Triglochin palustre*, *Primula sibirica*, *Hordeum secalinum var. brevisubulatum*, *Colpodium sp.*, *Poa pratensisa var.*, *Poa tibetica var.*, *Bryum subacutum*, and the water plants *Potamogeton amblyophyllus*, and *Hippuris vulgaris.*

Where the marshes are drier, they are white with salt, which enshrouds the tufts and encircles the pools. At the bottom of dried-out water-basins is a 3 cm thick salt crust over the mire. Here *Carex orbicularis* and *Kobresia Bellardi* are the main elements of the vegetation, while *Potentilla dealbata* is also common.

3. Near the little lake of Tuz-Kul, — (the name means 'salt-lake'), and near other lakes in its vicinity, considerable quantities of salt have been deposited on the surface of the ground, along the banks of the lakes and on the intervening stretches. It is apparent that water containing salt must ooze up from under the ground. (See above page 38.) Although it was in the midst of a dry season several small springs were observed, in which water gushed slowly and perpendicularly up from the ground. The miry springs, described above, seem to indicate the same.

The belt of salt encircling the lake of Tuz Kul varies in breadth according to the declivity of the slopes. On one side, where they are comparatively steep, it is only $^1/_2$ mètre broad, but in other places it is about 100 mètres broad. The salt is glistening white with a loose dusty surface. Underneath is a moist greenish brown layer of clay, with coal-black stripes and clumps. In dry places, where the salt was almost like dust, the thickness of it all was about 10 cm; where the salt was darker, wetter and more coherent, it was about 20 cm. Below the clay was sand. A blue-green alga was found everywhere underneath the wet salt.

On a broad salt stretch, east of the lake, practically nothing was growing, — only very sporadic specimens of a little grass, *Atropis convoluta var. subscariosa* and of *Suaeda setigera.* Near the north shore of the lake there was a tussock-salt-marsh stretch, where *Carex pseudofoetida* was the most important species; and besides *Carex orbicularis var. bulun-*

*gensis*, *Atropis convoluta*, *Primula sibirica*, *Triglochin maritimum*, and upon the Carex-tufts or along the edge of the salty stretch, *Sausurea crassifolia* and *Calamagrostis compacta.* Where the surface of the ground is even and less moist *Polygonum pamiricum* appears; that plant and *Carex pseudo-foetida* seem almost to exclude each other. *Senecio coronopifolius* grows on the extreme edge, where there is very little salt.

A little salt-hole, a short distance away, was composed for the most part of a very moist plantless salt surface. There was only a little water in the centre. Around the salt surface the following vegetation belts were found: Nearest the lake a 5—6 mètre broad belt of *Atropis convoluta var. subscariosa*, then an 8—20 mètre broad belt of *Carex pseudo-foetida* and finally a 20—25 mètre broad belt of *Saussurea crassifolia* and *Elymus dasystachys*, mixed with *Polygonum pamiricum*, *Suaeda setigera* and *Atriplex rosea.* These belts show us the varying grades of halophilia of the halophilous plants of Pamir.

4. Where the Mardjanaj River flows into Jashil Kul it forms a rather broad delta, which, at a distance, resembles a green meadow. This contains but a small amount of salt. Near its banks low bushes, (about 1,5 mètres high), of *Salix repens. var. rosmarinifolia* are growing. The main part of the plant growth here consists of large tufts of *Carex orbicularis, Kobresia Bellardi* and *Royleana.* Large tufts of *Triglochin maritimum* are likewise seen, as well as *Carex parva*, *C. vesicaria var. alpigena*, *Juncus triglumis*, *Poa pratensis*, *Pedicularis rhinanthoides*, *Saxifraga Hirculus*, *Swertia sp.*, *Gentiana barbata* and *prostrata*, *Primula sibirica*, *Polygonum viviparum*, *Euphrasia hirtella*, and the lovely little *Rheum spiciforme* with red peduncles and red fruits. A moss, *Bryum leptoglyphodon* is rather common here.

### B. The Hot Springs' Formation.

Very near Jashil Kul two hot springs are to be found. One of them lies north of the lake just north of the outlet of the Alitshur River. The other lies south of the lake.

The first, which is really a group, comprises 2 large and 23 smaller springs, and, in earlier days, similar springs have been found above them in a higher level in at least two places. The openings can still be seen and there are lime deposits below them where the water must have flowed.

The warm water gushes vertically up from the ground at no great speed, into a basin of at calcareous tuff, about 1 mètre in diameter, with yellow sulphurous deposits around its edge. The temperature of the water when it gushes out of the ground is 78° C. That the temperature was high was indicated by the clouds of vapour seen arising, and from the quantities of small frogs, which lay, scalded to death, in the basin. Algae-crusts were seen in the basin and its outlet. Along the outlet a dense vegetation of *Heleocharis palustris* (*subsp. eupalustris*), stretched in a fresh green stripe from the hot regions all the way out to the marsh of the Alitshur River. Here, too, were many low, barren *Phragmites communis*, a very rare plant in Pamir[1]).

The other hot-spring was far more interesting. It lies south of Jashil Kul, about 30 mètres above the surface of the lake on an exposure sloping north. This one, too, had several sources, five in all. The water in the largest had a temperature of 32° C, the others 26°, 26°, 22° and 19° respectively. The last could hardly be called a source, but the water oozed up out of the ground in a circle about 1 mètre in diameter. These hot sulphurous streams soon united and flowed in a warm but quickly cooling brook down into the lake.

From the opposite shore the crevice in which these springs are found appears like a fresh green stripe on the brown mountain-side. The vegetation is luxuriant with *Scirpus compressus* dominating. This plant covers the wettest parts of the ground, but does not seem to depend on the temperature of the water for it was just as abundant in the vicinity of a cold spring. At the basins themselves and along the warmer courses *Veronica oxycarpa* and *Epilobium thermo-*

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[1]) It is presumably introduced. In this neighbourhood is an ancient Chinese fort and a sepulchre, (Gumbas), for Abdullah Chan.

*philum* thrive. These depend both on moisture and warmth. They grow only in the immediate neighbourhood of water, their size and quantity diminishing the further they are removed from this element. Furthest away, where the brook flows into the lake and the temperature of the water was 20°, there were only a few small specimens to be found. Near the spring *Veronica* was 1 mètre high and *Epilobium* 30—40 cm. I have not seen these two species, which are both marsh perennials, anywhere else in Pamir. However *Veronica oxycarpa* is noted by Mme FEDTSCHENKO from other localities.

Other plant species are *Juncus lamprocarpus*, growing in the water near the main spring, *Geranium collinum var. candidum*, which was common beside the spring and all along the brook, and the following which grew in the hollow glen, but seemingly independent of the influence of the brook, *Carum Carvi*, *Agrostis alba*, *Ligusticum alpinum*, *Sisymbrium Sophia*, and *S. heteromallum*, *Potentilla bifurca*.

### C. The Submerse Formation.

I am best acquainted with this vegetation from the eastern end of Jashil Kul, a large shallow bay, 1—2 mètres deep, and from the equally shallow waters of Bulung Kul. These two places, which are very near each other, and connected by the outlet from Bulung Kul to Jashil Kul, have an identical plant-growth. In both places there is a rich, quite homelike vegetation, composed of *Potamogeton perfoliatus*, and *Friesii* (?) very luxuriant in their growth, and having long upper leaf-bearing stems floating on the surface of the water, combined with *Myriophyllum spicatum*. Farthest in the bay, this latter species dominated, almost filling the water. Scattered here and there were dense groups of *Potamogeton crispus* and dark green masses of *Ceratophyllum demersum*. *Batrachium paucistamineum f. Drouetii* formed submerse cushions, *Ranunculus natans*, *Potamogeton filiformis* and *Zanichellia pedicellata* were also to be found.

*Potamogeton amblyophyllus* has been seen both in stagnant and running water in the Murghab River near Pamirski Post; and the Zostera-like *Potamogeton pamiricus* formed dense woods at the bottom of Kara Kul.

There is nothing specially characteristic in the submerse vegetation of Pamir. *Potamogeton pamiricus*, alone, seems to be characteristic of High Asia.

### D. Stony River-Bed Formation.

Stony river beds, in which at certain seasons there must be much water, but which are almost dry in the summer, have a special characteristic vegetation. Here, as along lake-shores, willows are often growing, and in the Jaman Tal valley, (near Pamirski-post), which is a chasm, 30 mètres or more in depth, with perpendicular walls, I have seen willows, (*Salix oxycarpa*) attain a height of 4—5 mètres. *Myricaria squamosa* (= *davurica*) forms bushes ½—1 mètre tall, and, like *M. germanica* in Norway, seems to cling to such localities. The same is true of *Clematis orientalis var. tangutica*, for the most part procumbent, *Scrophularia incisa var. pamirica*, which forms great tufts, and the lovely white-flowering bush, *Potentilla Salessowii*, whose stiff, upright stems grow 20—40 cm tall. The following species are also found: *Glaux maritima*, *Calamagrostis compacta*, *Poa compressa*, *Potentilla dealbata* and *polyschista*, cespitose species with white-hairy leaves, *Carex macrogyna* and *pseudofoetida*, *Kobresia Royleana*, and, too, the delicate little *Parnassia subacaulis*, *Swertia marginata*, *Lappula sp.*, *Crepis tenuifolia* and *flexuosa*, both cespitose with narrow leaf-lobes. *Gypsophila cephalotes*, *Ligularia altaica*, with its broad blue-green leaves and close yellow flower-heads, *Scutellaria filicaulis*, *Astragalus nivalis*, *Sisymbrium humile*, and *S. Korolkowii*, *Tanacetum tibeticum*, *Allium odorum*, *Rheum spiciforme*, the beautiful *Delphinium cachemirianum*, ½ mètre tall, with its large pale blue flowers and broad leaves, and *Trigonella Emodi*. The majority of the herbaceous plants named here are cespitose in growth, only *Carex pseudofoetida* and *Glaux* have subterranean runners. All species are perennial and more or less mesophytic in structure, often broad-leafed and smooth. Only a few emigrants from dry localities (*Trigonella*) or from saline soil, (*Carex pseudofoetida*) have mixed in this characteristic, beautiful, luxuriant plant community. On the stony bottom there is space between the plants, the tufts are far apart, well developed and with no dead leaves, but often with beautiful blossoms. There are none of the poor procumbent plant-tufts so common in Pamir.

Examples:

1. Jaman Tal; a flat valley-bottom filled with large stones and sheltered by perpendicular walls[1]). Here were *Salix oxycarpa* 4—5 mètres tall, and *Myricaria squamosa* 1 mètre in height. We found, too, *Scrophularia incisa*, *Glaux maritima*, *Calamagrostis compressa*, *Poa compacta*, *Elymus sibiricus*, *Potentilla dealbata*.

2. Bos-tjilgá, a little tributary of Kara Su. Stony river-bed with the following species: *Potentilla Salessowii*, 20—40 cm tall, *Clematis orientalis var. tangutica*, *Swertia marginata*, *Lappula sp.*, *Parnassia subacaulis*, *Carex macrogyna*, (tufts 60 cm, in diameter at the root,) *Kobresia Royleana*, *Calamagrostis compacta*, *Poa compressa*, *Elymus sibiricus*. These were common; less common were *Potentilla dealbata*, *Dracocephalum heterophyllum*, *Myricaria squamosa*, *Crepis tenuifolia*, and *flexuosa*, *Trigonella Emodi*, *Gypsophila cephalotes*, *Ligularia altaica*, *Scutellaria filicaulis*, *Astragalus nivalis*, *Tanacetum tibeticum*, *Allium odorum*.

## E. The River-banks Formation.

Along the banks of rivers and lakes, when no marshes are present, there is a stripe of close vegetation on firm, moist ground. This is sometimes accompanied by bushes which grow at the edge of the water: *Myricaria*, *Salix repens var. rosmarinifolia* and a larger species, (*S. glauca?*), *Tamarix sp.*, *Lonicera coerulea*. The willows never grow higher than 2 mètres, the tamarisks, and *Lonicera* about 1/2 mêtre. The vegetation is of a meadow-like character. Grasses and cyperaceae play an important part. The following were observed: *Trisetum subspicatum*, *Carex orbicularis* and *gracilis*, *Festuca rubra* (*var.*), *Bromus crinitus*, *Kobresia Royleana*, and *Bellardi*, *Poa attenuata var. versicolor*, *P. persica var. soongoria*, — all cespitose. Among these, many other plants were scattered: *Astragalus brachytropis*, *Beketowii*, and *tibetanus*, *Oxytropis glabra*, all long-stalked richly foliate cespitose plants, *Cerastium trigynum*, *Stellaria brachypetala*, *Gymnandra Korolkowii*, and

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[1]) Pictured by Mme FEDTSCHENKO in "Flore du Pamir" tab. 5.

*Plantago gentianoides*, the two latter with undivided, broad leaves, *Saxifraga hirculus*, the smooth low creeping *Potentilla bifurca*, and *P. hypoleuca*, whose leaves are white underneath, the green Anthriscus-like *Selinum papyraceum*, *Gentiana prostrata* and *barbata*, *Pedicularis cheilanthifolia* and *uliginosa*, *Scrophularia incisa*, *Taraxacum bicolor*, *Erigeron uniflorus*, *Artemisia rupestris* (glabrous), and *A. macrocephala* (sericeous), *Crepis multicaulis*, *Tragopogon sp.*, *Delphinium speciosum* with gorgeous blue flowers and broad, smooth leaves, the glabrous *Geranium collinum* and the white-hairy *Tanacetum tibeticum*, *Ziziphorum clinopodioides var. dasyantha*, and finally the annuals *Pleurogyne carinthiaca*, glabrous and delicate, *Euphrasia hirtella*, the glabrous yellow-flowering *Erysimum sisymbrioides* and *Tauscheria lasiocarpa*. Of mosses, *Bryum leptoglyphodon* and *B. pamirio-mucronatum* were found.

This is a community for the most part of cespitose hemicryptophytes. Not a single species has runners. There are no chamaephytes, and only 3 therophytic species were observed. This is moreover a community of mesophytically adapted species. The majority are smooth and many have broad leaves. It seems most reasonable to compare this close vegetation (greensward) with a meadow, which is also characterized by mesophilous, cespitose hemicryptophytes.

Examples:

1. Bosala, near the Alitshur River, a narrow strip of meadow widening out between the windings of the river. There is a close, green meadow-vegetation formed largely of *Carex pseudofoetida* and *Poa pratensis var. subcoerulea*; scattered in between were *Primula sibirica*, *Pedicularis uliginosa*, *Crepis sp.*, *Polygonum viviparum*, *Stellaria brachypetala*, *Ranunculus pulchellus var. pseudo-hirculus*, *Astragalus brachytropis*, and *Gentiana leucomelaena*.

2. Along the little stream, Su Birgöt, near Bulung Kul. A thick green carpet of *Trisetum subspicatum var. glabrescens*, *Poa persica var. songorica*, *Bromus crinitus*, *Potentilla bifurca*, *Crepis sp.*, *Artemisia macrocephala*, *Primula sibirica*, *Tragopogon sp.*, *Cerastium trigynum*, *Selinum papyraceum*, *Astragalus brachytropis* and *tibetanus*, *Plantago gentianoides*, *Oxytropis glabra*, *Gentiana barbata*.

3. On a little peninsula, in Jashil Kul, formed by soil washed out by a stream now dry, we found growing along the waters edge willow bushes, (*Salix glauca?*) and *Tamarix sp.* Behind these was a close green carpet, formed mostly of Cyperaceae: *Kobresia Bellardi* and *Carex gracilis*; *Bromus crinitus* was very common. Beyond these was a quantity of red flowering *Allium (polyphyllum?)*, and still higher up, I found a curious mixture of mesophilous and xerophilous plants forming a rather dense vegetation. Among the mesophilous plants were *Potentilla bifurca*, by whose subterranean runners patches of ground, a mètre or so, in size were covered with its low smooth-leafed shoots, the annual, *Tauscheria lasiocarpa,* in great quantities, *Poa compressa var. tereliuscula* and *Astragalus scheremetewianus.* Among the xerophilous species were both *Acantholimon* species, *Artemisia maritima aff.*, *Hedysarum cephalotes, Solenanthus stylosus, Cousinia rava, Trigonella Emodi, Stipa orientalis, Scorzonera mollis, Polygonum paronychioides, Macrotomia euchromon, Elymus lanatus var. canus,* — species of the Trigonella-formation, that is to say not those belonging to the driest localities.

# PART III
# THE SOUTHERN VALLEYS OF PAMIR

## CHAPTER 10

### Wakhan.

Leaving the Chargush Pass the expedition went to the south and southwest following the river Pamir Daria to Wakhan. As soon as we descended to that river, which rushed along in a foaming torrent, we found thickets of willows both along the banks and in the deep valleys furrowed by its tributaries. The lower down we came the greater the number and the more luxuriant the thickets. The willow, forming them, is probably *Salix zygostemon* Bois. It generally grows to a height of 3—4 mètres, and occassionally 6—7 mètres. Further down the river other and large arborescent plants appear and small woods are formed in which the *Salix* mentioned still occupies the first place, but where a *Betula*, (*B. odorata*?)[1]), is likewise found, attaining a height of 10—12 m. Here, too are *Ribes*, (*aff. nigrum*), *Hippophaës rhamnoides* and *Rosa sp.* Between small woods are the great umbelliferous: *Archangelica songorica* and *Heracleum Olgae*, as well as *Artemisia aff. maritima*, *Elymus*, *Ephedra*, *Acantholimon alatavicum*, *Stipa orientalis*, *Astragalus lasiosemius*, *Trigonella Emodi*, *Arenaria Meyeri*, *Lactuca orientalis*, *Cousinia nemesskyana*, all known from up in Pamir, and the crisp thin-leafed *Saponaria Griffithiana*. Near springs *Veronica oxycarpa*, *Agrostis Paulsenii* and *Carex gracilis* were noted.

Salt-fields, whose existence is doubtless due to the evaporation of water oozing up from below, lay stretched in many places along the banks of Pamir Daria. Here we found *Saussurea crassifolia* in great quantities.

From Djangarlik our path led up and down along the river, through deep valleys worn by the tributaries of the Pamir Daria, — and high up, at a sudden turning the whole valley of the Pändsh spread out before us. Here lay a wide wooded plain, surrounded by high mountains, with the foaming Pamir Daria in a glistening white stripe among the trees. Still farther south, from the top of the next height, after many months spent in the barren mountains, we again saw cultivated land On the washed-out terraces north of the river lay the yellow squares of fields in green frames, with houses, smoke and tall pyramidical poplars. Down through small groves we rode, fording gurgling brooks, where the red wildbriar hung like fuchsias, and at a quick trot, reached Langarkish, and were at the same moment in Wakhan. It was September 7, and our first thought was, what a paradise of beauty and fertility. But after a short time in the narrow valleys with their fields,

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[1] The appearance of birch in these localities has already been shown by Trotter (1878) and quoted by Geiger, page 55.

dirty dwellings and cowed, primitive inhabitants we remembered with regret the lofty, barren, inspiring Pamir.

The remainder of September was spent in Wakhan, and the larger part of October in Goran and Shugnan, which lies at the due S. N. course of the Pänsh river. On October 27 we went into winter quarters in Chorock, which is in Shugnan at the outlet of the Gund into the Pändsh. In March we retraced our steps the same way we came and rode from Langarkish across Pamir back to Ferghana.

In the following pages are notes of scattered observations made during the autumn and winter spent in the southern and western valleys of Pamir.

Wakhan is the name given to the valley of the Pändsh river from Ishkashim toward the east. Its direction is mainly east-west. The highest point in the valley visited by the expedition, Langarkish, lies, according to OLUFSEN, 3,029 mètres above sea-level, while Rang, near where the Pändsh turns toward the north, is 2,702 mètres above the sea. As the distance between the two is about 100 km, the fall of the river during this stretch is only about 327 mètres, which does not occasion any great speed. The river does indeed flow quietly, at times almost forming lakes. In many places gravel and sand are deposited. The latter is dried by the prevailing western winds and tossed hither and thither, forming stretches of drift-sand. According to OLUFSEN's map the valley is 2—3 km broad in the eastern part, in the western end it is narrower, often hardly more than 1 km across. Yet it is wide enough everywhere to permit our riding on the bottom of the valley, without making it necessary to climb over the bordering mountains. However it seemed narrow enough to us journeying in it on its north side, where we had the mighty peaks of the Hindukush[1]) chain constantly before our eyes. These pinnacles of the Hindukush tower about 7,000 mètres high, according to OLUFSEN, and

[1]) In geographies of to-day we often find Hindu-Kooh (Kooh = mountain). The natives say Hindu-Kush (Kush = destroyer).

are for the most part covered with snow. During our stay in Wakhan, blizzards often raged up on the mountain-tops, hiding the summits from us for days at a time. — In several places glaciers are seen, from which many water-courses pour, more and larger than on the north side, but — as there — short.

According to Olufsen the climate of Wakhan is dry, almost rainless, with hot summers and cold winters. There is a great difference between the temperature of day and night. In September we sometimes found the thermometer registering over $20^0$ C. at noon and we experienced several night frosts. Western winds prevail, warm, dry, often filled with sand in summer, cold and dry in winter.

Only twice, while the expedition was in Wakhan, were there many clouds to be seen, the usual condition was clear blue sky or a small percentage of cumulus clouds.

We saw no rain whatever, and in March the covering of snow was slight or totally lacking.

In such a climate agriculture must depend on irrigation, and villages were only found where streams rushed down the mountain-side. Agriculture indeed depended on one other factor. Only where the disintegration of material brought down in land-slides had formed terraces along the river, was arable soil to be found. To these the mountain streams were conducted, often with great difficulty and labour. The country villages consisted of clay hovels, with flat roofs, built of clay and dung, and often so close together that it was possible to walk around the entire village stepping from roof to roof, and, at the same time peeping through the hatches, open by to emit smoke and admit air, witness the poverty-stricken, primitive lives of the inhabitants. Many fortified towers on the roofs of the houses, and caves, or other places of refuge in the mountains, bore witness to the sufferings endured by the inhabitants, — mountain-Tadshiks or Galtshas of Iranian origin, — prior to the Russian occupation, at the hands of the plundering bands of the Afghans, their neighbours. In many villages fruit-trees and pyramidical poplars were planted, and contributed no small degree of beauty.

Very curious were the huge fortresses found in many places in Wakhan, and built formerly by the Siaposhes, a tribe from Kafiristan.

But for this matter as well as for the geography of Wakhan, reference may be made to OLUFSEN, who in "The unknown Pamirs" has given a detailed description of the country. A map is published by him in "Geografisk Tidsskrift" vol. 14.

On the mountain-sides in Wakhan the vegetation was just as poor and dry as we had found it in High Pamir. However, in Wakhan we could study only the vegetation of southern slopes, because the expedition only followed the right bank, or north side, of the Pändsh River.

On these slopes, exposed to the south, *Anabasis wakhanica*, a low leafless suffrutex, usually having many dead twigs among the green, was the most common plant. *Peganum Harmala*, a hemicryptophytic Zygophyllacea, with deeply cleft leaves and thick narrow lobes, was likewise common, as were *Andropogon Ishaemum*, forming small tunicate tufts and having short gray hairy leaves, *Eurotia ceratoides*, *Artemisia fragans*, *Centaurea repens*, the annuals *Kochia stellaris*, *Bassia hyssopifolia*, both with narrow hairy leaves, and *Salsola collina* which has hard, very woody stems, and small, almost squamate leaves.

In a few places, on dry mountain slopes, I found *Astragalus lasiosemius*, on September 11, with its leaves quite withered and the rhachides, alone, sticking out like thorns; and near Dershai I found a very few specimens of *Acatholimon alatavicum*.

This vegetation can best be compared to the Eurotia-formation of Pamir. Like that, it is a chamaephyte formation, in that 5 out of 11 species (46 %) are chamaephytes. It differs from the Eurotia-formation in containing 3 therophytes, (27 %), all Chenopodiaceae belonging to the long-lived type, (summer-annuals, PAULSEN), with xerophytic anatomy. I will not carry my comparison between the rocky vegetation of Wakhan and the Eurotia-formation further, as my acquaintance with the former is too slight, based only on observations made during one autumn and winter.

As in Pamir, green stripes follow the river-courses, and here we find thickets of *Hippophaës*, willows, and *Rosa*-species. Here, too, are *Glycyrrhiza glabra*, *Geranium collinum v. wakhanicum*, *Agrostis alba*, *Artemisia Tournefortiana*, *Mulgedium tataricum*, *Calamagrostis emodensis var. breviseta*, *Stipa splendens*, *Bassia hyssopifolia*, *Mentha longifolia subsp. modesta*, *Thalictrum minus var. elata*, *Hordeum secalium*, *Elymus sibiricus*, *Sonchus oleraceus*, *Dracocephalum moldavicum*, *Senecio sp.*, *Scirpus setaceus*, *Gentiana umbellata* and *barbata*, in fact a mixture of xerophytes and mesophytes, many of the latter seeming to originate from cultivated soil, — but one and all hemicryptophytes or therophytes.

I have seen hydrophyte-vegetation in two places in Wakhan. The first was a little marsh near Sermut. The vegetation was closely cropped by cattle; green tufts were formed by an undetermined *Carex* and by *Triglochin palustre*. Flowerless *Phragmites* were also present, as well as *Glaux maritima* and a *Plantago*. In pools of water between the tufts were *Heleocharis palustris* (subsp. *eupalustris*) and *Scirpus Tabernaemontanus*, and of submerse plants, a little *Batrachium*, *Ceratophyllum demersum*, *Hippuris vulgaris* and *Chara sp.*

Two tiny shallow lakes near Rang, (in the neighbourhood of Ishkashim), were quite covered with *Heleocharis palustris*, 25—30 cm high, with an occasional *Phragmites* dotted here and there. Many *Polygonum amphibium* were floating on the surface of the water; *Limosella aquatica var. tenuifolia* was growing in the shallowest water, together with *Tillaea aquatica* and *Elatine hydropiper*[1]). In somewhat deeper water I found *Chara*, *Ruppia*, *Potamogeton perfoliatus*. Algae were very common in the lakes.

*Potamogeton amblyophyllus* and *Batrachium paucistamineum* were found in running water near Nut.

## The vegetation of the Pändsh River Valley in Wakhan.

In most places in Wakhan, the Pändsh River flows quietly along, with no great hurry, branching to embrace

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[1] The discovery of these two plants here, is surprising, as the place lies far from the localities, where they have hitherto been found.

(O. Olufsen *fot.*)

Fig. 27.

Thicket in the Pāndsh river valley. Hippophäes, Salix, Tamarix, Clematis.

small islands and uniting again as it continues its course. On these islands, and along the river-banks, where now, in September, there were broad dry strips — the river-bed being far wider than the river, — the soil was sandy or gravelled. Here a characteristic thicket of small trees or large bushes was found. In some places it was so dense as to be almost impenetrable. This was often the condition along the arms of the river, which were like winding streets leading from one open square to another. Wild boars were common; we found many tracks, but caught not a single glimpse of the animal itself. The main plant in the thicket was *Hippophaës rhamnoides*, which grew 2—4 mètres tall, (greatest height 5 mètres,) bore ripe fruit, and, with its dense thorny branches, was the cause of the density of the thicket. Here, too, was *Salix angustifolia var. carmanica*, a tall narrow-leafed willow, bushlike in form, and about as tall as *Hippophaës*, or perhaps slightly taller. *Tamarix sp.*, about 2 mètres tall, were also common.

Climbing over these plants was *Clematis orientalis var. acutifolia*, very common. It was in fruit now, and the great masses of long white hairy styles covered the tops of the trees or bushes like a thick overhanging roof.

The bottom of the thicket was almost bare. Only a few scattered species of herbaceous plants were observed: *Crepis corniculata*, *Arnebia guttata*, *Salsola Kali*, *Polypogon monspeliensis*, *Senecio pedunculatus*, *Artemisia sacrorum* and *Tournefortiana*, *Elymus dasystachys*, *Calamagrostis Epigejos*, *emodensis* and *pseudophragmites*, *Scirpus setaceus*, *Chenopodium glaucum* and *Botrys*. — These were mostly annuals but with no specially common characteristic, and presumably chance guests. *Crepis corniculata* is a sparsely-leafed hemicryptophyte, the *Calamagrostis*-species and *Elymus dasystachys* are large thriving grasses with horizontal runners.

In the river valley in Wakhan there are many places with drifting sand. This was very fine and contained mica. There was not much of it, so the dunes were usually small, but were found in many places. Stones, worn by sand, were likewise common. After the plants growing in the sand and contributing to the formation of the dunes, four different forms of dunes could be distinguished in Wakhan.

1. Hippophaës-dunes. These are small, not more than 2—3 mètres high, rounded, without distinct windward or leeside. This is probably due to the fact that they are so closely covered with *Hippophaës* bushes, which, in some places are $^{1}/_{2}$ mètre, in others 3 mètres tall. Between these grows *Inula ammophila*, a fresh green innerasiatic sand-plant with small perfoliate leaves, hairy on the under side.

*Phragmites*, too, grows here, — often 2—3 mètres tall, with its top waving like a flag above the bushes, — and *Salix angustifolia* and *Clematis*. All three, like *Hippophaës*, were probably indigenous to the locality before the sand came and drifted over them. They are what Cowles calls "antecedent", in contrast to *Inula ammophila* which must have come after the soil had been covered by sand.

2. Willow-dunes. These are formed by *Salix angustifolia* (?). Near Sermut they were 3—4 mètres high, while the willows, grouped close together, forming thickets up to 100 mètres in diameter, rose 4—5 mètres above the sand. Willows are probably "antecedent" here too, and were present before the sand came, but now continually gather it around them in the shelter found between their trunks. Between these the sand was bare or dotted with an occasional annual.

3. Eurotia-dunes. These were the most common and also the smallest. The largest were 2 mètres high, but as a rule they were not over 1 mètre. They were sometimes circular, but most often rectangular with the longest axis west-east. A crest of sand lay often east of the plant indicating that the prevailing winds were westerly. This was also shown by *Eurotia*-plants, which only had an all around development in places sheltered from wind, but which otherwise stretched their shoots slantingly upwards toward the east. The main-stem, which, as in Pamir, was fasciated, was furthest to the west and turned the sharp edge toward the direction from which the wind blew. It was often sanded over, and beneath the sand the entire system of ramification might be found, dead. New shoots had pushed their way upwards, but the

internodes were no longer than usual. *Eurotia* is a suffrutex, or here, under milder climatic conditions, preferably, a dwarf-bush, whose branches for the most part survive the winter.

On *Eurotia*-dunes I have found *Phragmites communis var. pumila*, a cespitose dwarf-form, with short closely-packed leaves. It contributed but little to the formation of the dune. There were also *Inula ammophila*, *Cirsium arvense*, *Calamagrostis pseudophragmites* and small tamarisks and willows about $^1/_2$ mètre tall.

The latter was perhaps "antecedent", possibly *Cirsium* also, — there may have been fields here, formerly, but they are just as apt to have been brought out with seeds from the open country. I am inclined to believe that *Eurotia*, too, was "antecedent", for it is by no means rare in the Wakhan-valley. It is difficult to imagine that, after germinating in the sand dunes, it would be able to live in the dunes and attain any great age, — for the broad totally woody stems must be several years old, — without being overcome by the sand and killed, while yet young and weak. It is probable that old *Eurotia* growths have recently been covered with sand which they have only partially resisted.

With the exception of the fact that fewer of the shoots above ground were dead, — those sanded over are not counted in this connection, — and that the plants were one-sided in their growth, *Eurotia* looked here very much as up in Pamir. One would fancy that its short shoots and the limited possibilities for growth would make it but little adapted to dune-vegetation; yet it is a remarkably plastic species. I saw a specimen near Langarkish in the form of a bush 1 mètre tall, with branches bent and twisted, climbing about a rose-bush almost as if it were a semi-liana. Near Sermut it appeared as a little tree with a crown and a cylindrical trunk, about one inch in diameter.

4. T a m a r i s k - d u n e s. These have been seen in many places in Wakhan. They attain a height of 4—6 mètres; they are circular or elongated with the longest axis east-west, — the direction of the river valley. They were rather closely covered with tamarisks 1—2 mètres tall; *Calamagrostis*

*pseudophragmites*, *Hippophaës*, *Inula ammophila*, *Salsola Kali* and *Cirsium arvense* were likewise seen.

The characteristic feature of Tamarisk-dunes is the fact that the sand lies in strata. These are about 2 cm thick and separated by dark layers of dead, half-disintegrated inflorescence-axes, flowers and other deciduous parts of the Tamarisk (sticks etc.). These layers are further divided into layers parallel with the thicker layers, but here no dark stripes intervene.

The dunes were completely rounded off on the top and covered by fine, constantly drifting sand.

How have these stratified Tamarisk-dunes been formed? The expedition found similar dunes in the lowlands of Transcaspia (PAULSEN, 1912, p. 96), which are described as "Tamarisk-knolls" and we read, — "they are presumbably remains of a former continuous tract of a sandy soil now blown away except where the roots and shoots of the Tamarisks have kept the sand at the old level. MAC DOUGAL has pictured sand-knolls formed in the same way by a *Rhus*-species."

It is possible that the Tamarisk-dunes of Wakhan have been formed in the same manner, but it is more probable that they have been formed free and that their growth continues, until they are finally blown out; for on our return to Wakhan in the winter (March), we revisited the Tamarisk-dunes examined in September, and which at that time had pure sandy surfaces, and found them covered with fallen twigs and inflorescence-axes.

It was impossible to tell the origin of the fine stripes in the strata. It may be that on calm days the sand is puttied fast (with rain?) and that every additional drift of sand contributes a layer (stripe).

Cultivated land i Wakhan lies on the terraces above the river as was stated above. It is irrigated by means of the brooks streaming down the mountain-sides. The method is as follows. From the point at which the brook flows out on to the terrace, a main canal with a slight fall is conducted above the town and its fields. From this main conduit the water is led out over the fields at different points and times. Stones and dirt act as sluices; which may be opened or shut at will. The Kasi (judge), makes it his business to see that the water is justly distributed. The fields are irrigated by means of flat parallel furrows terminating at

Fig. 28. A load of cereals in Wakhan.

each end in a cross furrow. When all the furrows are filled, the water is turned off. Before beginning to irrigate, the fields are fertilized and ploughed. The plough used is primitive indeed. It consist of a drawing-rod and a bent piece of wood, whose pointed end loosens up the soil. Harrowing is unknown as are fallow-fields.

The soil is stony but fertile. Wheat sometimes grows $1^1/_2$ mètres high. In upper Wakhan the following cultivated plants are grown:

"Gedim", wheat — (*Triticum sativum*).
*Triticum durum*.
"Zyrk", rye — (*Secale cereale*).
Naked barley — (*Hordeum himalayense Rtt.*).
"Zyrz", millet — (*Panicum miliaceum*).
"Shatrá", rape — (*Brassica napus*). Oil is pressed from the seeds and used for lighting.
"Sach", *Lathyrus sativus*. Fodder-plant.
"Bakla", horse-beans — *Vicia Faba*.
Alfalfa — *Medicago sativa*.

In the western part of the country, the province of Ishkashim, the following were also found:

"Sedörklang", peas (*Pisum sativum*).
"Saghér", flax (*Linum usitatissimum*), found also wild in upper Wakhan.
"Misfar", *Carthamus tinctorius*, an oleaginous plant.

In gardens or small fields the following plants are likewise grown, for the production of stimulants.

Tobacco (*Nicotiana rustica*), poppy (*Papaver somniferum*), and in Ishkashim the thorn-apple (*Datura stramonium*). No small percentage of the population is addicted to opium, and it is said that an intoxicating drink is distilled from the thorn-apple.

The sickle is used in harvesting. By the middle of September, when our expedition reached Wakhan, rye and barley were in, and the wheat and millet harvest begun. The sheaves are stacked for drying in curiously shaped shocks, and born home on the backs of men or donkeys. Carts are unknown, and only the wealthy own horses. The old primitive method of threshing is used. The cereal to be threshed is spread out on a flat place. Oxen or donkeys, which have been muzzled, are driven round a pole in the middle, and in this way the kernels are trampled or shaken out. A winnowing-shovel is used to separate the chaff from the grain. It is tossed into the air on a windy day. The chaff is blown out, and the grain falls to the ground.

Cereals are ground in an old-fashioned way, between two stones or in a hollow in the rock where a large stone is rolled over and over the kernels. Sometimes the inhabitants have a little water-mill, located where the brook leaves the mountains, and driving an horizontal mill-stone.

Further information on agriculture cattle-breeding, tools, utensils, etc., may be found in Olufsen's book, "Through the unknown Pamirs".

Among the trees growing in the cultivated part of the country, the apricot, (*Armeniaca vulgaris*), is the most important. The fruit is not only eaten in the autumn, but dried for winter use. The white mulberry, (*Morus alba*), is also common in the western part. This fruit is dried and ground to powder which is used as sugar. *Populus balsamifera*, and *Salix alba* are also seen. Rose-bushes and *Hippophaës* grow between the houses and the gardens. Flowers are sometimes cultivated. I have seen *Callistephus chinensis*, *Tagetes erectus*, *Ipomaea purpurea*, *Chrysanthemum coronarium*, *Calendula officinalis*, *Malva mauritanica*, *Amarantus sp.*, and *Dracocephalum moldavica*. Weeds abound everywhere in the cultivated land. The fields present a sorry spectacle indeed. The common corn-thistle, *Cirsium arvense*, is the commonest and most harmful weed, but beside this there was a quantity of weeds, mostly European: *Chenopodium Botrys* and *album*, *Capsella Bursa Pastoris*, *Polygonum aviculare* and *lapathifolium*, *Setaria viridis*, *Malva verticillata*, *Lepyrodiclis holosteoides*, *Lepidium latifolium*, *Centaurea repens*, *Bromus tectorum*, *Anchusa arvensis*, *Melilotus officinalis*, *Crepis corniculata*, *Eragrostis minor*, *Elsholtzia densa*, *Sonchus oleraceus*, *Mulgedium tataricum*, *Hordeum secalinum*, *Lycopus europaeus*, *Medicago lupulina*, *Salsola collina*, *Euphorbia Esula*, *Solanum nigrum*, *Phragmites communis*, *Vaccaria segetalis*.

# CHAPTER 11

## Goran and Shugnan.

At Ishkashim the Pändsh river changes its direction and makes a bend toward the north. The southern portion of the country through which it flows is known as Goran, the more northern, Shugnan. Our way led in September—October to Chorock, a village near the outlet of the Gund into the Pändsh. Here we went into winter quarters. The northern section of the Pändsh valley, as far as Kala-i-Wamar in Roshan, we have only seen at Christmas time, 1898, when everything was covered with deep snow.

The following remarks apply only to the Pändsh valley from Ishkashim to Chorock, a distance a little under 100 km. My notes are scanty and insufficient, for the journey — I was alone on this stretch, — was made in haste and the autumn was well advanced.

Between Ishkashim, where the Hindu-Kush chain turns off toward the south, and Chorock, which lies 2047 mètres above sea-level, the Pändsh river falls 702 m per 100 km. The fall is here more than twice the fall between Langarkish and Ishkashim, and, following the river, one is immediately aware that the stream is far swifter than in Wakhan. Most of the way here are rapids churning and foaming along between high, precipitous wall of rock. The valley, which according to Olufsen is about 2,500 mètres deep, is rather broad in the south but becomes very narrow toward the north. Here and there in the southern part thickets are seen, but no drifting-sand. Passage was often difficult, the paths were narrow, leading up and down steep slopes. North of Anderab it was either necessary to cross a high steep pass, — this was the only way for the horses, — or let one's self down through an aperture between a fallen boulder and the mountain-side, and then on all-fours crawl down an almost perpendicular wall where cracks afforded a slight foothold, and the river foamed below. Since then the Russians have built a bridle-path.

Along this stretch the river has but few tributaries, only one of any great size, Garm Chasma Daria, coming from the east.

The change from Wakhan to Goran was very great; — also from a botanical point of view. In the first place the altitude constantly diminishes, but, even more important, — there is a different exposure. The direction of the valley is now south-north, the western wind is shut off, the weather is almost calm, — and travelling along the right bank of the river, we have mountains with a western exposure. As far as we could tell the vegetation on these slopes was fare more abundant than in Wakhan, and comprised for the most part quite other species.

The extremely scanty, dry vegetation of the mountain-slopes in Wakhan is replaced here in Goran, by a more vigorous growth of denser and greener plants. In some places there were small thickets of wonderfully luxuriant, almost sub-tropical vegetation. The most common species of plants in the drier parts of the mountain-slopes are, *Artemisia herba alba*, a close bushy green *Ephedra* (*nebrodensis?*), *Cousinia Nemesskyana*, a tall *Echinops* (*xanthacanthum?*), *Lindelofia anchusoides*, and *Astragalus lasiosemius*. The latter is a spinous dwarf-bush; the others are hemicryptophytes with no decided xerophilous character. *Arenaria Meyeri*, known from up in Pamir, was found high up in the mountains near Kuh-i-lal. In wetter localities the beautiful hemicryptophyte, *Incarvillea Olgae*, 2 mètres high, bearing ripe fruit, a *Verbascum*-species, the recumbent, broad-leafed *Cissus aegirophylla, Impatiens parviflora, Geranium collinum, Mentha longifolia, Arctium Lappa*, large, 2—3 mètres tall, Umbelliferae, quite withered, and many bushes, were all common. These latter were mostly to be found in the river-valley or its neighbourhood or near brooks, and included: *Colutea persica, Halimodendron argenteum, Crataegus pinnatifida var. garanica, Cotoneaster multiflora, Lonicera Xylosteum, Hippophaës, Berberis sp., Rosa sp.*, and willows. In the northern part of Goran, near Anderab, the higher slopes of the mountains are dotted with dark patches, formed by small trees or bushes of *Juni-*

*perus chinensis*, standing apart from each other. I have never seen them close enough together to warrant calling them a thicket or wood. The thickets along the river-valley resemble those in Wakhan: *Hippophaës*, willows and *Clematis* are the most important species found in them, but in many places

(O. Olufsen *fot.*

Fig. 29. The camp of the expedition at Kuh-i-lal.

*Cynanchum acutum* and *Cuscuta reflexa var. grandiflora* are common.

In so far as the advanced season of the year permitted us to judge, the plants cultivated near the villages were the same as in Wakhan. By degrees others appeared, Cotton, (*Gossypium herbaceum*) was only cultivated in northern Goran, the village of Piesh is the highest point, where I have seen it growing. "Misfar", *Carthamus tinctorius* was cultivated here and there, all the way from Ishkashim, whereas "Kindjit", (*Sesamum indicum*), and "Mash", (*Phaseolus Mungo*), were only grown in northern Goran and in Shugnan. The fruit-trees cultivated, included white mulberries, apricots, peaches, apples, walnuts and "Sisd", *Elaeagnus hortensis*, whose mealy fruit is much eaten. In Shugnan, (Chorock), there were cherry-trees.

## CHAPTER 12

### Hot Springs in Goran.

While in Wakhan we visited the hot springs near Zunk, Sirgyn and Barshar. These have been described by Olufsen. The algae found in them and in fact all algae collected on the expedition, were in the hands of a specialist for a long time without being determined, when finally sent to another, the war came and interfered. I am sorry to say that at the present time therefore I am unable, to give facts concerning the algae-vegetation of the hot springs.

In October, the expedition visited Garm tshasma (= hot spring), which lies east of Anderab in Goran. Here are enormous hot well-springs, likewise described by Olufsen, and after him by Schultz who visited them in 1909. This latter scientist discovered that many changes had taken place in the 10 years which had elapsed since the Danish expedition visited the springs. This is why my notes, which were made on the spot are given here. They supplement those of Olufsen, and are being published, so that in time they may serve as a basis for comparison.

The springs lay on the north side of Garm-tshasma river-valley, which has its main direction, east-west. They were visible at a great distance by the white masses of sinter, (calcareous tuff), which sloped down toward the west. Their basins were filled with blueish water. Steam and penetrating fumes of sulphur revealed the presence of the springs. Schultz has published a good photograph of them.

There were at least 10 well-springs lying in a straight line (see the chart fig. 30) with direction east-west, and nearly parallel with the southern border mountains of the Garm-tshasma River valley, which had the direction N. 65° V.[1]) The description begins from the east.

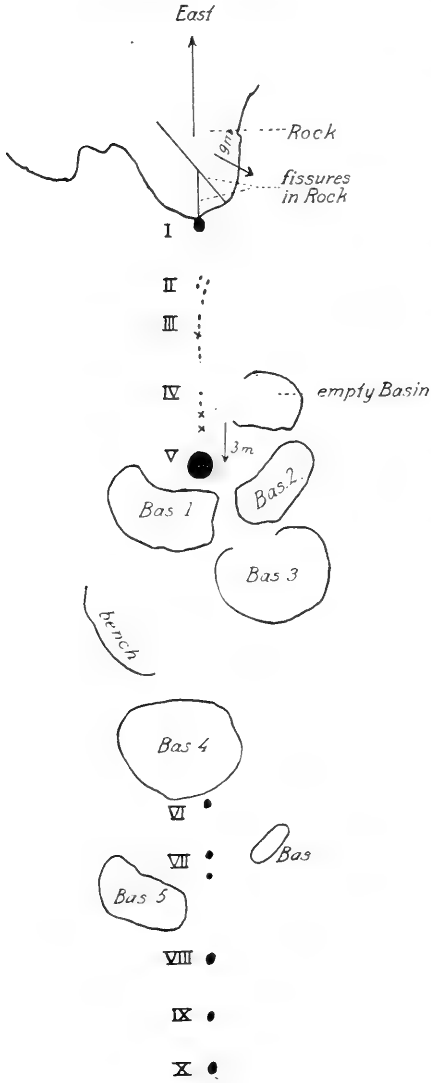


Fig. 30.

Northeast of the present springs, with their glittering white and yellow sinter deposits, lie 3 distinct, ancient disintegrated, sinter cliffs. I estimated the one furthest to the rear to be about 30 mètres in height and 150 mètres in length. The most eastern of the springs now active (I), gushes out of the western slope of a sinter cliff, whose upper edge was about 9 mètres above the enclosed "yard" (see below), at a height of 1—5 mètres above the bottom of the "yard". The spring was plainly seen issuing from a crack in the sinter, having the direction east-west, and this crack was contiguous with another, having a northwesterly direction. The temperature of the spring was 53° C; there was plenty of water but it did not bubble. The water had formed a white sinter shelf, which sloped toward the west, and had worn a furrow in the upper end. Further down it branched out in several arms and flowed down to the "yard", constantly depositing white sinter and a little yellow sulphur.

[1]) Olufsen, through an error in print, gives N. 35° V.

The "yard" is thus called, because enclosed by the natives with a stone-wall. Within this was (II) 8 or 9 small springs, (each one might gush forth at several points; only a few millimètres distant from each other). They are merely small holes but there were also the remains of an old crater, 16 cm in diameter, 4 cm high. Several sources are now dry. The temperature of these small springs was $54^{0}.9$, $46^{0}.0$, $45^{0}.3$, $46^{0}.0$, $55^{0}.0$, $55^{0}.5$, $56^{0}.0$, $55^{0}.0$, $53^{0}.0$, $53^{0}.0$, $53^{0}.0$. They all deposit sulphur and white stone "petrified water", as the natives call it.

III (on the chart) consists of three large bubbling springs with 10—15 cm between each, and 2—3 very small springs which also bubble. They are located on the ridge of a sinter hill with steep slopes on both sides. The middle one of the three larger springs has a crater 6 cm high and 8 cm in diameter, open toward the west. This spring works less regularly than the others. It bubbles for a while, rests, begins again etc. The others bubble continually; the temperature of the large springs was $47^{0}.0$, $52^{0}.0$, $49^{0}.0$, of the small $49^{0}.0$, $39^{0}.0$.

IV is located on the ridge of the same hill. It comprises two rather small, irregularly bubbling springs; their temperature was $31^{0}.0$, $31^{0}.5$, but in a little by-hole near one of them, it was $45^{0}$. Just westward lay two dried out holes.

V is a large well-spring, the largest of all the springs. The water spouts straight up into the air about 12 cm. It gushes out 3 mètres deeper down than IV and lies at the foot of a steep sinter slope. There are four source-openings with about 10 cm between each. Each of these openings comprises several smaller ones with only a few cm between. The temperature is $58^{0}.2$, $57^{0}.5$, $58^{0}.8$, $59^{0}.2$. The water flows down over a billow-furrowed shelf, whose upper edge was above 2 mètres above the surface of basin 1, and into 4 basins (1—4) with lovely billowy edges. The water in the basins, when seen from above, had a wonderful clear greenish-blue colour. 1. was 30 cm deep; there was white mire at the bottom. The temperature of the water was $41^{0}$, that of 2. was $42^{0}$, of 3. $35^{0}$, of 4. $25^{0}$, of 5. $25^{0}$. Between basin 3 and 4 there was a crack in which water with a temperature of 40$^{0}$, was bubbling. An outlet drain was cut into the edge of 1 and the groove between 3 and 4 was artificial. The natives used the springs for bathing and attributed healing powers to the water.

VI was a little spring on the slope from basin 4. It was inacessible.

VII had two source-holes, with a temperature of 37$^{0}$ and 58$^{0}$. There was white sand in the latter and sulphur in the former. The spring bubbles and scolds; rising perpendicularly a slight distance. The water flows into basin 5, which lies about 3 mètres below basin 4. Between VII and VIII there are many minor springs on a straight line.

VIII is a well-spring, sending streams of water, 30 cm long, horizontally out of the side of a hill. Its temperature is 59$^{0}$.0. It is larger than IX and X which are also well-springs. They were inacessible.

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## SOME OF THE ANIMALS COLLECTED BY THE EXPEDITION IN PAMIR

(Identified by the zoological museum of Copenhagen.)

| | |
|---|---|
| Crocidura aranea (Schreb.) | Shugnan. |
| Mustela erminea L. | Shugnan. |
| — alpina Gebler | Shugnan. |
| Lepus tolai Pall. | Shugnan. |
| Capra sibirica Meyer | Jashil Kul. |
| Ovis poli Blyth | Murghab. |
| Canis vulpes L. | Shugnan. |
| Cricetus arenarius (Pall.) | Jashil Kul, Wakhan. |
| Arvicola tiauschanicus (Büchner) | Jashil Kul. |
| Ellobius talpinus (Pall.) | Sary Tash. |
| Mus musculus L. (wild-coloured) | Shugnan. |
| — sylvaticus L. (yellowish) | Wakhan. |
| — — (typical) | Shugnan. |

| | |
|---|---|
| Anas querquedula L. | Goran. |
| Tadorna casarca (L.) | Jashil Kul. |
| Caccabis saxatilis (Meyer) | Shugnan. |
| Totanus glareola (Gmel.) | Jashil Kul. |
| — glottis (L.) | Jashil Kul. |
| — calidris (L.) | Jashil Kul. |
| Sterna hirundo L. | Jashil Kul. |
| Phalacrocorax carbo (L.) | Bulung Kul. |
| Haliaëtus leucoryphus (Pall.) | Jashil Kul. |
| Circus aeruginosus (L.) | Wakhan. |

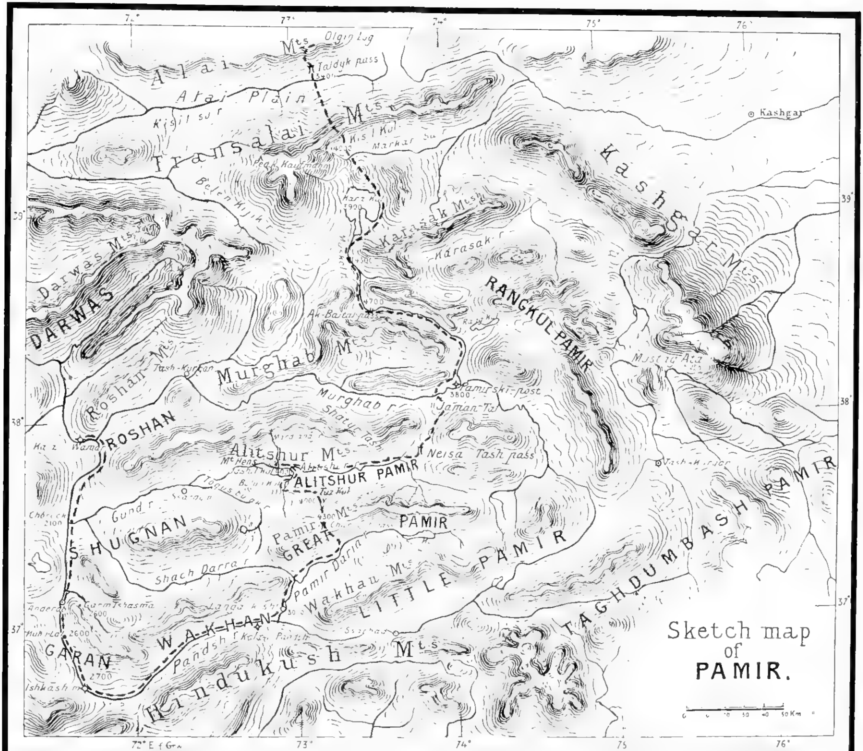
| | |
|---|---|
| Motacilla citreola Pall. | Jashil Kul. |
| — flava L. (?) | Jashil Kul. |
| Passer domesticus (L.) | Shugnan. |

| | |
|---|---|
| Tropidonotus tessellatus (Laur.) | Shugnan. |

| | |
|---|---|
| Bufo vividis Laur | Jashil Kul. |

| | |
|---|---|
| Schizothorax | Jashil Kul. |
| Schizopygopsis | Murghab. |
| — | Jashil Kul. |
| Nemachilus stoliczkae (Steind.) | Jashil Kul. |
| Gymnocypris | Jashil Kul. |
| Cyprinoid | Jashil Kul. |

The lower animals have not been determined. They are in the possession of the zoological museum.




Sketch map of **PAMIR.**

6.

# THE LICHEN FLORA AND LICHEN VEGETATION OF ICELAND

BY

OLAF GALLØE
PH. D.



1919—1920.

Arbejder fra den botaniske Have i København. Nr. 92

# INTRODUCTION.

In 1913, after deliberation with Professor E. Warming, I made a journey to Iceland to investigate the island lichenologically, as far as this could be done during the course of one summer. I had visited the island once before, (1906) and had become interested in its lichen-vegetation, which impressed me as presenting many features of great interest. At that time I had, however, very little opportunity of making investigations, therefore I eagerly seized the opportunity of investigating the lichens, which offered itself in 1913. Already, before this last journey, I had studied the lichen-vegetation more thoroughly in the different plant-associations of Denmark, and had published my investigations on this subject in 1908; afterwards (in the early summer of 1913) I published my "Forberedende Undersøgelser til en almindelig Likenøkologi" ("Introductory Investigations concerning a general Lichen-Ecology"), and was therefore now highly interested in extending my investigations to a country, which was not situated in the same climatic zone as Denmark, because I might expect to find there essentially different vegetational and floral conditions; and I was not disappointed with regard to this point. I made collections and notes as assiduously as the somewhat difficult conditions of travelling permitted, but I am sorry to say that I must admit, in my own case and probably in that of others also, that Iceland is too large to survey fully during one summer's travel.

However, I hope, and also believe, that the descriptions I have been able to give below, will not be altered essentially by investigations, which may possibly be made by future travellers.

The districts which I investigated most thoroughly were those around Reyðarfjörður and Seyðisfjörður on the east coast, the country around Húsavík and Eyjafjörður on the north coast, Isafjörður on the north-western peninsula, Reykjavík and Hafnarfjörður in South-west Iceland, the districts around Mývatn, Jökulsá and Laxá in the interior of North Iceland proper, and the districts about Thingvellir and Geysir. In addition, I paid a flying visit to the islands of Vestmannaeyjar.

I had a fairly good opportunity of investigating these districts somewhat thoroughly. But unfortunately, on the other hand, I had no chance of seeing anything worth mentioning of the desert-interior of Iceland. Among other specially interesting localities were the numerous sea-fowl cliffs along the coasts: no doubt these would prove remarkable in many ways, but I had no opportunity of making independent observations in such spots.

The results of these investigations I have embodied in the following Lichen Flora (which, by my work, contains a fairly considerable number of species not found previously,) and Lichen Vegetation of Iceland; this latter subject has been studied only partially and not at all exhaustively by others (Grönlund and Helgi Jónsson).

As regards the literature on the subject, reference should be made to Deichmann Branth's "Lichenes Islandiæ" (Botanisk Tidsskrift, vol. 25, 1903) in which all lichenological literature pertaining to Iceland has been enumerated, and a full record of collectors and collections from Iceland has been given. It is the newest and most exhaustive list of species, but now to it must be added those species which have subsequently been found by me. I have been obliged to make a few minor alterations in Branth's list, as the genus *Endococcus* can scarcely be maintained any longer as a lichen-genus, and is therefore omitted from the following list.

A full description of the conditions pertaining to vegetation in Iceland, and the references to literature will be found in the part of the present work (vol. I) written by Professor Thoroddsen. These two aids to the study of the literature are very exhaustive.

As regards the ecological and other biological conditions, I must refer the reader to my two papers mentioned above, "Danske Likeners Økologi" (Bot. Tidsskrift, vol. 28, 1908) and "Forberedende Undersøgelser til en almindelig Likenøkologi," (Dansk botanisk Arkiv, vol. I, no. 3, 1913). In these papers full references will be found to all the literature of the biology of Lichens, so that it is unnecessary to cite it more particularly here.

The Directors of the Carlsberg Fund have, with their usual generosity, supplied the funds for the investigations and for the journey to Iceland; for which I tender my best thanks to the said Directors.

# I. THE LICHEN FLORA OF ICELAND.

There is hardly any other group of plants in which the boundary line between the species is so indefinite as it is in the Lichens. Several types are easy to describe, and readily recognizable after description, but between such readily recognizable types there frequently occur so many intermediate forms, that we are quite perplexed in deciding to which type or species — or whatever we now choose to call it — the plant in question should be referred, when it is to be included in a list of species. No doubt the majority of botanists have occasionally tried to determine, for instance, some or other *Cladonia*-species and have thereby experienced for themselves the difficulties which thus arise. But as with *Cladonia,* so is it with the majority of the genera, only, in many cases, the difficulties are even more considerable. To the less skilful investigators any sure determination is usually impossible, but even for the best-trained lichenologist, it is often extremely difficult to identify a species which he has before him, with one already known and described by others, a circumstance which has caused much controversy, to a great extent unnecessary, between the "patres" of lichen-systematology.

The reason of this richness of forms, this abundance of forms intermediate between the most easily distinguishable types, is not known. We may naturally form our surmises on the subject. It may be assumed that the lichen-group, taken as a whole, is a group in process of rapid development, that is to say, in the act of forming numerous new species which, in the course of time, will separate themselves into a smaller number of easily distinguishable species, through many of the intermediate forms dying out. Or we may suppose that the types in themselves are few, but possess a wide, individual range of variations, which is the reason that the boundary line between the species, is difficult to distinguish.

But this is, at present, mere assumption, and as such will not be discussed here more fully. I shall only remark, that any certain decision on the matter can only result from making experimental cultures with the types along the lines, on which researches on heredity are now carried out. But unfortunately we have far to go before we reach this stage, for lichens are generally very difficult to cultivate and, in addition, grow very slowly, so that they would not give quick results.

This best mode of separating the species — the experimental mode — will perhaps never be followed by any one. The next-best method — which, indeed, must form the introduction to the experimental method — has not been adopted to any extent by lichenologists. I shall now briefly explain what I mean.

In order to be able to decide how many types (species) there exist, it is absolutely necessary to follow quite another method than that hitherto followed by lichenologists. From the infancy of lichenology up to the present time, the systematists, dazzled by Linné's short, emphatic diagnosis of higher plants, have endeavoured to create a similar diagnosis for the lichen-species. Anything like this is however impossible, and has caused the greater part of the systematic chaos in which we now find ourselves. If we bear in mind what I wrote above on the abundance of the intermediate forms, and the absence of corresponding boundary lines, it is self-evident that each single type must be described and figured as exhaustively as possible, in order to be recognized by other workers.

The only sure means of making a type recognizable for others is to examine, figure and describe one single individual of the type, making sure that we do not unintentionally confuse two nearly allied types together in one mixed description, as for instance might happen through investigating the thallus of one specimen and the apothecium of another.

This method, which has as yet never been practised in works on lichen-systematology, (I myself have, however, material in hand, not published, for some type-descriptions of such a kind), will be the only means of distinguishing the types from each other, and of eventually forming an introduction to culture-experiments, (which as already mentioned must begin with well-defined types), so that we may finally emerge from the systematic and synonym-chaos in which we now find ourselves.

The method in question involves however a certain danger, as it might end in our establishing almost every individual in the world as a distinct type. And a danger just like this can only be avoided by proving once for all, at some future time, by culture-experiments, how many of the types established by thorough observations and descriptions, are so nearly related to each other, that they must be referred to the same species.

It is clear that this "method of individuals," as I will call it, will be able to revolutionize our apprehension of species, and is for the time being the only way out of the difficulty. But it is equally clear that such a method is not a brief affair, which the individual investigator can accomplish with regard to more than a very restricted number of types. Lists of species and local floras — and also the present one — must consequently still be worked out according to the prevalent, old-fashioned principles, although, as I have been working with them, I have gradually become convinced of their drawbacks, and of how obsolete and defective they are.

Let us therefore briefly regard these defects and the lichen-synonymy, in order better to understand their nature.

The greatest defects of the lichen-systematology lie in the fact, that the one group of investigators are greatly inclined to include as many forms as possible in one large comprehensive species, while others (and these the majority) are inclined to separate the species into many smaller species, each with its own name. In the former group may be reckoned for instance Deichmann Branth in Denmark. This tendency of his to restrict the number of the species, runs as a leading thread through his works on the lichens of Iceland, Greenland and Denmark, and what I cite from his works in my following list will prove this in several instances. I must, however, acknowledge that his observations on species, and his critical remarks on the "species" of other investigators, have several times struck me on account of their original and clear-sighted view of the relationship and genealogical affinity of the species. I am not to be understood to concede that this investigator can prove, for instance, that *Cladonia uncialis* and *C. amaurocroea* (just to give one single example) are really genealogically allied, whilst others classify them as two distinct species; but Deichmann Branth's suggestions regarding this point, and his many other critical remarks on the unity where others see diversity of species, show a comprehension of the relationship of the lichens which, I believe, will prove to contain many truths when once, at some future time, we succeed, by experiments, in clearing up the limitation of the species. But it should be borne in mind that, for the time being, his systematic considerations (which are excellent according to my opinion) are theories, pure and simple, which experiment alone can set upon a firm foundation, and Deichmann Branth himself must have had a clear understanding of this. It is only to be hoped that, one day, the necessary culture-experiments will be made, which will eventually do that justice to his considerations, which up to the present, has been too scanty.

To the other group of investigators belong virtually all the lichenologists of the present day — all those who so often establish species upon quite slight peculiarities of structure in the individuals considered.

The inconveniences this causes with regard to the synonymy of the lichens, is evident. The same name is sometimes used in a limited and sometimes in a very wide sense. The same species is sometimes referred to one, and sometimes to another genus. This creates a confusion, which in several cases, is simply impossible to reduce to order.

In order to clear away the difficulties with regard to synonyms, it has been the custom from the earliest times, to preserve in museums "original specimens," i. e. the specimens on which the author has founded his species. This custom is very commendable, but by no means so satisfactory, as we are frequently inclined to believe; the fact being that lichens alter rather essentially in the course of time, frequently change colour, and alter their chemical reactions, etc., to say nothing of the fact that the specimen may not be cut up to ascertain the anatomical resemblance between it and other specimens, the identity of which is wished to be ascertained; and without such anatomical investigation, comparison is simply worthless in all difficult cases. This fact should be emphasized in order to remove, once for all, the entire foundation built up under the persistent worship of "original specimens." We must demand that the author of the species should describe his species well, and not only leave some gnawed or doubtful original specimen, which is respected so highly that no one dares to dissect it, and thereby deprive it of its importance, while often the very specimen proves, on closer investigation, to be an intermixture of individuals of fairly different species, and we are unable to decide, with any certainty, the individual for the sake of which the author has left it in trust for after times! Else we must yield to the inevitable, viz., that lichen determinations become rather uncertain, as they also prove to be in many cases, or that later lichenologists shall simply disregard the oldest author's right of priority, and re-establish the species with better definition. It is absolutely necessary to get away from the exaggerated belief in the principle of "original specimens."

The following list of the lichens of Iceland, as indicated above, is not based on my own studies of the species, according to the "method of individuals" mentioned above, — that would be an almost impossible work for one man, — but is arranged in compliance with the frequently-employed limitation of species, as they are presented to us in the commonly known lichenological works of Th. Fries, Crombie, Koerber, Nylander and others; the list, consequently, has the synonymic and systematic weaknesses belonging to the works in question, but also has their strong point, viz., it can safely and easily be compared with other lists worked out on the same principles, a thing rather necessary for lichenological reasons.

In the list given I have drawn special attention to the species which were found by myself as "new to Iceland," and which are not found in Deichmann Branth's list of 1903. The reason why these species have been specially mentioned is simply that I am myself responsible for their correct identification, and not that special attention might be drawn to these new finds, and this so much the less, as I cannot see anything specially meritorious in finding new species; every well-trained collector can do so much.

The following list by no means renders Deichmann Branth's excellent work superfluous. In his work we find geographical stations for all the species, and my own list merely supplements his by describing more fully the species new to Iceland, and by modernizing his limitation of species, making it more in agreement with the demands of the time, — without necessarily constituting a real improvement in the apprehension of the species, which, as already mentioned, will not be attained except by detailed investigations in the future, according to my "method of individuals."

The following species have been found: —

# I. PYRENOCARPEÆ.

## VERRUCARIACEÆ.

(Microglaena, Polyblastia, Staurothele, Verrucaria.)

### Microglaena.

**M. sphinctrinoides** Nyl. (D. B., p. 220, under Pyrenula)[1].
This species is wanting in Greenland.

### Polyblastia.

**P. hyperborea** Th. Fr.
On Basalt, Seyðisfjord, O. Galløe, 1913. New to Iceland.

**P. Henscheliana** Koerb. (D. B., p. 220, Pyrenula).
Absent from Greenland. Great Britain (Crombie)[2].

### Staurothele.

**S. clopima** Wnbg. (D. B., p. 220, Pyrenula).
G. Brit.

### Verrucaria.

**V. margacea** Wnbg. (D. B., p. 219, with var. **aethiobola** Wnbg.).
Absent from Greenland. G. Brit.

**V. maura** Wnbg. (D. B., p. 219).
Greenland. G. Brit.

**V. mucosa** Wnbg. (D. B., p. 219).
Greenland. G. Brit.

**V. nigrescens** Pers. (D. B., p. 219).
Absent from Greenland. G. Brit.

**V. rupestris** Schrad. (D. B., p. 219).
Greenland. G. Brit.

## DERMATOCARPACEÆ.

(Dermatocarpon.)

### Dermatocarpon.

**D. cinereum** Pers. (D. B., p. 219, Verrucaria).
Not found in Greenland. G. Brit.

**D. hepaticum** Ach. (D. B., p. 219).
Greenland. G. Brit.

**D. miniatum** L. $\beta$. **complicatum** Sw. (D. B., p. 219).
Greenland. G. Brit.

[1] Deichmann Branth: Lichenes Islandiæ, Botanisk Tidsskrift, 1903, vol. 25.
[2] Crombie: British Lichens, 1894—1911.

PYRENULACEÆ.

(Arthopyrenia, Microthelia.)

### Arthopyrenia.

**A. analepta** Ach. (D. B., p. 220, Sagedia, with f. **punctiformis** Ach.).
Greenland. G. Brit.

**A. grisea** Schleich. (D. B., p. 220, Sagedia).
Greenland. Not found in G. Brit.

### Microthelia.

**M. micula** Flot. (D. B., p. 220).
Not found in Greenland. G. Brit.

## II. CONIOCARPINEÆ.

CALICIACEÆ.

(Coniocybe).

### Coniocybe.

**C. furfuracea** L. (D. B., p. 220).
Greenland. G. Brit.

SPHÆROPHORACEÆ.

(Sphærophorus).

### Sphærophorus.

**S. coralloides** Pers. (D. B., p. 220, Sphærophoron).
Greenland. G. Brit.

**S. fragilis** L. (D. B., p. 220, Sphærophoron).
Greenland. G. Brit.

## III. GRAPHIDINEÆ.

ARTHONIACEÆ.

(Arthonia.)

### Arthonia.

**A. proximella** Nyl. (D. B., p. 219).
Greenland. G. Brit.

**A. punctiformis** Ach. (D. B., p. 219).
Not found in Greenland. G. Brit.

**A. ruderalis** Nyl. On tuff, Reyðarfjord, O. Galløe, 1913.
New to Iceland. G. Brit.

# IV. CYCLOCARPINEÆ.

## DIPLOSCHISTACEÆ.

(Diploschistes).

### Diploschistes.

**D. scruposus** L. (D. B., p. 212, Urceolaria).
Greenland. G. Brit.

## GYALECTACEÆ.

(Gyalecta.)

### Gyalecta.

**G. cupularis** Ehrh. (D. B., p. 217).
Not found in Greenland. G. Brit.

**G. geoica** Ach.
Upon moss on blocks of basalt, Seyðisfjord, O. Galløe, 1913. New to Iceland. G. Brit.

**G. foveolaris** Ach. (D. B., p. 217).
Not found in Greenland. G. Brit.

## COENOGONIACEÆ.

(Coenogonium, Racodium).

### Coenogonium.

**C. ebeneum** Dillw. (D. B., p. 202, Cystocoleus).
Not found in Greenland. G. Brit.

### Racodium.

**R. rupestre** Pers.
On basalt, Seyðisfjord, O. Galløe, 1913. New to Iceland. G. Brit.

## LECIDEACEÆ.

(Bacidia, Lecidea, Rhizocarpon, Catillaria, Lopadium, Toninia).

### Bacidia.

**B. abbrevians** Nyl. (D. B., p. 217, Gyalecta).
Not found in Greenland and in G. Brit.

**B. atrosanguinea** Schaer. (D. B., p. 216, Gyalecta).
Not found in Greenland. G. Brit.

**B. arceutina** Ach. (D. B., p. 217, Gyalecta, with var. **egenula** Nyl. and var. **albescens**).
Not found in Greenland. G. Brit.

**B. Beckhausii** Koerb. (D. B., p. 217, Gyalecta).
Not found in Greenland. G. Brit.

**B. caudata** Nyl. (D. B., p. 216, Gyalecta).
Not found in Greenland. G. Brit.

**B. (Bllimbia) coprodes** Koerb.
On pebbles, Húsavík (N. Iceland), O. Galløe. New to Iceland.

**B. (Arthrorhaphis) flavo-virescens** Dicks. (D. B., p. 217, Mycobacidia).
Greenland. G. Brit.

**B. herbarum** Hepp. (D. B., p. 217, Gyalecta).
Not found in Greenland. G. Brit.

**B. milliaria** Fr. (D. B., p. 216, Gyalecta).
Not found in Greenland. G. Brit.

**B. obscurata** Sommerf. (D. B., p. 216, Gyalecta).
Greenland. G. Brit. Var. **microcarpa** Th. Fr. was also found.

**B. rubella** Ehrh. (D. B., p. 216, Gyalecta).
Not found in Greenland. G. Brit.

**B. sphaeroides** Sommerf. (D. B., p. 216, Gyalecta).
Greenland. G. Brit.

**B. squalescens** Nyl. (D. B., p. 215, Gyalecta).
Not found in Greenland. G. Brit.

**B. subfuscula** Nyl. (D. B., p. 216, Gyalecta).
Greenland.

**B. umbrina** (Ach.) Br. & Rostr. (D. B., p. 217, Gyalecta).
Greenland. G. Brit.

## Lecidea.

**L. aglæa** Sommerf. (D. B., p. 214).
Greenland.

**L. alpestris** Sommerf. (D. B., p. 215).
Greenland. G. Brit.

**L. arctica** Sommerf. (D. B., p. 215).
Greenland. G. Brit.

**L. arctogena** Th. Fr.
On palagonite-mountains south of Húsavík, N. Iceland, O. Galløe, 1913. New to Iceland.

**L. assimilata** Nyl. with v. infuscata (D. B., p. 215).
Greenland.

**L. atrobrunnea** Ram. (D. B., p. 215).
Greenland.

**L. atrorufa** Dicks. (D. B., p. 212, Psora).
Greenland. G. Brit.

**L. auriculata** Th. Fr. (D. B., p. 214).
Greenland. G. Brit.

**L. Berengeriana** Mass. (D. B., p. 213).
Greenland. G. Brit.

**L. cinereoatra** Ach.
Pebbles on mountain south of Húsavík, N. Iceland, O. Galløe, 1913. On lava near Havnefjord, SW. Iceland, O. Galløe, 1913. New to Iceland.

**L. confluens** Fr. (D. B., p. 214).
Greenland. G. Brit.

**L. contigua** Hoffm. with var. flavicunda Ach., macrocarpa D. C. and platycarpa Ach. (D. B., p. 214).
Greenland. G. Brit.

**L. convexa** (Fr.) Th. Fr.
On lava near Havnefjord, SW. Iceland, O. Galløe, 1913. On the mountain south of Húsavík, N. Iceland, O. G., 1913. New to Iceland.

**L. crassipes** Th. Fr. (D. B., p. 215).
Not found in Greenland.

**L. crustulata** (Ach.) Koerb.
On pebbles, mountain south of Húsavík in N. Iceland, O. Galløe, 1913; on stones, high on the mountains, Öfjord, in N. Iceland, O. G., 1913. New to Iceland.

**L. cuprea** Sommerf. (D. B., p. 213).
Greenland. G. Brit.

**L. cyanea** (Ach.) Th. Fr. (D. B., p. 214, L. tesellata).
Greenland.

**L. decipiens** Ehrh. (D. B., p. 212, Psora).
Greenland. G. Brit.

**L. decolorans** Hoffm. (D. B., p. 213).
Greenland. G. Brit.

**L. Diapensiæ** Th. Fr. (D. B., p. 213).
Not found in Greenland.

**L. Dicksonii** Ach. (D. B., p. 215, L. atroferrata v. Dicksonii).
Greenland. G. Brit.

**L. elæochroma** Ach. (D. B., p. 213, L. enteroleuca with var. **muscorum** Wulf., **achrista** Sommerf., **Laureri** Hepp., **latypea** Ach., **pilularis** Dav., **dolosa** Ach.).
Greenland. G. Brit.

**L. elata** Schær. (D. B., p. 214).
Greenland.

**L. erratica** Koerb.
Vertical face of basalt, Seyðisfjord, O. Galløe, 1913. New to Iceland.

**L. erythrophæa** Flk. (D. B., p. 213).
Greenland.

**L. furvella** Nyl.
Lava near Reykjavík, O. Galløe, 1913. New to Iceland.

**L. fusca** Schaer. (D. B., p. 212).
Greenland.

**L. fuscescens** Sommerf. (D. B., p. 212).
Greenland. G. Brit.

**L. fuscoatra** Ach. (D. B., p. 215).
Greenland.

**L. granulosa** (Ehrh.) Schær.
On birch, Reykjavík in N. Iceland, O. Galløe, 1913. New to Iceland.

**L. helvola** (Koerb.) Th. Fr. (D. B., p. 213, L. vernalis f. helvola).

**L. lapicida** (Ach.) Fr. (D. B., p. 214).
Greenland. G. Brit.

**L. limosa** Ach. (D. B., p. 215).
Greenland. G. Brit.

**L. lithophila** Ach. (D. B., p. 214).
Greenland. G. Brit.

**L. lugubris** Sommerf. (D. B., p. 212, Psora).
Greenland. G. Brit.

**L. lurida** Sw. (D. B., p. 212, Psora).
Greenland. G. Brit.

**L. neglecta** Nyl. (D. B., p. 215).
Not found in Greenland. G. Brit.

**L. Nylanderi** Anzi (D. B., p. 213).
Not found in Greenland.

**L. panæola** Ach. (D. B., p. 214).
Greenland. G. Brit.

**L. pantherina** (Ach.) Th. Fr. (D. B., p. 214; L. polycarpa).
Greenland.

**L. paupercula** Th. Fr.
Lava near Reykjahlið near Mývatn, O. Galløe, 1913; stones, high on the mountains, near Öfjord, O. G., 1913. New to Iceland.

**L. ramulosa** Th. Fr.
On earth near Háls parsonage, N. Iceland, O. Galløe, 1913. New to Iceland.

**L. rubiformis** Wahlenbg. (D. B., p. 212, Psora).
Greenland. G. Brit.

**L. Siebenhaariana** Koerb.
Uppermost bare summit of the mountain of "Sulur" near Öfjord, O. Galløe, 1913. New to Iceland.

**L. speirea** Ach. (D. B., p. 214).
Not found in Greenland. G. Brit.

**L. subconfluens** Th. Fr.
Gravelly soil on the mountain of "Sulur" near Öfjord, O. Galløe, 1913. New to Iceland.

**L. tenebrosa** Flot. (D. B., p. 215).
Greenland. G. Brit.

**L. Tornoensis** Nyl. (D. B., p. 213).
Greenland.

**L. uliginosa** Schrad. (D. B., p. 213).
Greenland. G. Brit.

**L. vernalis** (L.) Ach. (D. B., p. 213).
Greenland. G. Brit.

## Rhizocarpon.

**R. alboatrum** Th. Fr. v. **epipolia** Ach. (D. B., p. 218, Buellia).
Not found in Greenland. G. Brit.

**R. calcareum** Weis. (D. B., p. 218, Buellia).
Greenland. G. Brit.

**R. geminatum** (Fw.) Th. Fr. (D. B., p. 218, Buellia).
Greenland. G. Brit.

**R. geographicum** (L.) D. C. (D. B., p. 218, Buellia).
Greenland. G. Brit.

**R. petraeum** Wulfen. (D. B., p. 218, Buellia, including the species R. grande Arn., distinctum Th. Fr., obscuratum Th. Fr.).

**R. viridiatrum** Flk. (D. B., p. 218, Buellia).
Not found in Greenland. G. Brit.

## Catillaria.

**C. athallina** (Hepp.) Hellb.
On earth near Einarstaðir parsonage, N. Iceland, O. Galløe, 1913. New to Iceland.

**C. cumulata** Sommerf. (D. B., p. 216, Gyalecta).
Greenland. G. Brit.

**C. Jemtlandica** Th. Fr. (D. B., p. 216, Gyalecta).

**C. tenticularis** Ach. (D. B., p. 216, Gyalecta).
Not found in Greenland. G. Brit.

## Lopadium.

**L. fuscoluteum** Dicks. (D. B., p. 218, Buellia).
Greenland. G. Brit.

**L. pezizoideum** (Ach.) Koerb. (D. B., p. 218, Buellia).
Greenland. G. Brit.

## Toninia.

**T. squalida** (Ach.) Nyl. (D. B., p. 216, Gyalecta squarrosa).
Greenland. G. Brit.

**T. syncomista** (Flk.) Th. Fr. (D. B., Gyalecta).
Greenland. G. Brit.

**T. vesicularis** Hoffm. (D. B., p. 215, Gyalecta).
G. Brit.

## CLADONIACEÆ.

(Baeomyces, Cladonia, Stereocaulon).

### Baeomyces.

**B. byssoides** (L.) Th. Fr. (D. B., p. 212, Sphyridium).
Not found in Greenland. G. Brit.

**B. placophyllum** Wahlenbg. (D. B., p. 212, Sphyridium).
Not found in Greenland. G. Brit.

### Cladonia.

**C. amaurocræa** (Flk.) Schaer. (D. B., p. 202, under C. uncialis).
Greenland. G. Brit.

**C. bellidiflora** (Ach.) Schaer. (D. B., p. 202).
Greenland. G. Brit.

**C. cariosa** (Ach.) Spreng. (D. B., p. 201).
G. Brit. Not found in Greenland.

**C. coccifera** (L.) Willd. (D. B., p. 201, C. cornucopioides).
Greenland. G. Brit.

**C. decorticata** (Floerke) Spreng. (D. B., p. 201).
Greenland.

**C. fimbriata** (L.) Fr. (D. B., p. 201).
Greenland. G. Brit.

**C. Floerkeana** (Fr.) Sommerf. (D. B., p. 201).
Greenland. G. Brit.

**C. foliacea** (Hudg.) Schaer. (D. B., p. 201, C. alcicornis).
Greenland. G. Brit.

**C. furcata** (Huds.) Schrad. (D. B., p. 201, with var. **subulata** Flk., **racemosa** Hoffm. and **pungens** Ach.).
Greenland. G. Brit.

**C. gracilis** (L.) Willd. (D. B., p. 201, with var. **chordalis** Flk., **cervicornis** Ach. and **firma** Nyl.).
Greenland. G. Brit.

**C. pityrea** (Floerke) Fr. (D. B., p. 201, under C. pyxidata).
G. Brit.

**C. pyxidata** (L.) Fr. (D. B., p. 201, with var. **pityrea** Flk.).

**C. rangiferina** L. (D. B., p. 201, with var. **silvatica** Hoffm.).
Greenland. G. Brit.

**C. rangiformis** Hoffm.
On earth among Empetrum, Seyðisfjord, O. Galløe, 1913. New to Iceland.

**C. uncialis** (L.) Web. (D. B., p. 202, with var. **adunca** Wahlenbg. and **amaurocræa** Flk.).
Greenland. G. Brit.

**C. turgida** (Ehrh.) Hoffm.
On earth, the mountain of "Sulur" near Öfjord, N. Iceland, O. Galløe, 1913. New to Iceland.

## Stereocaulon.

**S. condensatum** Hoffm. (D. B., p. 201).
Not found in Greenland. G. Brit.

**S. coralloides** Fr.
Empetrumheath, Seyðisfjord, O. Galløe, 1913. New to Iceland.

**S. denudatum** Flk. (D. B., p. 201, especially v. **pulvinatum** Schaer.)
Greenland. G. Brit.

**S. evolutum** Graewe (D. B., p. 201):
Greenland. G. Brit.

**S. incrustatum** Flk.
On earth, Reyðarfjord, East Greenland, O. Galløe, 1913. New to Iceland.

**S. paschale** (L.) Fr. (D. B., p. 201).
Greenland. G. Brit.

**S. tomentosum** (Fr.) Th. Fr. (D. B., p. 200, Ster. tom. and var. alpinum Laur.).
Greenland. G. Brit.

# GYROPHORACEÆ.

(Gyrophara).

## Gyrophora.

**G. arctica** Ach. (D. B., p. 205, G. hyperborea v. arctica Ach.).
Greenland. G. Brit.

**G. cylindrica** L. (D. B., p. 206).
Greenland.

**G. erosa** Web. (D. B., p. 205).
Greenland. G. Brit.

**G. hyperborea** Ach. (D. B., p. 205).
Greenland. G. Brit.

**G. murina** D C (D. B., p. 206).
G. Brit.

**G. polyphylla** L. (D. B., p. 206).
Greenland. G. Brit.

**G. proboscidea** L. with var. **deplicans** (D. B., p. 205).
Greenland. G. Brit.

**G. vellea** L. (D. B., p. 206).
Greenland. G. Brit.

## ACAROSPORACEÆ.

(Acarospora, Biatorella).

### Acarospora.

**Ac. discreta** (Ach.) Th. Fr.
Pebbles and firm rock near Húsavík, N. Iceland, O. Galløe, 1913. New to Iceland.

**Ac. fuscata** (Schrad.) Th. Fr. (D. B., p. 212, Ac. fusc. v. rufescens).
Not found in Greenland. G. Brit.

**Ac. Heppii** (Naeg.) Koerb.
On basalt, Seyðisfjord in E. Iceland; on lava, Havnefjord in SW. Iceland; O. Galløe, 1913. New to Iceland.

### Biatorella.

**B. Morio** Flk. with var. **pallescens.** (D. B., p. 218).
Greenland. G. Brit.

## EPHEBACEÆ.

(Ephebe, Polychidium).

### Ephebe.

**E. pubescens** L. (D. B., p. 202).
G. Brit.

### Polychidium.

**P. muscicola** Sw. (D. B., p. 206).
Not found in Greenland. G. Brit.

## LICHINACEÆ.

(Lichina).

### Lichina.

**L. confinis** O. F. Müller (D. B., p. 202).
Greenland. G. Brit.

## COLLEMACEÆ.

(Collema, Leptogium).

### Collema.

**C. crispum** L. (D. B., p. 206).
Not found in Greenland. G. Brit.

**C. flaccidum** Ach. (D. B., p. 206, Synechoblastus).
Greenland. G. Brit.

**C. nigrescens** L. (D. B., p. 206, Synechoblastus).
Not found in Greenland. G. Brit.

**C. pulposum** Bernh. (D. B., p. 206).
Greenland. G. Brit.

**C. verrucaeforme** L. (D. B., p. 206).
Not found in Greenland.

### Leptogium.

**L. lacerum** Sw. (with v. **pulvinatum** Ach.) (D. B., p. 206).
Greenland. G. Brit.

**L. (Collemodium) plicatile** Ach.
On basalt, Seyðisfjord, O. Galløe, 1913. New to Iceland.

**L. scotinum** Ach. (D. B., p. 206).
Greenland. G. Brit.

## PANNARIACEÆ.

(Massalongia, Placynthium, Pannaria, Psoroma).

### Massalongia.

**M. carnosa** (Dicks.) Koerb.
Almannagjá near Thingvellir, SW. Iceland, O. Galløe, 1913. New to Iceland.

### Placynthium.

**P. delicatulum** Th. Fr. (D. B., p. 207, Lecothecium).
Not found in Greenland. G. Brit.

**P. nigrum** Huds. (D. B., p. 207, Lecothecium).
G. Brit.

### Pannaria.

**P. brunnea** Nyl. (D. B., p. 207).
Greenland. G. Brit.

**P. elaeina** Wahlenbg. (D. B., p. 207).
Not found in Greenland.

**P. granatina** Sommerf. (D. B., p. 207).
Greenland.

**P. Hookeri** Sm. (D. B., p. 207).
Greenland. G. Brit.

**P. lepidiota** Sommerf. (D. B., p. 207).
Greenland. G. Brit.

**P. microphylla** Nyl.
On earth near the summit of the mountain of "Sulur" (Öfjord in N. Iceland), O. Galløe, 1913, and on the mountains in the same place, east of the fjord, *idem*, 1913. New to Iceland.

**P. triptophylla** Ach. (D. B., p. 207).
Greenland. G. Brit.

### Psoroma.

**P. (Lecanora) Hypnorum** (Hoffm.) Ach. (D. B., p. 209, Squamaria).
Greenland. G. Brit.

## STICTACEÆ.

(Sticta).

### Sticta.

**St. scrobiculata** Scop. (D. B., p. 203).
Greenland. G. Brit.

## PELTIGERACEÆ.

(Nephroma, Peltigera, Solorina).

### Nephroma.

**N. arcticum** L. (D. B., p. 203).
Greenland.

**N. expallidum** Nyl. (D. B., p. 203).
Greenland.

**N. laevigatum** v. **parile** Ach. (D. B., p. 203).
Greenland. G. Brit.

**N. tomentosum** Hoffm. (D. B., p. 203).
Greenland. G. Brit.

### Peltigera.

**P. aphtosa** L. (D. B., p. 202.
Greenland. G. Brit.

**P. canina** (L.) Fr. (D. B., p. 202).
Greenland. G. Brit.

**P. horizontalis** L.
Empetrum-heath, Seyðisfjord, O. Galløe, 1913. New to Iceland.

**P. lepidophora** Nyl.
On volcanic tuff near Ljósavatn farm, N. Iceland; heaths near Einarstaðir, N. Iceland; heath near Mývatn, N. Iceland; mountain-heath near Húsavík, N. Iceland; mountain-heath near Öfjord, N. Iceland. O. Galløe, 1913. New to Iceland.

**P. malacea** (Ach.) Fr. (D. B., p. 202).
Greenland. G. Brit.

**P. polydactyla** f. **collina** Ach. (D. B., p. 202).
Greenland. G. Brit.

**P. rufescens** Fr. (D. B., p. 202).
Greenland. G. Brit.

**P. venosa** (L.) Hoffm. (D. B., p. 203).
Greenland. G. Brit.

### Solorina.

**S. bispora** Nyl. (D. B., p. 203).
Greenland. G. Brit.

**S. crocea** Ach. (D. B.), p. 203).
Greenland. G. Brit.

**S. saccata** L. (D. B., p. 203).
Greenland. G. Brit.

## PERTUSARIACEÆ.

(Pertusaria).

### Pertusaria.

**P. communis** D C. (D. B., p. 211).
Not found in Greenland. G. Brit.

**P. coriacea** Th. Fr. (D. B., p. 211).
Not found in Greenland.

**P. corallina** (L.) Arn.
On lava, Havnefjord in SW. Iceland, O. Galløe, 1913. New to Iceland.

**P. dactylina** Ach. (D. B., p. 211).
G. Brit.

**P. oculata** Dicks. (D. B., p. 210, Lecanora).
Greenland. G. Brit.

**P. rhodoleuca** Th. Fr. (D. B., p. 211).
Not found in Greenland.

**P. xanthostoma** (Sommerf.) Fr. (D. B., p. 211).
Not found in Greenland. G. Brit.

## LECANORACEÆ.

(Haematomma, Lecania, Lecanora).

### Haematomma.

**H. coccineum** (Dicks.) Koerb.
On lava near Havnefjord, SW. Iceland, O. Galløe, 1913. New to Iceland.

**H. ventosum** L. (D. B., p. 211, Lecania).
Greenland. G. Brit.

### Lecania.

**L. athroocarpa** (Dub.) Nyl. (D. B., p. 211).
Not found in Greenland. G. Brit.

**L. cyrtella** Ach. (D. B., p. 211).
Not found in Greenland. G. Brit.

### Lecanora.

**L. albescens** v. **dispersa** Pers. (D. B., p. 210).
Not found in Greenland. G. Brit.

**L. alphoplaca** Wahlenbg. (D. B., p. 209, Squamaria).
Greenland. G. Brit.

**L. alpina** Sommerf.
On Liparite, Hliðarfjall near Mývatn, N. Iceland; erratic blocks on the mountains east of Öfjord; on stones in Almannagjá, SW. Iceland. O. Galløe, 1913. New to Iceland.

**L. atra** (Huds.) Ach. (D. B., p. 210).
Greenland. G. Brit.

**L. atriseda** Fr. (D. B., p. 210).
Not found in Greenland. G. Brit.

**L. atrosulphurea** (Wahlenbg.) Ach. (D. B., p. 210, L. variæ forma).

**L. badia** (Pers.) Th. Fr. (D. B., p. 210).
Greenland. G. Brit.

**L. calcarea** (L.) Sommerf.
On basalt, Reyðarfjord in E. Iceland, O. Galløe, 1913. New to Iceland.

**L. cartilaginea** Westr. (D. B., p. 208, Squamaria).
Not found in Greenland. G. Brit.

**L. castanea** (Hepp.) Th. Fr. (D. B., p. 210).
Not found in Greenland.

**L. chrysoleuca** Sm. (D. B., p. 209, Squamaria) f. **rubina** Vill. and **melanophthalma** Nyl.
Greenland. G. Brit.

**L. cinerea** (L.) Sommerf. (D. B., p. 210).
Greenland. G. Brit.

**L. cinereo-rufescens** Dicks. (D. B., p. 211).
Greenland. G. Brit.

**L. coarctata** v. **ornata** Sommerf. (D. B., p. 210).
G. Brit.

**L. frustulosa** (Dicks.) Koerb. (D. B., p. 209).
Greenland. G. Brit.

**L. gelida** (L.) Ach. (D. B., p. 208, Squamaria).
Greenland. G. Brit.

**L. gibbosa** (Ach.) Nyl. (D. B., p. 210).
Greenland. G. Brit.

**L. Hageni** (Ach.) Koerb. (D. B., p. 209).
Greenland. G. Brit.

**L. lacustris** Wither. (D. B., p. 211).
Greenland. G. Brit.

**L. pallescens** (L.) Schær. (D. B., p. 211) with var. **parella** L. and **Upsaliensis** L.
Greenland. G. Brit.

**L. poliophæa** Wahlenbg. (D. B., p. 209).
G. Brit.

**L. polytropa** Ehrh. (D. B., p. 210, L. variæ forma).

**L. protuberans** Sommerf. v. **carneopallida** Nyl. (D. B., p. 210).
Greenland. G. Brit.

**L. saxicola** (Poll.) Stenh. (D. B., p. 209, Squamaria).
Greenland. G. Brit.

**L. sordida** (Pers.) Th. Fr. v. **glaucoma** (Hoffm.) Th. Fr. (D. B., p 209).
G. Brit.

**L. straminea** Wahlenbg. (D. B., p. 209, Squamaria).
Greenland.

**L. subfusca** (L.) Ach. (v. **coilocarpa** Ach., **Hypnorum** (Wulf.) Schær., **glabrata** Ach., **rugosa** Pers., **atrynea** Ach.) (D. B., p. 209),
Greenland. G. Brit.

**L. tartarea** L. (D. B., p. 211).
Greenland. G. Brit.

**L. varia** (Ehrh.) Nyl. (D. B., p. 210, with var. **symmicta** Ach., **polytropa** Ehrh., **intricata** Schrad., **atrosulphurea** Wahlenbg., **leptacina** Sommerf.).
Greenland. G. Brit.

**L. verrucosa** Ach. (D. B., p. 211).
Greenland. G. Brit.

## PARMELIACEÆ.

(Cetraria, Parmelia).

### Cetraria.

**C. aculeata** Fr. (D. B., p. 200).
Greenland. G. Brit.

**C. cucullata** Bell. (D. B., p. 204).
Greenland. G. Brit.

**C. Fahlunensis** (L.) Schær. (D. B., p. 204).
Greenland.

**C. hiascens** (Fr.) Th. Fr.
On earth on mountains near Húsavík, N. Iceland; on mountains east of Öfjord, O. Galløe, 1913. New to Iceland.

**C. Islandica** Ach. with var. **crispa** Ach. and **Delisei** Bory. (D. B., p. 203).
Greenland. G. Brit.

**C. nivalis** (L.) Ach. (D. B., p. 203).
Greenland. G. Brit.

**C. sæpincola** (Ehrh.) Ach. with v. **chlorophylla** Humb. (D. B., p. 204).
Greenland. G. Brit.

### Parmelia.

**P. alpicola** Th. Fr. (D. B., p. 205).
Greenland. G. Brit.

**P. ambigua** Ach. (D. B., p. 204).
Greenland. G. Brit.

**P. encausta** Sm. (D. B., p. 204, P. enc. v. **intestiniformis** Vill.).
Greenland. G. Brit.

**P. incurva** Pers. (D. B., p. 204).
Greenland. G. Brit.

**P. lanata** (L.) Walbr. (D. B., p. 204).
Greenland. G. Brit.

**P. olivacea** L. (D. B., p. 204, f. **prolixa, fuliginosa, sorediata, aspidota**).
Greenland. G. Brit.

**P. physodes** L. (D. B., p. 204).
Greenland. G. Brit.

**P. saxatilis** L. with v. **omphalodes** (L.) Fr. (D. B., p. 204).
Greenland. G. Brit.

## USNEACEÆ.

(Alectoria, Evernia, Ramalina, Thamnolia, Usnea).

### Alectoria.

**A. divergens** Ach. (D. B., p. 200).
G. Brit.

**A. jubata** L. (D. B., p. 200, Bryopogon).
Greenland. G. Brit.

**A. nigricans** Nyl. (D. B., p. 200).
Greenland. G. Brit.

**A. ochroleuca** Nyl. (D. B., p. 200, with v. **cincinnata** Fr.).

### Evernia.

**E. furfuracea** L. (D. B., p. 204).
G. Brit.

### Ramalina.

**R. scopulorum** Retz (D. B., p. 200, "inclusis **cuspidata** Nyl. et formis inter farinaceam L. et R. scop. intermediis").

**R. subfarinacea** Nyl. (D. B., p. 200, probably included in R. scop.).

### Thamnolia.

**Th. vermicularis** Schær. (D. B., p. 202).
Greenland. G. Brit.

### Usnea.

**U. melaxantha** Ach. (D. B., p. 200).
Greenland.

## CALOPLACACEÆ.

(Caloplaca).

### Caloplaca.

**C. aurantiaca** Lightf. (D. B., p. 208, Placodium).
G. Brit.

**C. cerina** (Ehrh.) Th. Fr. (D. B., p. 207, Placodium cer. f. **stillicidiorum**).
Greenland. G. Brit.

**C. citrina** Ach. (D. B., p. 208, Placodium).
G. Brit.

**C. diphyes** Nyl. (D. B., p. 208, Placodium).
Not found in Greenland.

**C. elegans** (Link) Th. Fr. (D. B., p. 205, Xanthoria).
Greenland. G. Brit.

**C. ferruginea** (Huds.) Th. Fr. v. **obscura** Th. Fr. (D. B., p. 208, Placodium).
Greenland. G. Brit.

**C. Jungermanniæ** (Vahl) Th. Fr. (D. B., p. 208, Placodium jung. and var. **leucoraeum**).
Greenland.

**C. murorum** Hoffm. with var. **miniatum** Ach. and **obliteratum** Pers. (D. B., p. 207, Placodium).

**C. nivale** Koerb. (D. B., p. 208, Placodium).
G. Brit.

**C. obscurella** Lahm. (D. B., p. 208, Placodium).
Not found in Greenland.

**C. pyracea** (Ach.) Th. Fr. (D. B., p. 208, Placodium).
Greenland. G. Brit.

**C. tetraspora** Nyl. (D. B., p. 208, Placodium).
Not found in Greenland.

**C. vitellina** (Ehrh.) Th. Fr. (D. B., p. 207, Placodium).
Greenland. G. Brit.

## THELOSCHISTACEÆ.

(Xanthoria).

### Xanthoria.

**X. lychnea** (Ach.) Th. Fr. (D. B., p. 205, X. par. v. lychnea).
Greenland. G. Brit.

**X. parietina** L. (D. B., p. 205).
Greenland. G. Brit.

## BUELLIACEÆ.

(Buellia, Rinodina).

### Buellia.

**B. aethalea** (Ach.) Th. Fr.
Palagonite-tuff near Húsavík, N. Iceland, O. Galløe, 1913. New to Iceland.

**B. atroalba** Ach. (D. B., p. 218, with var. **chlorospora** Nyl.).

**B. badia** Koerb. (D. B., p. 217).
Not found in Greenland.

**B. coniops** Wahlenbg. (D. B., p. 217).
Greenland. G. Brit.

**B. leptocline** Flot. (D. B., p. 217).
Not found in Greenland. G. Brit.

**B. myriocarpa** (D C.) Mudd. (D. B., p. 217).
Greenland. G. Brit.

**B. parasema** (Ach.) Th. Fr. var. **muscorum** (Schær.) Th. Fr., **papillata** (Sm.) Th. Fr., **triphragmia** (Nyl.) Th. Fr., **albocincta** (D. B., p. 217).
Greenland. G. Brit.

**B. scabrosa** Koerb. (D. B., p. 212, Karschia).
G. Brit.

**B. stellulata** Tayl. (D. B., p. 218).
Greenland. G. Brit.

**B. tesserata** Koerb.
Cliffs, Seyðisfjord in E. Iceland, O. Galløe, 1913. New to Iceland.

**B. vilis** Th. Fr. (D. B., p. 217).
Not found in Greenland.

### Rinodina.

**R. Conradi** Koerb. (D. B., p. 212, Urceolaria).
Greenland. G. Brit.

**R. mniaroea** (Ach.) Th. Fr. v. **cinnamomea** Th. Fr. (D. B., p. 212, Urceolaria).

**R. sophodes** Ach. (D. B., p. 212, Urceolaria soph. and var. **confragosa** Ach., v. **exigua** Ach.).
Greenland. G. Brit.

**R. turfacea** Wahlenbg. (D. B., p. 212, Urceolaria).
Greenland.

## PHYSCIACEÆ.

(Physcia).

### Physcia.

**P. aipolia** Nyl.
On basalt, Seyðisfjord in E. Iceland, O. Galløe, 1913. New to Iceland.

**P. aquila** Ach. (D. B., p. 205).
G. Brit.

**P. caesia** (Hoffm.) Nyl. (D. B., p. 205, P. stellaris v. caesia).
Greenland. G. Brit.

**P. ciliaris** L. (D. B., p. 205, P. cil. and v. **scopulorum** Nyl.).
Greenland. G. Brit.

**P. pulverulenta** Nyl. v. **muscigena** Nyl. (D. B., p. 205).
Greenland. G. Brit.

**P. obscura** (Ehrh.) Nyl. (D. B., p. 205).
Greenland. G. Brit.

**P. stellaris** L. (D. B., p. 205).
Greenland. G. Brit.

# II. THE MEANS OF PROPAGATION AND DISPERSAL OF THE ICELAND LICHENS.

After having considered, in the above, the composition of the Flora, the next point to be investigated is, by which means of propagation we can imagine that the species have been dispersed over the island, and have immigrated from the surrounding countries into Iceland, and *vice versa.*

Lichens are propagated by Ascospores, Pycnoconidia, Soredia, and detached portions of thallus.

Ascopores must be assumed to be the original means of propagation, which, as we know, has been handed down directly from the prototypes of the lichens, the Ascomycetes. Those lichens which still stand on a low, primitive phylogenetic stage, viz. the Crustaceous Lichens, have still, almost all, as a rule more or less numerous apothecia, usually with numerous well-developed spores. In the synoptic list of the chief biological conditions of the lichens of Iceland (see below) it will be seen that all the crustaceous lichens have been, and as a rule will be, found with apothecia. Among the Foliaceous Lichens there are several which often occur in great abundance, but are nevertheless rarely found with apothecia. This is for instance the case with *Cetraria aculeata, C. cucullata, C. hiascens, C. nivalis, Nephroma* spp., some *Peltigera* spp., *Physcia pulverulenta* v. *muscigena,* and perhaps a few other species. As will be seen, it is all the leaf-shaped earth-lichens which can undoubtedly be propagated by detached portions of thallus, which, when the plant is in a dry condition, are widely dispersed by the wind, or perhaps also, in part, by animals; but no thorough investigations are to hand as regards this point. What has been said of the foliaceous lichens is also frequently the case among the Fruticose Lichens, namely, that apothecia are rare, while other means of propagation, soredia or detached portions of thallus, are extremely common. This is the case for instance with *Alectoria* and several *Cladonia* spp. Here there undoubtedly also exists a certain correlation between these means of propagation, vegetative means of propagation in several species being of far greater importance for the dispersal of the species, than ascospores. This phenomenon of vegetative propagation is known from several places; thus in Denmark *Cladonia rangiferina* is sterile as a rule, and is most frequently propagated there by detached portions of podetia, and the same is the case with *Cladonia uncialis,* etc.: this circumstance, however, has been exhaustively discussed by me previously (Galløe, 1913, p. 41, and under the different species in the same paper). As regards *Thamnolia vermicularis,* it never forms apothecia.

As to how the ascospores escape from the ascus and their mode of dispersal, are but little known. There is much which goes to show that in the majority of species the spores are dry bodies, which are carried away by the wind and thereby dispersed. But it is just possible that in some of the species they are sticky, and require other means of dispersal.

Pycnoconidia. At present very little is known as regards the extent to which pycnoconidia occur among the Crustaceous, Foliaceous and Fruticose Lichens, nor is it known what rôle they play as regards propagation. They have been regarded both as male reproductive cells, and as vegetative means of propagation. In some cases, investigators have succeeded in producing the lichen-thallus by bringing together pycnoconidia and gonidia in a pure culture, that is, have succeeded in propagating lichens vegetatively by pycnoconidia; this, however, does not necessarily compel us to regard the pycnoconidia of all species as vegetative means of propagation.

To regard pycnoconidia as male reproductive cells, is perhaps more disputable; their importance as such has not at any rate been proved; their entire biological importance is consequently rather problematic. To make investigations regarding this point will, no doubt, well repay the trouble. According to what has just been said, nothing can be stated at the present time as to whether there exists any correlation between the occurrence of pycnoconidia and the occurrence or absence, respectively, of other means of propagation.

Soredia, as is well-known, are small bodies which consist partly of hyphæ and partly of gonidia, and are formed sometimes in quite accidental places the on thallus, sometimes in fairly well-defined patches, the so-called sorals. They have been regarded partly as a peculiar means of propagation produced recently, from a phylogenetic point of view, in the more differentiated (little primitive) species, partly as a pathological phenomenon, due to the fact that the gonidia, with abundant moisture, grow "wild," and burst the outer morphological frame, which the lichen-hyphæ would give to each species, as the one characteristic to the species.

That soredia-production may be pathological, and in many cases is exclusively so, I take for granted, but I am equally convinced that it is not so in all cases. Because in that case, *Cladonia pityrea*, for instance, which is always sorediiferous, must be regarded as a pathologically deformed form of another species, which, under normal conditions, has a quite different appearance. Something to that effect we were obliged to assume as regards the many other lichens, entirely or partially covered with soredia, which occur all over the world. But that such a view cannot be maintained, I consider as certain. It must, however, be pointed out that cultural experiments alone, can decide this question, and such experiments have not been made. It would be necessary, for instance to cultivate soredia in a place drier than that where the sorediiferous species in question has been collected, and try if such a culture would produce a totally different, non-sorediiferous individual, which might, perhaps, prove to be a species already known. Whether soredia-production is a pathological or a normal feature, at all events there is no doubt that it is promoted by dampness.

Soredia have also been regarded as a normal means of propagation in the species in question, and there is no reason whatever to doubt that they may be of this importance. In itself there is nothing to prevent soredia-production from being in some cases pathological, in others normal.

In the Crustaceous Lichens of Iceland soredia-production does not appear to be a common phenomenon. I did not find it widely distributed. *Lepraria* appears to be much less widely distributed in Iceland than in Denmark. Among the Foliaceous Lichens, soredia-production is met with in *Cetraria saepincola* v. *chlorophylla*, *Parmelia ambigua, incurva, physodes, saxatilis, stygia, Physcia cæsia, obscura* and *stellaris*.

Among the Fruticose Lichens it is found in several *Cladonia* species (*Floerkeana, pityrea, fimbriata,* etc.), *Ramalina subfarinacea* and *Usnea melaxantha*. In several of these species soredia appear to be a very common means of propagation, and to occur where apothecia are rare, or not very frequent, (e. g. *Cladonia fimbriata, Ramalina subfarinacea* and *Usnea melaxantha*). The soredia are dispersed by the wind, or perhaps by adhering to the hair of animals.

Detached portions of thallus as a means of propagation are not known to occur with any certainty in a single Crustaceous Lichen. It is probable that this happens in the above-mentioned Foliaceous Lichens. In the Fruticose Lichens it has been demonstrated with certainty in several earth-lichens (*Cladonia*, etc., for instance *Cladonia rangiferina, uncialis, rangiformis*, etc.). In 1913 I fully mentioned and figured it in several species. It appears to be a very important and widely distributed means of propagation in several species, and largely replaces propagation by ascospores, which in such species usually occur rather rarely.

Dispersal takes place no doubt both by the agency of the wind and of animals.

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If we consider the way in which lichens may be assumed to have been dispersed in Iceland itself, we must understand clearly that ascospores, pycnoconidia, soredia, and detached portions of thallus are, as far as we know at present, generally dispersed by the agency of the wind. But animals also no doubt, more or less, play their part in it. It may be regarded as certain that almost all animals that wander about in Iceland occasionally get lichen-spores, portions of thallus, etc. attached to them. Sheep that roam about almost everywhere, undoubtedly play no small rôle as disseminators, and the same, I dare say, applies to the majority of the other terrestrial animals, wild as well as tame. How far means of propagation such as ascospores and pycnoconidia, after having passed through the digestive organs of lichen-eating animals (sheep and reindeer), retain their power of germination, is not known in any single instance. Here, as everywhere in the lichen-biology, we stand at the present time just at the stage of asking questions, without as yet having got very many of them answered, because lichenologists do not, on the whole, occupy themselves with biological problems. But in a general way it may be said that species which play any essential part as articles of food for animals, namely the larger shrub-like earth-lichens, are generally little dispersed by ascospores, for they bear fruit rather sparingly, as mentioned above.

Species such as *Cladonia rangiferma, Alectoria ochroleuca, Cetraria aculeata,* and *Alectoria nigricans* are undoubtedly far more frequently propagated by detached portions of thallus, some carried away by the wind, and others adhering to the body of animals.

That portions of thallus should be able to pass through the digestive organs of animals uninjured, is *a priori* improbable, — if such were the case, they would be rather useless as fodder! Any possibility of such dispersal by means of herbivorous animals, is thus scarcely possible.

But water, also, plays a part in the dispersal of lichens. By the agency of water, the submerged *Verrucaria* spp. which live along the coasts, are undoubtedly dispersed. Then it is probable that the lichens which occur by water-falls, part of which live washed by the falling water (for instance *Staurothele clopima*), are dispersed by the downward-flowing water.

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If we now consider the agencies which play or have played a part in the exchange of lichen-species with the surrounding countries, we must, as in the case of dispersal in Iceland itself, point out three different agencies: wind, water and animals.

The lichens which may be assumed to have immigrated, (respectively emigrated,) by the agency of the wind, are firstly all those that propagate by ascospores, consequently, practically all the crustaceous lichens, at any rate, by far the greater part of the species (about 65 %); then next, the majority of the foliaceous lichens, possibly all of them (there are altogether about 21 % of them); and lastly some fruticose lichens. As regards the latter, however, it must be taken for granted, that at least *Thamnolia vermicularis* did not migrate in the form of spores, as it never bears fruit.

Some of the species have probably also migrated by means of pycnoconidia, but as the occurrence of the latter in the species is very incompletely known, and as their importance as a means of propagation may be disputed, it is not possible to form any opinion as to what importance they are of or have been, in respect to immigration.

Lastly, some species have migrated as soredia. As mentioned above the soredium is not a very common means of propagation in the Icelandic species; in the crustaceous lichens it is extremely rare. I am not prepared to state with any certainty in how many species it occurs, but if it be found in about 20 species, that is no doubt all, and does not form even one-tenth of the species. The chief means of propagation of crustaceous lichens is, as we know, ascopores.

In the foliaceous lichens it has been found in the species — about 9 — mentioned above, that is to say, in about one-sixth of the total number of species.

In how many species of fructicose lichens it has been found, cannot be stated with any certainty, but doubtless, the number does not greatly exceed that of the foliaceous species.

Whether any immigration has taken place by means of detached portions of thallus which have been conveyed by the wind, it is impossible to decide. It has been mentioned above that this mode of dispersal plays a considerable part within the boundaries of the country, with regard to many of the fruticose and foliaceous lichens. But whether portions of thallus, capable of germination, are really transported through the air from the surrounding countries, cannot, of course, be known, but the possibility is scarcely precluded.

Judging from the above, the rôle which we must assume that the wind has played in the immigration and emigration of Iceland's species, is thus very considerable, as all the crustaceous lichens and the majority — perhaps even all — of the fructicose and foliaceous lichens have such means of dispersal (ascospores, pycnocodia, soredia and detached pieces of thallus) as justify us in believing that the wind in particular has transported them to the country.

Water has played a far less considerable part as a means of dispersal, in fact, it can be assumed only with regard to the few submerged *Verrucaria* spp., and the emergent *V. maura*, that they have immigrated by this means. They occur doubtless, over nearly the whole of the Arctic, and over great parts of the adjoining climate-areas, on cliffs out in the sea. They are common on the coasts of Greenland, Iceland, Norway, the Færöes, Denmark and Great Britain, consequently both in Arctic and in temperate regions. They constitute altogether not above 2—3 % of the flora of Iceland.

What importance animals have had as regards immigration is quite unknown. Here again it must suffice us to frame questions which will, perhaps, in the future, be taken up and answered by others.

Primarily it may be supposed that birds of passage which migrate backwards and forwards between Iceland and milder regions, according to the season of the year, may transport lichen-"germs" capable of germination, to Iceland, but nothing is known regarding this point. At the present time it is not even possible to procure a list of the lichens, which grow on cliffs inhabited by sea-fowl in both Scotland and Iceland, from which an opinion could be formed as to how far such transport between these countries is probable. But even if there were a distinct agreement of flora between such localities, that would by no means prove that the transport had been made only by birds. We should be justified in assuming that the lichen-"germs" have been carried along by wind or perhaps water and that this agreement is due to the similarity of the substratum, i. e. one especially manured by birds, as regards the solution of this question, there is scarcely any other way out of the difficulty, than by a direct investigation of what migrating birds can possibly carry of lichen spores and parts along with them, adhering to their feet or to other parts of their bodies, when they arrive at the country in spring; but this will be a very minute and difficult investigation.

But whatever the result may be at which we arrive by that method, it will not be able to modify, to any degree worth mentioning, the view that all other means of migration taken together, scarcely play so great a part in the immigration, as does transport by wind. Even if we imagined all other means eliminated, the flora would, in all probability, have acquired the same essential composition, as that now existing, by the agency of the wind alone; all our knowledge of the means of dispersal of the species is suggestive of this. But this does not exclude the possibility that many species are transported into the country in more ways than one, for instance both by birds and by wind.

It is only with regard to the few submerged species, that the wind has probably played no part at all. Here I believe ocean-currents, and perhaps sea-fowl, have been the transporting agencies.

# III. THE BIOLOGY OF THE LICHENS OF ICELAND.

Lichens may be divided into the following biological types: — Bark, (Epiphyllous), Earth, Rock, (Parasitic) and (Saprophytic) lichens. The three enclosed in brackets are wanting in Iceland, (but possibly one or other of the last two groups may be found there), and therefore will not be discussed here. With regard to these it will suffice to refer the reader to my treatise "Forberedende Undersøgelser til en almindelig Lichenøkologi" (1913).

## 1. BARK LICHENS.

To this group I refer not only those which grow on the bark of trees, but also such as grow on bare wood (telegraph poles, surfaces of wooden houses, etc.). These substrata have practically not been investigated as regards lichen-biology, whilst their anatomy has been investigated long ago.

The chemical properties of the bark and their importance to lichens, are as yet very superficially known. The bark always contains organic substances (suberin, cellulose, tannin, resin, etc.), inorganic salts, etc. Besides, it may be taken for granted, that the outside layer of bark is generally more decomposed than are the inner ones. That the bark differs distinctly as a substratum according to whether it is young or old, is evident from the investigations which Lotsy (1890) and I myself have made, regarding the immigration-history of the lichens on bark. These investigations have shown that the pioneer vegetation always consists of certain crustaceous lichens, and is not replaced until later by the permanent vegetation. I have no certain knowledge of this immigration-history as regards Iceland, but I have reason to believe that the rule mentioned above also holds good there.

Judging from what is known, the reason for this vegetation order is a fairly similar process of decomposition in the different kinds of bark, for barks even very different physically (smooth and scaly) show quite analogous features in the development-history of the vegetation.

I am not aware of the existence of any thorough chemical investigation of the different kinds of bark, nor do I believe that such exists, except perhaps as regards the officinal barks.

Neither have, as yet, the physical conditions of bark been investigated. We can, upon a superficial survey, immediately distinguish between the two, well-known groups, smooth bark and scaly bark. They are easily distinguished from each other.

I have known, as a general fact, that the systematic species of the tree, is of no importance to the biological types which settle down on its bark, as crustaceous, foliaceous and fruticose lichens may be found on all of them. Which of these types is to dominate the vegetation when it is fully developed, depends on the degree of light to which the tree is exposed, and other meteorological circumstances, as I have shown in my work on "Danske Licheners Økologi" (1908).

On the other hand, the floristic composition of the vegetation varies essentially, according to the systematic species of the tree. Experience shows that certain lichens occur by preference on certain species of trees, (*Usnea* spp. on coniferous trees, etc.). It is possible that, by more thorough investigations, we shall also be able to find fixed rules for this association, but as yet nothing is known regarding this point. At present we must be content with the lists of lichens compiled for each species of tree, as has been done in "Danske Likeners Økologi," and as regards Iceland, when discussing the lichens of the Birch later on in this paper.

W o o d. Many species which occur most frequently on bark, may occasionally be found on bare wood. Wood is chemically closely related to bark, and the lichens which occur on it can, as a matter of course, be classified among the bark lichens. It must, however, be mentioned with respect to the growth-tensions which occur in the bark during the growth of the tree, and which are inclined to stretch the crust-shaped lichens into elliptical or oval crusts, with the main axis of the ellipse at right-angles to the longitudinal axis of the tree, that these, of course, will not be fonnd in dead wood. There, on the contrary, the crustaceous lichens grow parallel with the "fibres," i. e. parallel with the longitudinal axis of the stem, hence the reason why lichen-crusts which grow uninfluenced by neighbours and competitors, are very often oval or elliptic in shape, with their main axis parallel with the longitudinal axis of the tree.

In Iceland there occurs rather a common wood-substratum, namely the old decomposed walls of the wooden houses. On such walls I found the following common species: —

| | |
|---|---|
| Buellia myriocarpa. | Caloplaca vitellina. |
| Lecanora Hageni. | — pyracea. |
| — varia. | Physcia obscura. |
| — subfusca. | |

Bark-lichens may be divided into Crustaceous, Foliaceous and Fruticose lichens.

Of Crustaceous bark-lichens there are two different types, hypophlœodal and epiphlœodal.

The hypophlœodal crustaceous-lichens (numerous *Graphideæ*, etc.) have, as regards their attachment to the substratum, been long ago investigated very thoroughly by Lindau (1895), to whose treatise I refer the reader.

Their thallus lives in the interior of the bark of trees, covered by its cells, which afford the lichen protection against evaporation. According to Lindau their hyphæ appear to be quite unable to dissolve the cellulose of the bark, so they probably live on its decomposition-products. They themselves, however, contribute towards decomposition by bursting asunder the cells by the tension of their growth, whereby air and water gain access to the bark. The thallus is otherwise homoiomerous in structure in several of the species, in others distinctly heteromerous; consequently, on the whole, very primitive, and only slightly removed from the purely mycelial fungal prototypes.

The hypophlœodal crustaceous-lichens stand extremely low both in respect to morphology and anatomy, and as regards their capacity for competition with other plants. They live exclusively on the bark of trees and have no analogues among the earth-lichens and only a few (and these even very disputable,) among the rock-lichens with endolithic thallus. Only where other bark-lichens are absent for various reasons, may these occur, but if the conditions are favourable to fruticose and foliaceous lichens, they are immediately expelled by these. They are most frequent on smooth bark — the numerous smooth-barked trees of the tropics house an abundance of them — and they remain there so long as the bark is not decomposed enough to house other, more pretentious types.

The course of development in the decomposition of the bark, and the consequent change of vegetation from hypophlœodal to epiphlœodal and other bark lichens, may be studied on almost every old tree.

How many of Iceland's bark lichens are hypophlœodal, has not been investigated.

The epiphlœodal crustaceous-lichens are fastened to the substratum like the hypophlœodal; they have been investigated by Lindau (1895). They have a hyphal tissue that sinks into the bark and ruptures the cells of the bark, but is not able to dissolve their cellulose. The gonidia-containing part of the thallus is on the surface of the bark, — hence their name — and is more or less distinctly covered with a cortex, showing all transitions between species with the thinnest and the thickest cortex.

In several crustaceous lichens soredia are formed which can propagate the plant, for instance in the *Variolaria* spp. This mode of propagation indicates a higher morphological stage than that of the hypophlœodals, in which anything like it appears to be rare.

With regard to competitive capacity, in most of the habitats the epiphlœodals stand above the hypophlœodals, but they generally appear to need a more advanced stage of decomposition of the bark, than do the latter, so that they frequently succeed to them as the bark gradually gets older. It is possible that they also require more light.

Of crustaceous bark-lichens Iceland has the following: —

Arthonia proximella Nyl.
— punctiformis Ach.
Arthopyrenia analepta Ach.
— grisea Schleich.
Bacidia abbrevians Nyl.
— arceutina Ach.
— atrosanguinea Schaer.
— Beckhausii Koerb.
— rubella Ehrh.
— sphaeroides.
Buellia myriocarpa (D C) Mudd.
— parasema (Ach.) Th. Fr.
Caloplaca cerina (Ehrh.) Th. Fr.
— citrina Ach.
— ferruginea (Huds.) Th. Fr.
Diploschistes scruposa L.
Lecania athroocarpa (Dub.) Nyl.
Lecania cyrtella Ach.
Lecanora atra (Huds.) Ach.
— Hageni (Ach.) Koerb.
— pallescens (L.) Schaer.
— protuberans Sm.
— subfusca (L.) Ach.
— tartarea L.
— varia (Ehrh.) Nyl.
Lecidea crustulata (Ach.) Koerb.
— Diapensiæ Th. Fr.
— elaeochroma (Ach.) Th. Fr.
— erytrophæa Flk.
— fuscescens Sm.
— helvola (Koerb.) Th. Fr.
— Nylanderi Anzi.
— Tornoensis Nyl.
Lepraria.

Microthelia micula Flot.
Pertusaria communis D C.
Pertusaria xanthostoma (Sm.) Fr.
Rinodina sophodes Ach.

The Foliaceous bark-lichens appear to be far richer and more varied in structure, and probably comprise very different types, which have not yet, however, been investigated from a biological point of view. With regard to this point, it will suffice for me to draw attention to the striking difference between such species as are adpressed to the substratum *(Physcia pulverulenta)*, the surface of which the lichen follows along all its irregularities; and on the other hand *Parmelia physodes,* the greater part of which rises into the air, and lastly *Evernia Prunastri,* which hangs down in tufts from trunks and branches.

The thallus of the foliaceous lichens is dorsiventral, is covered by a cortex, and has rhizines on its under surface. The rhizines attach the lichen to the substratum in the way described by Lindau, for, on coming into contact with the bark, they spread out flat over the substratum and, when the bark is well decomposed, send hyphæ down into its cracks for further attachment. The rhizines are unable to dissolve the cellulose, but it may be presumed that they absorb the salts set free by the decomposition of the bark.

The gonidia-containing thallus itself is, as is well-known, indented in various ways, and grows centrifugally over the substratum, for which reason it often dies away in the centre, a fact commonly observed, especially in *Parmelia saxatilis* and *Sticta pulmonacea.* The edge of the thallus gradually forms new rhizines on the side turned downwards. The gonidia are situated just below the cortical layer of the morphological upper-surface.

Propagation takes place by means of spores, possibly by pycnoconidia and soredia, which are extremely common in several species (*Parmelia* and *Evernia* spp.).

In their competitive capacity the foliaceous lichens stand, in many habitats, far above the crustaceous lichens. They generally require more thoroughly decomposed bark than do the latter, therefore (with a few exceptions) they do not live on young branches. In addition, they generally demand more light. Consequently, where abundant light and well-decomposed bark are found, the vegetation of the bark of the tree consists of foliaceous lichens, which easily grow over and exterminate the original vegetation of crustaceous lichens. In the birch coppices of Iceland this may be observed here and there on older trunks and branches, especially in particularly wind-affected coppices of which the tops of the shoots are dead.

The conditions pertaining to propagation in the foliaceous lichens do not appear to differ from those in the crustaceous lichens.

Iceland has the following foliaceous bark-lichens: —

Cetraria sæpincola (Ehrh.) Arn.
Collema flaccidum L.
— nigrescens L.
Evernia furfuracea L.
Leptogium plicatile Ach.
Nephroma laevigatum.
— tomentosum.
Pannaria triptophylla Ach.
Parmelia ambigua Ach.
Parmelia olivacea L.
— physodes L.
— saxatilis L.
Physcia ciliaris L.
— obscura (Ehrh.) Nyl.
— stellaris L.
Sticta scrobiculata Scop.
Xanthoria lychnea (Ach.) Th. Fr.
— parietina L.

Fruticose bark-lichens *(Usnea, Ramalina, Bryopogon)* are not found in Iceland, so they will not be discussed more fully here. They are described in my treatise of 1913, pp. 19 et seq.

## 2. EPIPHYLLOUS LICHENS.

are not found in Iceland. They require evergreen leaves as a substratum. These extremely interesting plants received brief mention in my paper of 1913. The chief work on them is Ward's treatise of 1893.

## 3. EARTH LICHENS.

Three types may be distinguished: Crustaceous, Foliaceous and Fruticose lichens, all three of which are found in Iceland.

In all Crustaceous earth-lichens there is a distinct demarcation between that part of the thallus which is buried in the ground (subterranean, hypogaean thallus) and that which rests upon the surface of the ground (epigaean thallus). The subterranean thallus may vary fairly markedly in appearance: it may be composed of small, more or less loosely connected grains *(Lecidea uliginosa, L. alpestris, L. arctica, Gyalecta geoica),* or it may consist of a homogeneous crust (*Bilimbia sabuletorum, Lecidea Diapensiæ,* etc.), or of small, somewhat scale-like parts coherent at the base *(Sphyridium byssoides).* The biological importance of these forms has not yet been investigated.

The gonidia occur sometimes evenly distributed in the whole of the epigaean thallus, sometimes arranged in a definite layer immediately beneath the cortex.

The subterranean thallus normally is free of gonidia (barring foreign-gonidia). It may be very strongly developed, and it pushes its way down among the particles of soil, which may gradually become entirely enclosed by its hyphæ. I have sometimes observed shapeless enclosed lumps of black humus *(Lecidea decolorans, Bilimbia sabuletorum* (D. Lik. Ø., pl. 4, fig. 15), *Bacidia citrinella),* sometimes organic remains with the cell-structure preserved *(Lecidea decolorans),* and sometimes grains of mineral matter *(Buellia scabrosa).* In no case has it been possible to demonstrate whether solution takes place by the agency of the lichen-hyphæ. It is almost incomprehensible that something of this kind should not happen, but it has not been proved. It is possible that what is set free of the enclosed organic remains, or of the mineral grains by purely chemical decomposition, suffices for the lichens.

In some few cases *(Lecidea decolorans* (D. Lik. Ø., pl. 10, fig. 53, c), *Pannaria brunnea)* I found, enclosed in the subterranean thallus, an undetermined species of green algæ. The gonidia were dead and decoloured, but the lichen-hyphæ had not sent haustoria into them (nor do they do so as a rule to their normal gonidia). The death of the gonidia was undoubtedly due to contact with the hyphæ, and possibly some use had been made of their contents. The whole thing must be regarded as a Cephalodium-formation, a "hypogaean" cephalodium or perhaps a "pseudocephalodium."

About the mode of propagation of the crustaceous lichens very little is known. Ascospores, perhaps pycnoconidia, are probably their most common means of propagation, I have not observed soredia or detached portions of thallus in them, as in the fruticose lichens. It is a very interesting fact, that these means of propagation appear to be at any rate rare in the primitive, crustaceous lichens.

Crustaceous lichens are very weak in competition with other plants, as these easily cover them over and exterminate them. They are most favourably situated in Iceland, and in other Arctic countries; this will be discussed more fully below.

Iceland has the following crustaceous earth-lichens: —

Bacidia arceutina Ach.
— caudata Nyl.
— flavo-virescens Dicks.
— herbarum Hepp.
— milliaria Fr.
— obscurata (Sm.) Th. Fr.
— squalescens Nyl.
Baeomyces byssoides (L.) Th. Fr.
— placophyllum Wahlenbg.
Buellia badia Koerb.
— parasema (Ach.) Th. Fr.
— scabrosa Koerb.
Caloplaca cerina (Ehrh.) Th. Fr.
— Jungermanniæ (Vahl) Th. Fr.

Caloplaca nivale Koerb.
— tetraspora Nyl.
— vitellina (Ehrh.) Th. Fr.
Catillaria cumulata Sm.
— Jemtlandica Th. Fr.
Collema verrucaeforme L.
— pulposum Bernh.
Coniocybe furfuracea L.
Gyalecta cupularis Ehrh.
— foveolaris Ach.
Lecanora castanea (Hepp.) Th. Fr.
— Hageni (Ach.) Koerb.
— pallescens (L.) Schaer.
— subfusca (L.) Ach.
— tartarea L.
— varia (Ehrh.) Nyl.
Lecidea alpestris Sm.
— arctica Sm.
— assimilata Nyl.
— atrorufa Dicks.
— Berengeriana Mass.
— crassipes Th. Fr.
— cuprea Sm.
— decipiens Ehrh.
— decolorans Hoffm.
— elæochroma (Ach.) Th. Fr.
— fusca Schaer.
Lecida granulosa (Ehrh.) Schaer.
— limosa Ach.
— lurida ,Sw.
— neglecta Nyl.
— rubiformis Wahlenbg.
— ramulosa Th. Fr.
— uliginosa Schrad.
— vernalis (L.) Ach.
Lepraria.
Lopadium fuscoluteum Dicks.
— pezizoideum (Ach.) Koerb.
Massalongia carnosa (Dicks.) Koerb.
Microglaena sphinctrinoides Nyl.
Pannaria brunnea Nyl.
— lepidiota Sm.
Pertusaria coriacea Th. Fr.
— dactylina Ach.
— oculata Dicks.
Placynthium delicatulum Th. Fr.
Psoroma Hypnorum (Hoffm.) Ach.
Rinodina Conradi Koerb.
— mniaræa (Ach.) Th. Fr.
— turfacea Wahlenbg.
Toninia squalida (Ach.) Nyl.
— syncomista (Flk.) Th. Fr.
— vesicularis Hoffm.

The Foliaceous earth-lichens may be divided into at least two groups, procumbent and erect. To the procumbent group belong, e. g. *Peltigera (canina, horizontalis, venosa, aphtosa, lepidophora), Solorina (crocea, saccata, bispora), Physcia (pulverulenta* v. *muscigena, stellaris), Dermatocarpon (hepaticum, dædaleum, cinereum).* To the erect group belong *Cetraria (islandica, odontella, cucullata, nivalis, glauca, lacunosa)* and some of the species of *Collema* and *Leptogium.* It is possible that some of the species may be procumbent under certain circumstances, and erect under others. It is clear that these species differ essentially as regards their competitive capacity against other plants. The erect species must be regarded as the best equipped in that respect, and are also those which are most frequent and most numerous in nature. As is well-known the *Cetraria* spp. are much more numerous than are any of the procumbent earth-lichens.

The Procumbent foliaceous lichens grow centrifugally from the centre of the plant, and are provided with scattered bundles of rhizines on their under surface. The rhizines attach themselves gradually to the substratum, as they come in contact with it. How they attach themselves, and how far they are of any other importance than to fix the plant in the substratum, is not known. The thallus itself is always dorsiventral and in some species it dies away in the middle, its single lobes thus becoming isolated. Zukal (1895) has shown that several of the earth-lichens "wander" by a kind of mycelium, which proceeds from their rhizines, and run horizontally below the surface of the ground, forming new thalli here and there, as in *Peltigera venosa* and *Solorina saccata*. This mode of propagation corresponds exactly with that by which crustaceous lichens with a mycelium of radiating, centrifugal growth, form numerous small balls of gonidia, which by their abundance fuse into a granulose thallus; or with that by which *Cladonia* forms its centrifugally-growing scales (primary thallus) or *Stereocaulon* its scales which afterwards develop into podetia (Danske Likeners Økologi, fig. 91); it is no doubt the most natural explanation of the fact, that the form of many foliaceous lichens is that the thallus consists of one or more lobes, which have a base on the surface of the earth itself, and grow from thence unilaterally forward away from that base.

The Erect foliaceous lichens are, although erect, very commonly dorsiventral. So far as my investigations go, they die away below (the spot corresponding with the centre of the procumbent lichens) and keep on growing at the apex. They escape being blown away by being fastened by their "haptera" each to the other or to other things (Sernander, 1901). These haptera, which have not been investigated more closely, have been found by Sernander in *Cetraria islandica*, *cucullata*, *hiascens* and *nivalis*, and are transformed cilia, which, as is well-known, are extremely common in this genus.

The means of propagation in the foliaceous earth lichens appear to be ascospores, or perhaps pycnoconidia. On the other hand, soredia and detached portions of thallus do not appear to play any part in the dispersal of these species either. Otherwise, the whole class has been as yet very little investigated. It is evident that procumbent foliaceous lichens are weak competitors, and are easily covered by other plants. As regards abundance of individuals they also play but a slight rôle in nature. They have far better chances on stones and trees, and are very common in such stations. The erect foliaceous lichens have far greater advantages in competition, and are much richer in individuals than are the others.

Iceland has the following foliaceous earth lichens: —

Cetraria cucullata Bell.
— hiascens (Fr.) Th. Fr.
— nivalis (L.) Ach.
Dermatocarpon cinereum Pers.
— hepaticum Ach.
— rufescens Ach.
Leptogium lacerum Ach.
— scotinum Ach.
Nephroma arcticum L.
— expallidum Nyl.
— tomentosum (Hoffm.) Nyl.
Pannaria microphylla Nyl.
Parmelia lanata Wallr.
Peltigera aphtosa L.
— canina (L.) Fr.
— horizontalis L.
— lepidophora Nyl.
— malacea (Ach.) Fr.
— polydactyla(Neck.)Hoffm.
— rufescens Fr.
— venosa (L.) Hoffm.
Physcia pulverulenta Nyl. (v. muscigena).
Solorina bispora Nyl.
— crocea Ach.
— saccata L.

The Fruticose earth-lichens. Three types may be distinguished, which are however connected by intermediate forms, namely, Hypothallus-wanderers, Podetium-wanderers and Primary-scale-wanderers, which have been exhaustively described and for the first time established by me in 1913. From these groups I quote as examples: —

Hypothallus-wanderers: *Stereocaulon condensatum, Cladonia papillaria, C. pyxidata, C. pityrea, C. fimbriata, C. squamosa, C. crispata, C. cornuta, C. macilenta, C. Floerkeana, C. coccifera, C. deformis, C. verticillata* (see figs. in Forb. Unders., 1913).

Podetium-wanderers: *Stereocaulon tomentosum, S. evolutum, S. coralloides, S. paschale, Dufourea arctica, D. muricata, Siphula ceratites, Cladonia degenerans, C. gracilis, C. furcata, C. rangiformis, C. uncialis, C. rangiferina, Thamnolia vermicularis, Alectoria ochroleuca, Cornicularia aculeata, Bryopogon jubatus* v. *nitidulus, Sphærophorus fragilis* (see figs. in Forb. Unders., 1913).

Primary-scale-wanderers: *Cladonia foliacea* (see figs. in Forb. Unders., 1913).

As an example of the structure of a hypothallus-wanderer, a description of *Cladonia pyxidata* will suffice. When the spore in this species germinates, it gives rise to a mycelium which spreads out radially in the ground (Dan. Lik. Øk., fig. 39 a), and is called a hypothallus. Wherever these purely mycelial hyphæ encounter *Pleurococcus*-algæ on the surface of the ground, they establish — as has already been described by Krabbe (1891) and Wainio (1898), — a connection with these latter, and form lichens. We may then, on a somewhat older hypothallus, distinguish between the purely mycelial hyphæ, which have not as yet begun their lichen-formation, and within these (nearer to the germinating point) a belt, where the primary scales are fully formed, and in the centre, still older scales with podetia, which are frequently placed distinctly in a circle ("fairy ring"). The hypothallus can wander in the ground for years, exactly as a fungal mycelium wanders; the podetia, on the other hand, live a few years only, and are gradually replaced by new ones. They are erect as long as they are alive, and end by dying away at the base, so that, ultimately, they rot and fall down, as they very rarely cohere with one another by haptera.

This type is the most primitive of the fruticose lichens, as is shown by the fact that it is still the vegetative thallus which keeps on living, while the podetia, the curiously transformed apothecia-stalks, die away and are destitute of all the peculiar contrivances which are found in the type of podetium-wanderers, such as prostrate, creeping podetia, haptera, etc.

It is, however, a type which is well-adapted to live on the ground, which the hypothallus can easily penetrate. On the other hand they are ill-adapted for life on the bark of trees or on stones, which can only with great difficulty be penetrated by the hypothallus. Nor do there occur, as far as is known, any species among the bark or rock lichens which may be included among the hypothallus-wanderers. On the other hand, they are more unfavourably situated in regard to competition than are the podetium-wanderers, which die away below and keep on growing at the apex, by which means they can outgrow several other species. They are also far rarer as regards individuals than are the excellently equipped podetium-wanderers, *Alectoria ochroleuca*, or *Cladonia rangiferina*.

*Cladonia rangiferina* is the most highly developed of all the podetium-wanderers we know. When the spore germinates, a crust-shaped thallus is formed, but this is very rarely obtained, and has been observed only by a few lichenologists, (Krabbe, Wainio and Galløe), as it is very small and disappears very quickly. Upon it the first podetia are developed, and they branch rapidly. The primary thallus dies away and from henceforward the podetium is left to look after itself; it gradually dies away at the base, but keeps on growing "per secula" (Wainio) at the apex, so that it gradually comes to rest upon a cake of lichen-peat made by itself. By the dying away of the podetium, its lateral branches become gradually isolated from one another; those that are placed somewhat horizontally come gradually into touch with the surface of the ground, and take hold of it at their apices by sending pencil-shaped haptera into it (Mentz, 1900; Sernander, 1901; Galløe, 1908 and 1913). The podetium-branch thus anchored forms new vertical branches, which in turn also die away below, etc. All the vertical podetium-branches and podetia, which are naturally very slightly attached to the ground (by the decaying bases), are mutually connected by numerous haptera, which hold them so closely together, that it is impossible to obtain uninjured any isolated podetium from a tuft.

The characteristic features of this type are, that the primary thallus (here crustaceous) very soon dies, and that the podetia (at the edge of the tuft) may lie down horizontally and wander in this way, attached to the ground and to one another by haptera, while they die away at the base, and keep on living perhaps for centuries at their apex.

The podetium-wanderer is an excellent earth-lichen-type, capable of competition beyond any of the others, by the fact of its dying away at the base, and keeping on growing at the apex, which enables it to grow above both crustaceous and foliaceous lichens, and also above hypothallus- and primary-scale-wanderers. The type is consequently exceedingly rich in individuals in nature; reindeer moss, as is well-known, is the most abundant earth-lichen in the world. But the type is poor in species. It is not adapted to life on rocks and trees, for its dying away at the base would deprive it of its substratum.

The primary-scale wanderers are represented by *Cladonia foliacea,* which is in reality intermediate between a fruticose and a foliaceous lichen. The spore, on germinating, quickly forms a primary thallus consisting of large, well-developed lobes, which spread out in a tuft-formation over the ground, while the hypothallus decays quickly. Along the edge of the tuft the lobes lie horizontally, but towards the centre they stand upright. They die away at the base, and keep on growing at the apex, exactly as in *Cetraria,* for instance. They are closely connected with one another by numerous haptera, which prevent them from being scattered to the winds. Consequently, so far, *C. foliacea* is a foliaceous lichen, but podetia may also be developed on the lobes of the thallus — although not frequently in Denmark or in Iceland — which makes it impossible to include it, as a matter of course, among the foliaceous lichens. The primary-scale wanderers, as regards their competitive capacity, are like the lower species of the erect foliaceous lichens; they are few in number both as regards individuals and species. The fact that they die away at their base make them unfit for life on the bark of trees and on stones, and consequently they do not occur there.

Some fuller data concerning the biology of the fruticose lichens will be given here: —

The hypothallus is the purely mycelial lichen-tissue, free of gonidia, which is formed by the germination of the spore (the soredium or perhaps the pycnoconidium). It has been observed in all the species of the genus *Cladonia*, and in *Stereocaulon condensatum;* but as to all the other species of the latter genus, it has, in some, never been observed, and in others, is very insignificant, and is then, only for a time, of importance to the life of the species, as it dies away early. It lives long in all hypothallus-wanderers, and constitutes — as suggested by the name — their only means of wandering. On the other hand, it disappears very early in the primary-scale wanderers, and in the majority of the podetium-wanderers.

It is always formed of very loosely woven hyphæ, which grow centrifugally from the germination-centre. Wherever green algæ suitable for the species, is encountered by it on the surface of the ground, it weaves its hyphæ round them, and forms thereby the first beginning either of primary scales *(Cladonia)* or of direct podetia *(Stereocaulon)*. This process has, as regards *Cladonia,* been described by Krabbe (1891) and Wainio (1898).

Some of the hypothallal hyphæ are often formed as fairly thick, dark hyphal bundles, almost devoid of intercellular spaces, especially where they are continued up into the base of the primary scale *(Cladonia cornuta, C. verticillata)*. The hyphæ easily come into contact with mineral-grains, humus-particles, plant-remains with their structure still intact, and earth algæ. About this the following is to be noted: —

Mineral-grains, especially sand-grains, adhere to the hyphæ of several species. I believe that this happens through the cell-walls being covered with a slight (microscopically-invisible) covering of mucus. The sand-grains themselves are always finely striated on the surface, no doubt from weathering, for it cannot be proved that the hyphæ exercise any chemical influence upon them, and we must be careful not to state definitely that the roughnesses are marks of corrosion.

The humus-particles are opaque under the microscope. Where they are lying interwoven with the hyphæ-bundles, it cannot be shown that the hyphæ affect them. I have observed them very commonly in *Cladonia pityrea, squamosa, crispata* and *Floerkeana.*

Plant-remains, with their structure intact, occur very commonly in the hypothallus. Thus I have found *Cladonia pityrea* adhering to the bark of a dead heather-twig. The hyphæ of the hypothallus behave here exactly as does the hypophloedal hyphal system in the bark-lichens: The cork-lamellæ were split from one another into small-scales, but the cork could not be proved to have been corroded by the hyphæ. The same lichen often spreads out its hypothallus over dead moss-leaves on the ground, but these have, as a rule, turned so brown and are so broken, that it cannot be shown whether the hyphæ have had any part in their disintegration.

Very commonly the hyphæ encounter various green algæ and *Cyanophyceæ* (*Gloeocapsa,* etc.); in no case did I find haustoria in the algæ, nor did I, on the whole, see the hyphæ attach themselves to the algæ, or by their mode of branching, etc. show the least interest in the algæ in question. They appear almost always to be of no importance whatever to the lichen-hyphæ, even if they are lying encysted amongst them. The fact that dead specimens may be found amongst them does not show with any certainty that death is due to any influence exerted by the lichens, although the possibility of it is not excluded.

The primary thallus (in *Cladonia*) consists, as is well-known, of small, leaf-shaped thallus-scales of dorsiventral structure, which proceed directly from the hypothallus, and are developed in centrifugal succession from it. In all hypothallus-wanderers the primary scales live very long as "nutrition-shoots," co-equal with the podetia. They are of far less importance to the more primitive podetium-wanderers *(Cladonia gracilis, furcata, rangiferina)* in which the podetia, at an early stage in the plant's life, become its chief, and finally its only assimilatory organ; finally, in the more advanced podetium-wanderers *(Cladonia rangiferina, uncialis),* they are so insignificant, that they form quite a crust-shaped thallus, which perishes so early, that the majority of the lichenologists have not even seen it. Moreover, several podetium-wanderers are, as a rule, propagated in quite a different manner (by fragments of podetia, etc.) and thus have, on the whole, very rarely any opportunity of developing a primary thallus.

In *Cladonia foliacea* the primary thallus is the chief assimilatory organ of any length of duration.

Consequently, three types may be distinguished: (1) Permanent primary thallus, which keeps on growing along the edge and dies away at the base; this is found in the primary-scale-wanderers *(Cladonia foliacea)*. (2) Permanent primary thallus, which does not die away behind, found in the hypothallus-wanderers and in the more primitive podetium-wanderers *(Cladonia papillaria, pyxidata, pityrea, fimbriata, squamosa, crispata, cornuta, macilenta, Floerkeana, coccifera, deformis, verticillata, gracilis, rangiferina, furcata)*. (3) Quickly perishing, crust-shaped primary thallus, found in the most decided podetium-wanderers *(Cladonia uncialis* and *rangiferina)*.

From the under surface of the primary scales, in several cases, hyphæ may proceed from the cortical layer. Sometimes it is difficult to decide with any certainty, whether they are simply hypothallal hyphæ or — which may be the case — secondary hyphæ, which from the medullary layer, push their way into the soil, and attach themselves to it, and are therefore, properly speaking, haptera. Undoubted haptera I have found in *Cladonia foliacea,* where they occur in the form of a hyphal pencil, in *C. pityrea,* where they are similar in form, in *C. squamosa,* where they form solid hyphal bundles, and in *C. pyxidata, macilenta* and *furcata,* in which they consist of scattered hyphæ, produced from the under surface of the scales.

The haptera attach themselves to mineral-grains, humus-lumps, etc., in exactly the same manner as do the hypothallal hyphæ, and it is true also with regard to them, that it has not been possible to demonstrate microscopically that they have any chemical influence. Interwoven in a hapteron of *Cladonia foliacea* I found green algæ, which were apparently uninfluenced by the proximity of the hyphæ.

Another type of primary-scale haptera I found in *Cladonia foliacea* and in *C. cornuta.* By means of these the scales attached themselves to one another or to podetia of the same species.

Podetia. Of these, four types may be distinguished, which differ in duration of life and in mode of growth. All the fruticose earth-lichens are erect, and their thalli are, as a rule, called "podetia," but these, however, differ greatly in the history of their development. Here the term is used as a biological conception to indicate the subærial thallus, mainly of a radiating form; (consequently not the primary scales of *Cladonia*). Of this I have set up four types, viz. (1) erect, radial, permanent podetia; (2) erect, radial podetia, dying away at the base; (3) procumbent, dorsiventral, hapteron-producing podetia, dying away at the base behind; (4) procumbent, dorsiventral, hapteron-free podetia, dying away at the base behind.

Type 1 is found only in the hypothallus-wanderers, and in the majority of these.

Type 2 is found in some of the hypothallus-wanderers, and in all the podetium-wanderers. As a rule, we may take for granted that podetia of type 1, when they become old, ultimately pass over to type 2 for a short time, before they die away entirely. But even if the boundary line between the two types is thereby made very uncertain, it is advisable to maintain both of them, as there are undoubtedly species which never die away below or, at any rate, very rarely do so (e. g. *Stereocaulon condensatum, Cladonia papillaria, C. pyxidata, C. pityrea* and possibly others).

Type 3 like type 4 is commonest in the podetium-wanderers, in which the edge of the tuft usually grows in circumference by the marginal podetia lying down and creeping over the surface of the ground, and like runners spreading out on the substratum. By this the podetia often become somewhat dorsiventral and, in addition, send in some cases haptera into the ground (the majority of the podetium-wandering *Cladonias*); in other cases nothing like this happens *(Stereocaulon, Dufourea)*.

Consequently, in the same tuft and in the same species more than one type of podetium may be found, so that types 1 and 2 are united, in that the old podetia may belong to type 2, and the young, on the other hand, to type 1; but, as already mentioned, in some species type 1 is the dominant one.

Types 2 and 3 are, as a rule, united in the same species and in the same tuft, in that type 3 forms the runners of the tuft, and type 2 the old erect shoots in the middle of the tuft.

In the same way, types 2 and 4 are as a rule united in the same tuft.

It is evident, that all species which have on the whole erect, permanent podetia, are less adapted to grow on the earth, because they are so dependent on the substratum for their attachment, and are therefore easily overgrown and crowded out by other species. Their apical growth also is very limited, which in addition reduces their capacity for competition.

Podetium-wanderers, on the other hand, are excellent competitors. With regard to these I shall add some further notes about the relation of the podetia to the substratum and mutually to one another.

As already mentioned, the oldest podetia die away below, and form thereby a peaty mass, while they keep on growing at their apex "per secula" as Wainio writes.

The question now arises how the podetia, on a century-old cake of lichen-peat, obtain their mineral food. So long as the lichens are in somewhat close contact with mineral soil, every shower will saturate the upper layers of earth, and the water will become nutritive to a certain extent. But later on, when the cakes of lichen-peat are formed, they will no doubt gradually become washed free from minerals, and the water which the lichens can absorb from the substratum (which is, as is well-known, very little, because they lead the rainwater down into the ground much more easily than upwards from it, as demonstrated by Zukal, 1891—96) must become poorer and poorer in nutriment. Can this ultimately bring about the result that the lichen-covering, by its continued growth, brings about its own destruction? It is a question which lichenologists, who have easy access to Alpine lichen-heaths, ought to take up for investigation.

Haptera have been first demonstrated and described by Sernander (1901) in a small and very interesting, but unfortunately only too brief, treatise. Sernander distinguishes several types (*Cladonia*-type, *Alectoria*-type, etc.). I prefer another classification, because haptera of several different types occur on the same plant, and cannot therefore be named after different genera. Sernander does not describe them anatomically. In my "Forberedende Undersøgelser" (1913) they have been very fully treated and figured, and the chief points will now be recapitulated here.

According to my classification the types to which the haptera may be referred, are the following: —

(1) Apical haptera,
(2) Lateral haptera,
(3) Primary-scale haptera,
(4) Podetium-scale haptera.

Some of these, especially the two last, have not been mentioned at all by Sernander.

The haptera may attach themselves to the ground (when the podetia are procumbent); or to other individuals of the same species (but no parasitic relation ever arises from this contact); or to other species of lichens (again no parasitic relation appears to arise), or, lastly, to quite other plants, e. g. moss, heather, etc.

Apical haptera put into the ground I have found in the more differentiated podetium-wanderers, with distinctly procumbent marginal podetia, the apices of which occasionally come into contact with the ground, and are then immediately transformed into pencil-shaped bundles of hyphæ, which penetrate into the ground, and fix the podetia for the time being, and absorb water and nourishment. The hyphæ are frequently H-shaped by attachment to one another (fusions), and they behave exactly like hypothallal hyphæ; they attach themselves to mineral-grains, humus-particles, and dead plant-remains with the structure intact, nor can it be microscopically proved that they affect these bodies chemically. In one single case I have seen earth-algæ (*Zygogonium*-filaments) entangled and attacked by the haustoria of the hyphæ, namely in *Cladonia rangiferina;* otherwise earth-algæ do not appear to be attacked by them. Apical haptera put into the ground I have found in *Cladonia furcata.*

Apical haptera which attach themselves to individuals of the same species, I have observed in *Cladonia crispata, coccifera, rangiformis, rangiferina, Cornicularia aculeata.*

Apical haptera which attach themselves to the podetia of other species, I have found in *Cladonia degenerans, rangiformis, uncialis, rangiferina, Alectoria ochroleuca, Cornicularia aculeata, Bryopogon jubatus* v. *nitidulus.* In none of these cases does the part attacked appear to sustain any damage. The haptera appear to be exclusively organs of attachment, not suckers.

The lateral haptera put into the ground (in *Cladonia gracilis, furcata, rangiformis, uncialis, rangiferina*) are biologically identical with the apical haptera put into the ground.

Lateral haptera between podetia of the same species (in *Cladonia papillaria, crispata, coccifera, Dufourea arctica, muricata, Cladonia gracilis, rangiformis, uncialis, rangiferina, Thamnolia vermicularis, Cornicularia aculeata, Sphærophorus fragilis*) are widely distributed. The cortical layer of the podetia grow mutually together, but the gonidium- and the medullary layers are not at all influenced by this.

A totally different kind of haptera is found in *Siphula ceratites,* where the podetia grow completely together, cortex with cortex, medulla with medulla, etc.; Sernander has described this (1901).

Lateral haptera put into other species (heather, moss and other lichens) I have seen in *Dufourea arctica, Siphula ceratites, Cladonia* *degenerans, uncialis, Thamnolia vermicularis, Cornicularia aculeata, Bryopogon jubatus* v. *nitidulus, Sphærophorus fragilis*; they play exactly the same rôle as do apical haptera put into other species.

Primary-scale haptera I found only in *Cladonia foliacea.* By means of them the primary scales of long duration which die away at the base, are attached to one another; no parasitic relation arises by this attachment.

Podetium-scale haptera I found only in *Cladonia cornuta.* By means of them the podetia are attached to one another, the scales of the one podetium attaching themselves to the wall of another podetium of the same species; no parasitic relation arises by this attachment.

When procumbent podetia are buried in the ground, they die. No species known to me can endure being covered with earth for a long time. First the gonidia appear to die, sometimes after a short period of intense division, which is probably occasioned by the increased dampness. Then the lichen-hyphæ die, the walls, as a rule, turning brown.

The fruticose earth-lichens are propagated in a widely different manner according to their morphological structure. Hypothallus-wanderers very commonly bear fruit, and are propagated, no doubt as a rule, by ascospores. Some of them are propagated far more frequently by soredia, and in that case apothecia are much rarer in them *(Cladonia fimbriata, deformis),* so that in such species there appears to exist a correlation between these two modes of propagation. In others again these two modes of propagation appear to be equally common, a quantity of soredia and apothecia being developed on the same individual. However it requires to be more closely investigated, whether the asci in strongly soredia-bearing individuals are empty, as they frequently are in *Cladonia.*

In the podetium-wanderers propagation takes place in several cases by the breaking off of fragments of podetia which are then carried away by the wind to other places where they form new tufts. This has already been described by Wainio (1898) and afterwards mentioned by Mentz (1900) and Galløe (1913 and 1918).

Species of *Stereocaulon* do not appear to be able to propagate themselves in this way, as podetia-fragments have not yet been observed to put out haptera into the ground. On the other hand, they are often found bearing apothecia.

Of fruticose earth-lichens Iceland has the following: —

Alectoria divergens Ach.
— jubata L.
— nigricans Nyl.
— ochroleuca Nyl.
Cetraria aculeata Fr.
Cladonia amaurocræa.
— bellidiflora.
— cariosa.
— coccifera.
— decorticata.
— fimbriata.
— Floerkeana.
— foliacea.
— furcata.
— gracilis.
Cladonia pityrea.
— pyxidata.
— rangiferina.
— rangiformis.
— turgida.
— uncialis.
— verticillata.
(Polychidium muscicola Sw., dwarf-formed).
Sphærophorus fragilis L.
Stereocaulón condensatum Hoffm.
— incrustatum Flk.
— paschale (L.) Fr.
— tomentosum (Fr.) Th. Fr.
Thamnolia vermicularis Schaer.

These and numerous other species have been specially treated in "Forberedende Undersøgelser" (1913), to which the reader is referred.

## 4. ROCK LICHENS.

When the climatic conditions are favourable to the growth of lichens, a lichen-vegetation may eventually develop on a rocky substratum. But other demands also must be satisfied, namely those which have regard to the physical and chemical conditions of the substratum.

Many different rocky substrata may be distinguished, and some differences in their lichen-vegetation may also be pointed out.

The most important physical conditions are, as far as is known, the following: —

Stahlecker has observed that on stratified rocks lichens first choose those surfaces which are perpendicular to the stratification. How this phenomenon is to be explained is yet unknown but, *à priori*, we might be tempted to believe, that the lichen-hyphæ more easily penetrate the rock parallel with the stratification, than transverse to it (compare with this the fact that wood-lichens are best able to grow parallel with the "fibres" of the wood). Perhaps such surfaces disintegrate also more quickly.

The importance of the chemical conditions are far better known, owing to investigators like Krempelhuber, Fuisting, Steiner, Zukal, Zahlbruckner, Hulth, Bachmann, Fünfstück, Lang, Friederich and Stahlecker.

The researches of these investigators have proved that there is a distinct anatomical difference between lichens from primitive rocks, (silica-lichens), and those from calcareous rocks, (calcareous lichens), although the observers disagree somewhat among themselves as regards the explanation of this phenomenon.

Stahlecker has shown that rocks composed of different kinds of mineral-grains, are affected by the lichens so that the basic grains are the first to be corroded, then the acid. The physical and mineralogical qualities of the mineral-grains are, on the other hand, of no importance. The same author maintains that lichens are able to corrode quartz; this is denied by Bachmann.

On the other hand, how rocks with glassy structure, without distinct, separate grains of mineral matter, as for instance obsidian, the ground-mass in porphyries, pumice, etc., are affected, is not known.

The corrosion must be assumed to take place in part actively on the part of the hyphæ, by their excreting acids. But nothing is known regarding this point.

The degree to which the rock is disintegrated is, as I have shown (1908, p. 300), of great importance, the freshest, recently-bared rock-surfaces being devoid of lichens, while progressive disintegration is accompanied by the presence of crustaceous, foliaceous and fruticose lichens in fixed succession.

As far as my knowledge and that of other investigators goes, I must assume that a floristic difference will be proved to exist in the lichen-vegetation found on different kinds of rock, especially between that found on calcareous and siliceous rocks — a circumstance which is already partially known.

It is thus seen that both floristically and biologically the chemical condition of the substratum is the determining factor, whilst its physical condition appears to be less important (compare above on bark-lichens). But as yet exhaustive lists of lichens from different kinds of rock are wanting, and these alone can give a closer insight into this floristic difference. That species exist which are confined to one particular substratum, for instance lichens which are exclusively "calcareous lichens," is quite certain, but I do not think it has been definitely proved.

Rock-lichens may be divided into three groups: crustaceous, foliaceous and fructicose lichens.

In the crustaceous lichens two sub-groups may be recognized: the epilithic and the endolithic.

The epilithic crustaceous lichens have a hyphal layer devoid of gonidia, which is sunk into the substratum and which corrodes the individual grains of mineral matter. According to A. Friederich this hyphal layer is thin in the silicicolous lichens, and cannot at all be compared, as regards size, with the corresponding tissue in the calcareous lichens. Besides, according to Friederich, it is never furnished with oil-hyphæ or sphæroid-hyphæ; but according to Bachmann, such are said to occur. At any rate, Fünfstück's investigations show that where the same lichen grows both on calcareous and on siliceous rocks, the individuals from the calcareous rocks contain oil, while those from the siliceous rocks do not. Fünfstück, whose results have since been strongly supported by E. Lang's renewed investigations, appears to differ somewhat from Bachmann as regards the occurrence of oil-hyphæ in the silicicolous lichens; this disagreement need not, however, be a fundamental one, as there will probably be various degrees with regard to the oil-contents connected with the larger or smaller amount of lime contained in the rock-species in question. At any rate, it is certainly an undisputable fact that the amount of oil is greatest in the calcareous lichens.

The biological importance of the oil-contents is much contested. Zukal is of opinion — but quite wrongly, according to Fünfstück's investigations, — that the oil is a supply stored for fruit-setting. Hulth also, regards the oil-containing tissue as reservoirs for reserve food-material. Fünfstück shows that there exists no connection between the fruit-setting and the oil-contents, and is of opinion, that the oil is an excretion formed owing to the accumulation of the carbon dioxide, which is set free by the hyphæ penetrating into the calcium carbonate.

As mentioned by Bachmann and Stahlecker the hyphæ affect the mineral grains in various ways. According to Stahlecker they corrode quartz. This is denied by Bachmann. Basic mineral-grains are affected before the acid mineral-grains, according to Stahlecker. When there is a decided cleavage-plane in the mineral-grains (as in mica), the hyphæ, according to Bachmann, follow the direction of the cleavage, whereby the existing cleavages are widened and filled with hyphæ.

The epilithic part of the thallus contains gonidia. It frequently consists of a growing lichen-mycelium produced centrifugally from the centre of germination, bearing on the thallus numerous small, rounded or irregularly angular areas containing gonidia; according to Friederich, these gonidia-areas have come into existence in places where the gonidia (algæ) have accidentally fallen on the lichen-mycelium. According to Stahlecker each area has originally been an independent thallus, which, by coming into contact with similar neighbouring thalli, forms with these a "Gesamtthallus," which may afterwards grow as a unity, starting from a common centre. This interpretation sounds quite incredible, and I think it is very rarely, if ever, in accordance with fact. Can it, on the whole, be understood that these smaller thalli are "independent," as they have all been produced by the same lichen-mycelium?

It is quite another question, whether a group of really independent thalli, produced each from its own ascospore, on meeting, can alter and carry on a joint growth. About this nothing is known, *à priori,* it does not seem very probable.

In reality, these small thallus-patches containing gonidia, mentioned by Stahlecker, must quite naturally be regarded as analogous, for instance, to the primary scales in *Cladonia,* which are also small green gonidia-containing thalli on a common mycelium; or with the exactly corresponding balls of gonidia in numerous crustaceous earth-lichens (*Lecidea alpestris, L. uliginosus,* etc.).

Quite another separation into patches may moreover take place by existing patches splitting asunder into separate parts by growth-tensions (or by drying?) (see "Dan. Lik. Øk.," fig. 19, a, b, c, d).

When the thallus is smooth and non-partitioned, Stahlecker is of opinion that it is an old, formerly partitioned thallus. I cannot believe this interpretation of the condition.

Friederich has found the gonidia-layer of the silicicolous lichens to be thicker than that of the calcareous lichens, Fünfstück has also found this to be the case.

The mode of propagation has been investigated by Beckmann, who found that some species *(Lecanora badia. L. cenisea),* the thalli of which are partitioned, may reproduce by means of detached portions of the thallus, whereas soredia are absent. On the other hand, the partitioned thalli of the *Rhizocarpon* spp. do not appear to be able to reproduce in this way.

Thin, cohering (non-partitioned) thalli do not appear to be able to reproduce in this way. Whether this mode of propagation, on the whole, plays any important part in nature, compared with propagation by spores, I regard as doubtful.

With regard to capacity for competition, the crustaceous lichens have no equals when the surface of the substratum is fresh, i. e. has been recently bared or is non-disintegrated. They cannot, however, live on very recently bared rock; a slight inorganic disintegration must first take place, and then they make their appearance. They themselves contribute towards disintegration whereby they prepare the substratum for other, more pretentious forms (foliaceous and fruticose lichens) and so bring about their own destruction, as mentioned in "Dan. Lik. Øk.," p. 360.

The endolithic crustaceous lichens appear to occur only on calcareous rocks. As an example may be mentioned *Biatora immersa* (Web.) Arn., which is exhaustively treated by Fünfstück. There is in this species a slightly developed epilithic thallus, containing gonidia, which at the base passes over into a more vigorous endolithic thallus, with a great abundance of oil-cells of various forms. There is evidently a certain connection between the great abundance of oil in the thallus, and the chemical nature of the substratum, especially its wealth of carbonates. This class and the calcareous lichens richer in gonidia, that is to say, on the whole, the endolithic and the epilithic species, are connected by a series of intermediate forms; and there is hardly any lichen which is endolithic in the sense that the whole of the thallus is hidden in the substratum and covered over by it. For the rest, there are many points in the natural history of the endolithic lichens, which still remain to be explained. With regard to special modes of propagation, nothing is known.

At the point of transition between crustaceous and foliaceous lichens there stands a group of "placoid" species (Beckmann, 1907), for instance, *Placodium (Lecanora) saxicola, Caloplaca murorum, Dimelæna oreïna*, all of which have along their edges leaf-like thallus-lobes, devoid of cortex on their under surface.

In *Placodium saxicola* there may occasionally be found an indication of a cortical layer on the under surface, when it is growing on a smooth, polished rock-surface (Dan. Lik. Øk., fig. 62, b). Beckmann has shown that the species mentioned here may be propagated by the thallus-lobes becoming detached, and sprouting out into new individuals.

Of crustaceous lichens Iceland has the following species: —

| | |
|---|---|
| Acarospora discreta. | Arthonia ruderalis. |
| — fuscata. | Bacidia caudata. |
| — Heppii. | — coprodes. |

Bacidia milliaria.
— sphæroides.
— subfuscula.
Bæomyces byssoides.
Biatorella Morio.
Buellia æthalea.
— atroalba.
— badia.
— coniops.
— leptocline.
— myriocarpa.
— stellulata.
— tesserata.
— vilis.
Caloplaca aurantiaca.
— cerina.
— citrina.
— diphyes.
— elegans.
— ferruginea.
— murorum.
— pyracea.
— vitellina.
Catillaria athallina.
— lenticularis.
Diploschistes scruposa.
Gyalecta cupularis.
Hæmatomma coccineum.
— ventosum.
Lecania athroocarpa.
Lecanora albescens.
— alphoplaca.
— alpina.
— atra.
— atriseda.
— atrosulphurea.
— badia.
— calcarea.
— cartilaginea.
— chrysoleuca.
— cinerea.
— cinereorufescens.
— coarctata.
— frustulosa.
— gelida.
— gibbosa.
— Hageni.
— lacustris.
— pallescens.
— poliophæa.
Lecanora polytropa.
— saxicola.
— sordida.
— straminea.
— subfusca.
— tartarea.
— varia.
Lecida aglæa.
— arctogena.
— atrobrunnea.
— atrorufa.
— auriculata.
— cinereoatra.
— confluens.
— contigua.
— convexa.
— crustulata.
— cyanea.
— Dicksonii.
— elata.
— elæochroma.
— erratica.
— fuscoatra.
— furvella.
— impavida.
— lapicida.
— lithophila.
— lugubris.
— panæola.
— pantherina.
— paupercula.
— Siebenhaariana.
— speirea.
— subconfluens.
— tenebrosa.
— vernalis.
Lepraria.
Pannaria elæina.
— granatina.
— Hookeri.
— microphylla.
Pertusaria corallina.
— rhodoleuca.
Placynthium nigrum.
Polyblastia Henscheliana.
— hyperborea.
Rhizocarpon alboatrum.
— calcareum.
— geminatum.
— geographicum.

| | |
|---|---|
| Rhizocarpon petræum. | Verrucaria margacea. |
| — viridiatrum. | — mucosa. |
| Staurothele clopima. | — nigrescens. |
| Verrucaria maura. | — rupestris. |

As regards a few of these species it is true that they not only occur on common rocks, but also on disintegrated, bleached bones of various animals, usually on bones of sheep, which are rather commonly found lying out in the open air. With regard to this point further particulars will be found in the table of the chief biological conditions of the different species.

The Foliaceous rock-lichens. The numerous species of *Umbilicaria*, *Gyrophora*, *Parmelia*, etc., may be sub-divided into at least two types, viz. the *Gyrophora*-type and the *Parmelia*-type.

The *Gyrophora*-type *(Gyrophora, Umbilicaria)*, as we know, consists of lichens which are attached to the substratum at a single point on the under surface of the thallus — the "umbilicus". This is the reason why the lichens cannot die away in the centre and form "fairy rings." With regard to absorbtion of food from the substratum, such species are differently conditioned from the *Parmelia*-like-lichens which are attached to the substratum at various points. With regard to capacity for competition, all the species stand very high, as they very easily grow across their competitors. Hence, in many places in Arctic regions, they form, on the rocks, growths very conspicuous and rich in individuals.

The *Parmelia*-type. Its many species are attached to the substratum by numerous rhizines, and die away in the centre, forming "fairy rings," without thereby losing their foothold. This feature is very commonly seen in *Parmelia saxatilis*.

The ordinary anatomical structure has already been long known from the investigations of Schwendener and others. I shall only draw attention to the fact that there are cortical layers on both sides, as also a gonidial and a medullary layer.

The morphological structure still requires much investigation, especially from a biological point of view.

The means of propagation are, in addition to ascospores, in some species soredia also. How widely distributed the latter are, is not known. Propagation by means of detached portions of thallus, does not appear to have been observed in any of the species.

In competition the foliaceous lichens are far superior to the crustaceous lichens, when the substratum has, in some measure, been prepared by the growth of the latter. I have never observed any foliaceous lichens on a quite recently bared surface. The crustaceous lichens appear always to be the first to arrive, and are afterwards succeeded and exterminated by the foliaceous lichens.

Of Foliaceous rock-lichens Iceland has the following: —

| | |
|---|---|
| Cetraria Fahlunensis. | Leptogium plicatile. |
| Collema crispum. | Parmelia alpicola. |
| — flaccidum. | — encausta. |
| — pulposum. | — incurva. |
| Dermatocarpon miniatum. | — lanata. |
| Evernia furfuracea. | — olivacea. |
| Gyrophora arctica. | — physodes. |
| — cylindrica. | — saxatilis. |
| — erosa. | — stygia. |
| — hyperborea. | Physcia aipolia. |
| — murina. | — aquila. |
| — polyphylla. | — caesia. |
| — proboscidea. | Xanthoria lychnea. |
| — vellea. | — parietina. |

The Fruticose lichens are not numerous. As I have previously shown, they rest almost exclusively on a substratum prepared by other lichens, and consequently are not really true rock-lichens, as they are dependent on the peat-formation, which the first inhabitants of the rocks leave behind them on their decay. Consequently, if we investigate more closely such apparently rock-inhabiting species of *Stereocaulon* and others, we shall find under them — not rock — but first a thin layer of peat, and under that, the rock. Consequently, they are in reality earth-lichens.

A few species are, however, undoubtedly true inhabitants of rocks, for instance *Usnea melaxantha, Roccella, Ramalina* and a few *Stereocaulon* spp. They have at their base a permanent thallus, which is thread-shaped *(Usnea)* or ribbon-shaped *(Ramalina)* and isolateral. Formation of haptera between the individuals (see under earth-lichens) is unknown, and would appear also to be rather superfluous, as they do not die away at the base. Consequently, as regards these two points, they appear to differ greatly from their fruticose relatives among the earth-lichens, — which is quite in harmony with the different substratum.

Special modes of propagation — by detached portions of thallus, etc., are not known.

With regard to competitive capability the fruticose lichens generally stand very high. In Denmark species of *Ramalina* can form continuous, almost pure growths on rocks (*Ramalina*-belt) on the cliffs of Bornholm. Species of *Roccella* appear to form similar carpets on the cliffs of the sub-tropical and perhaps tropical regions.

Of Fruticose rock-lichens the following are found in Iceland: —

Alectoria ochroleuca.
Coenogonium ebeneum.
Ephebe pubescens.
Lichina confinis.
Racodium rupestre.
Ramalina scopulorum.
— subfarinacea.
Sphærophorus coralloides (?).
— fragilis (?).
Stereocaulon coralloides (?).
— denudatum.
— evolutum.
Usnea melaxantha.

With regard to these it should be remarked that it is somewhat doubtful how far *Racodium* and *Coenogonium* should, on the whole, be reckoned among the fruticose lichens; they have a thread-shaped, somewhat procumbent-ascending thallus. Also a query has been placed against several of the other species, to indicate that it is doubtful whether they are true rock-lichens occurring on bare rock because, at any rate when older, they are rarely, in fact very rarely, attached to the rocky substratum.

## 5. SYNOPSIS OF THE CHIEF BIOLOGICAL CONDITIONS OF THE LICHENS OF ICELAND.

| Names | Bark-lichens | Epiphyllous lichens | Earth-lichens | Rock-lichens | Propagation by | | | Thallus | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Ascospores | Soredia | Thallus fragments | Crust-like | Leaf-like | Shrub-like |
| Acarospora discreta | | | | + | + | | | + | | |
| — fuscata | | | | + | + | | | + | | |
| — Heppii | | | | + | + | | | + | | |
| Alectoria divergens | | | + | | + | | | | | + |
| — jubata | | | + | | | | | | | + |
| — nigricans | | | + | | | | | | | + |
| — ochroleuca | | | + | + | + | | | | | + |
| Arthonia proximella | + | | | | + | | | + | | |
| — punctiformis | + | | | | + | | | + | | |
| — ruderalis | | | | + | + | | | + | | |
| Arthopyrenia analepta | + | | | | + | | | + | | |
| — grisea | + | | | | + | | | + | | |
| Bacidia abbrevians | + | | | | + | | | + | | |

| Names | Bark-lichens | Epiphyllous lichens | Earth-lichens | Rock-lichens | Propagation by: Ascospores | Propagation by: Soredia | Propagation by: Thallus fragments | Thallus: Crust-like | Thallus: Leaf-like | Thallus: Shrub-like |
|---|---|---|---|---|---|---|---|---|---|---|
| Bacidia arceutina | + | | + | | + | | | + | | |
| — atrosanguinea | + | | | | + | | | + | | |
| — Beckhausii | + | | | | + | | | + | | |
| — caudata | | | + | + | + | | | + | | |
| — coprodes | | | | + | + | | | + | | |
| — flavo-virescens | | | + | | + | | | + | | |
| — herbarum | | | + | | + | | | + | | |
| — milliaria | | | + | + | + | | | + | | |
| — obscurata | | | + | | + | | | + | | |
| — rubella | + | | | | + | | | + | | |
| — sphæroides | + | | | + | + | | | + | | |
| — squalescens | | | + | | + | | | + | | |
| — subfuscula | | | | + | + | | | + | | |
| — umbrina | | | | + | + | | | + | | |
| Bæomyces byssoides | | | + | + | + | | | + | | |
| — placophyllum | | | + | | + | | | + | | |
| Biatorella Morio | | | | + | + | | | + | | |
| Buellia æthalea | | | | + | + | | | + | | |
| — atroalba | | | | + | + | | | + | | |
| — badia | | | | + | + | | | + | | |
| — coniops | | | | + | + | | | + | | |
| — leptocline | | | | + | + | | | + | | |
| — myriocarpa | + | | | + | + | | | + | | |
| — parasema | + | | + | | + | | | + | | |
| — scabrosa | | | + | | + | | | + | | |
| — stellulata | | | | + | + | | | + | | |
| — tesserata | | | | + | + | | | + | | |
| — vilis | | | + | | + | | | + | | |
| Caloplaca aurantiaca | | | | + | + | | | + | | |
| — cerina | + | | + | + | + | | | + | | |
| — citrina | + | | | + | + | | | + | | |
| — diphyes | | | | + | + | | | + | | |
| — elegans | | | | + | + | | | + | | |
| — ferruginea | + | | | + | + | | | + | | |
| — Jungermanniæ | | | + | | + | | | + | | |
| — murorum | | | | + | + | | | + | | |
| — nivalis | | | + | | + | | | + | | |
| — obscurella | + | | | | + | | | + | | |
| — pyracea | + | | | + | + | | | + | | |
| — tetraspora | | | + | | + | | | + | | |
| — vitellina | + | | + | + | + | | | + | | |
| Catillaria athallina | | | | + | + | | | + | | |

| Names | Bark-lichens | Epiphyllous lichens | Earth-lichens | Rock-lichens | Propagation by | | | Thallus | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Ascospores | Soredia | Thallus fragments | Crust-like | Leaf-like | Shrub-like |
| Catillaria cumulata | | | | + | + | | | + | | |
| — Jemtlandica | | | + | | + | | | + | | |
| — lenticularis | | | | + | + | | | + | | |
| Cetraria aculeata | | | + | | + | | | | | + |
| — cucullata | | | + | | + | | ? | | + | |
| — Fahlunensis | | | | + | + | | ? | | + | |
| — hiascens | | | + | | + | | ? | | + | |
| — nivalis | | | + | | + | | ? | | + | |
| — sæpincola | + | | | | + | | ? | | + | |
| Cladonia amaurocræa | | | + | | + | | | | | + |
| — bellidiflora | | | + | | + | | ? | | | + |
| — cariosa | | | + | | + | | ? | | | + |
| — coccifera | | | + | | + | | ? | | | + |
| — decorticata | | | + | | + | + | ? | | | + |
| — fimbriata | | | + | | + | + | ? | | | + |
| — Floerkeana | | | + | | + | + | ? | | | + |
| — foliacea | | | + | | + | | ? | | + | + |
| — furcata | | | + | | + | | + | | | + |
| — gracilis | | | + | | + | | + | | | + |
| — pityrea | | | + | | + | + | ? | | | + |
| — pyxidata | | | + | | + | | ? | | | + |
| — rangiferina | | | + | | + | | + | | | + |
| — rangiformis | | | + | | + | | + | | | + |
| — turgida | | | + | | + | | + | | | + |
| — uncialis | | | + | | + | | + | | | + |
| — verticillata | | | + | | + | | ? | | | + |
| Coenogonium ebeneum | | | | + | + | | | | | + |
| Collema crispum | | | + | + | + | | | | + | |
| — flaccidum | + | | | + | + | | | | + | |
| — nigrescens | + | | | | + | | | | + | |
| — pulposum | | | + | + | + | | | | + | |
| — verrucæforme | | | + | | + | | | | + | |
| Coniocybe furfuracea | + | | | | + | | | + | | |
| Dermatocarpon cinereum | | | + | | + | | | | + | |
| — hepaticum | | | + | | + | | | | + | |
| — miniatum | | | | + | + | | | | + | |
| — rufescens | | | + | | + | | | | + | |
| Diploschistes scruposus | + | | | + | + | | | + | | |
| Ephebe pubescens | | | | + | + | | | | | + |
| Evernia furfuracea | + | | | + | + | | | | + | |
| Gyalecta cupularis | | | + | + | + | | | + | | |
| — foveolaris | | | + | | + | | | + | | |

| Names | Bark-lichens | Epiphyllous lichens | Earth-lichens | Rock-lichens | Propagation by Ascospores | Soredia | Thallus fragments | Thallus Crust-like | Leaf-like | Shrub-like |
|---|---|---|---|---|---|---|---|---|---|---|
| Gyrophora arctica | | | | + | + | | | | + | |
| — cylindrica | | | | + | + | | | | + | |
| — erosa | | | | + | + | | | | + | |
| — hyperborea | | | | + | + | | | | + | |
| — murina | | | | + | + | | | | + | |
| — polyphylla | | | | + | + | | | | + | |
| — proboscidea | | | | + | + | | | | + | |
| — vellea | | | | + | + | | | | + | |
| Hæmatomma coccineum | | | | + | + | + | | + | | |
| — ventosum | | | | + | + | ? | | + | | |
| Lecania athroocarpa | + | | | + | + | | | + | | |
| — cyrtella | + | | | | + | | | + | | |
| Lecanora albescens | | | | + | + | | | + | | |
| — alphoplaca | | | | + | + | | | + | | |
| — alpina | | | | + | + | | | + | | |
| — atra | + | | | + | + | | | + | | |
| — atriseda | | | | + | + | | | + | | |
| — atrosulphurea | | | | + | + | | | + | | |
| — badia | | | | + | + | | | + | | |
| — calcarea | | | | + | + | | | + | | |
| — cartilaginea | | | | + | + | | | + | | |
| — castanea | | | + | | + | | | + | | |
| — chrysoleuca | | | | + | + | | | + | | |
| — cinerea | | | | + | + | | | + | | |
| — cinereorufescens | | | | + | + | | | + | | |
| — coarctata | | | | + | + | | | + | | |
| — frustulosa | | | | + | + | | | + | | |
| — gelida | | | | + | + | | | + | | |
| — gibbosa | | | | + | + | | | + | | |
| — Hageni | + | | + | + | + | | | + | | |
| — lacustris | | | | + | + | | | + | | |
| — pallescens | + | | + | + | + | | | + | | |
| — poliophæa | | | | + | + | | | + | | |
| — polytropa | + | | | + | + | | | + | | |
| — protuberans | | | | + | + | | | + | | |
| — saxicola | | | | + | + | | | + | | |
| — sordida | | | | + | + | | | + | | |
| — straminea | | | | + | + | | | + | | |
| — subfusca | + | | + | + | + | | | + | | |
| — tartarea | + | | + | + | + | | | + | | |
| — varia | + | | + | + | + | | | + | | |
| Lecidea aglæa | | | | + | + | | | + | | |

| Names | Bark-lichens | Epiphyllous lichens | Earth-lichens | Rock-lichens | Propagation by | | | Thallus | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Ascospores | Soredia | Thallus fragments | Crust-like | Leaf-like | Shrub-like |
| Lecidea alpestris | | | + | | + | | | | | |
| — arctica | | | + | | + | | | + | | |
| — arctogena | | | | + | + | | | + | | |
| — assimilata | | | + | | + | | | + | | |
| — atrobrunnea | | | | + | + | | | + | | |
| — atrorufa | | | + | + | + | | | + | | |
| — auriculata | | | | + | + | | | + | | |
| — Berengeriana | | | + | | + | | | + | | |
| — cinereoatra | | | | + | + | | | + | | |
| — confluens | | | | + | + | | | + | | |
| — contigua | | | | + | + | | | + | | |
| — convexa | | | | + | + | | | + | | |
| — crassipes | | | + | | + | | | + | | |
| — crustulata | + | | | + | + | | | + | | |
| — cuprea | | | + | | + | | | + | | |
| — cyanea | | | | + | + | | | + | | |
| — decipiens | | | + | | + | | | + | | |
| — decolorans | | | + | | + | | | + | | |
| — Diapensiæ | | | + | | + | | | + | | |
| — Dicksonii | | | | + | + | | | + | | |
| — elata | | | | + | + | | | + | | |
| — elæochroma | + | | + | + | + | | | + | | |
| — erratica | | | | + | + | | | + | | |
| — erythrophæa | + | | | | + | | | + | | |
| — fusca | | | + | | + | | | + | | |
| — fuscescens | + | | | | + | | | + | | |
| — fuscoatra | | | | + | + | | | + | | |
| — furvella | | | | + | + | | | + | | |
| — granulosa | | | + | | + | | | + | | |
| — helvola | + | | | | + | | | + | | |
| — impavida | | | | + | + | | | + | | |
| — lapicida | | | + | | + | | | + | | |
| — limosa | | | + | | + | | | + | | |
| — lithophila | | | | + | + | | | + | | |
| — lugubris | | | | + | + | | | + | | |
| — lurida | | | + | | + | | | + | | |
| — neglecta | | | + | | + | | | + | | |
| — Nylanderi | + | | | | + | | | + | | |
| — panæola | | | | + | + | | | + | | |
| — pantherina | | | | + | + | | | + | | |
| — paupercula | | | | + | + | | | + | | |
| — rubiformis | | | + | | + | | | + | | |

| Names | Bark-lichens | Epiphyllous lichens | Earth-lichens | Rock-lichens | Propagation by: Ascospores | Propagation by: Soredia | Propagation by: Thallus fragments | Thallus: Crust-like | Thallus: Leaf-like | Thallus: Shrub-like |
|---|---|---|---|---|---|---|---|---|---|---|
| Lecidea ramulosa | | | + | | + | | | + | | |
| — Siebenhaariana | | | | + | + | | | + | | |
| — speirea | | | | + | + | | | + | | |
| — subconfluens | | | | + | + | | | + | | |
| — tenebrosa | | | | + | + | | | + | | |
| — Tornoënsis | + | | | | + | | | + | | |
| — uliginosa | | | + | | + | | | + | | |
| — vernalis | | | + | + | + | | | + | | |
| Lepraria | + | | + | + | | | | + | | |
| Leptogium lacerum | | | + | | + | | | | + | |
| — plicatile | + | | | + | + | | | | + | |
| — scotinum | | | + | | + | | | | + | |
| Lichina confinis | | | | + | + | | | | | + |
| Lopadium fuscoluteum | | | + | | + | | | + | | |
| — pezizoideum | | | + | | + | | | + | | |
| Massalongia carnosa | | | + | | + | | | + | | |
| Microthelia micula | + | | | | + | | | + | | |
| Microglæna sphinctrinoides | | | + | | + | | | + | | |
| Nephroma arcticum | | | + | | + | | | | + | |
| — expallidum | | | + | | + | | | | + | |
| — lævigatum | + | | | | + | | | | + | |
| — tomentosum | + | | + | | + | | | | + | |
| Pannaria brunnea | | | + | | + | | | + | | |
| — elæina | | | | + | + | | | + | | |
| — granatina | | | | + | + | | | + | | |
| — Hookeri | | | | + | + | | | + | | |
| — lepidiota | | | + | | + | | | + | | |
| — microphylla | | | + | + | + | | | + | | |
| — triptophylla | + | | | | + | | | + | | |
| Parmelia alpicola | | | | + | + | | | | + | |
| — ambigua | + | | | | + | + | | | + | |
| — encausta | | | | + | + | | | | + | |
| — incurva | | | | + | + | + | | | + | |
| — lanata | | | + | + | + | | | | + | |
| — olivacea | + | | | + | + | | | | + | |
| — physodes | + | | | + | + | + | | | + | |
| — saxatilis | + | | | + | + | + | | | + | |
| — stygia | | | + | | + | | | | + | |
| Peltigera aphtosa | | | + | | + | | | | + | |
| — canina | | | + | | + | | | | + | |
| — horizontalis | | | + | | + | | | | + | |
| — lepidophora | | | + | | + | | | | + | |

| Names | Bark-lichens | Epiphyllous lichens | Earth-lichens | Rock-lichens | Propagation by | | | Thallus | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Ascospores | Soredia | Thallus fragments | Crust-like | Leaf-like | Shrub-like |
| Peltigera malacea | | | + | | + | | | | + | |
| — polydactyla | | | + | | + | | | | + | |
| — rufescens | | | + | | + | | | | + | |
| — venosa | | | + | | + | | | | + | |
| Pertusaria communis | + | | | | + | | | + | | |
| — corallina | | | | + | + | | | + | | |
| — coriacea | | | + | | + | | | + | | |
| — dactylina | | | + | | + | | | + | | |
| — oculata | | | + | | + | | | + | | |
| — rhodoleuca | | | | + | + | | | + | | |
| — xanthostoma | + | | | | + | | | + | | |
| Physcia aipolia | | | | + | + | | | | + | |
| — aquila | | | | + | + | | | | + | |
| — cæsia | | | | + | + | | | | + | |
| — ciliaris | + | | | | + | | | | + | |
| — obscura | + | | | | + | + | | | + | |
| — pulverulenta | | | + | | + | | | | + | |
| — stellaris | + | | | | + | + | | | + | |
| Placynthium delicatulum | | | + | | + | | | + | | |
| — nigrum | | | | + | + | | | + | | |
| Polyblastia Henscheliana | | | | + | + | | | + | | |
| — hyperborea | | | | + | + | | | + | | |
| Polychidium muscicola | | | + | | + | | | | | + |
| Psoroma hypnorum | | | + | | + | | | | + | |
| Racodium rupestre | | | | + | + | | | + | | |
| Ramalina scopulorum | | | | + | + | | | | | + |
| — subfarinacea | | | | + | + | | | | | + |
| Rhizocarpon alboatrum | | | | + | + | | | | | + |
| — calcareum | | | | + | + | | | + | | |
| — geminatum | | | | + | + | | | + | | |
| — geographicum | | | | + | + | | | + | | |
| — petræum | | | | + | + | | | + | | |
| — viridiatrum | | | | + | + | | | + | | |
| Rinodina Conradi | | | + | | + | | | + | | |
| — mniaræa | | | + | | + | | | + | | |
| — sophodes | + | | | | + | | | + | | |
| — turfacea | | | + | | + | | | + | | |
| Solorina bispora | | | + | | + | | | | + | |
| — crocea | | | + | | + | | | | + | |
| — saccata | | | + | | + | | | | + | |
| Sphærophorus coralloides | | | | + | + | | | | | + |
| — fragilis | | | + | + | + | | | | | + |

| Names | Bark-lichens | Epiphyllous lichens | Earth-lichens | Rock-lichens | Propagation by: Ascospores | Propagation by: Soredia | Propagation by: Thallus fragments | Thallus: Crust-like | Thallus: Leaf-like | Thallus: Shrub-like |
|---|---|---|---|---|---|---|---|---|---|---|
| Staurothele clopima | | | | + | + | | | + | | |
| Stereocaulon condensatum | | | + | | + | | | | | + |
| — coralloides | | | | + | + | | | | | + |
| — denudatum | | | | + | + | | | | | + |
| — evolutum | | | | + | + | | | | | + |
| — incrustatum | | | + | | + | | | | | + |
| — paschale | | | + | | + | | | | | + |
| — tomentosum | | | + | | + | | | | | + |
| Sticta scrobiculata | + | | | | + | | | | + | |
| Thamnolia vermicularis | | | + | | | | + | | | + |
| Toninia squalida | | | + | | + | | | + | | |
| — syncomista | | | + | | + | | | + | | |
| — vesicularis | | | + | | + | | | + | | |
| Usnea melaxantha | | | | + | ? | | ? | | | + |
| Verrucaria maura | | | | + | + | | | + | | |
| — margacea | | | | + | + | | | + | | |
| — mucosa | | | | + | + | | | + | | |
| — nigresens | | | | + | + | | | + | | |
| — rupestris | | | | + | + | | | + | | |
| Xanthoria lychnea | + | | | + | + | | | | + | |
| — parietina | + | | | + | + | | | | + | |

# IV. THE CLASSIFICATION OF THE LICHENS INTO ASSOCIATIONS.

## 1. BARK-LICHEN ASSOCIATION. EPIPHYTIC-LICHEN ASSOCIATION (BARK-LICHENS).

In Iceland there is only one kind of tree which bears a lichen-vegetation worth mentioning, viz. the birch, *Betula odorata.*

This, like all other kinds of trees, runs through a fixed development as regards its lichen-vegetation, as I have formerly shown in my treatise "Danske Likeners Økologi" (1908). When quite young it is devoid of lichens, after which crustaceous lichens make their appearance, and later on foliaceous, and eventually fruticose lichens.

The bark of the birch, as is well-known, is smooth and arranged in layers; it contains plenty of birch-resin which helps to preserve it, so that it is but slightly liable to decomposition and rotting; it is especially for this reason that it is used for covering wooden houses, for soles of boots, etc.

When the trunks become old, the bark bursts and is thrown off in thin sheets, and at the foot of the trunk more or less distinctly radial cracks are formed in the bark, so that the bark becomes "scaly" in that part. Moreover, fissures, wounds from fallen-off branches, and cracks due to old lenticels, etc., are abundantly formed on the persistent parts of the bark.

Generally, the rule holds good that the lichen-vegetation begins on damaged, rough bark, in bark-cracks, lenticels, etc., while the smooth, undamaged bark is devoid of lichens.

As is well-known birches form coppices of very varying extent in Iceland. The highest are found in Hallormstaðskogur (see Thoroddsen's fig. 36 in Part I of this work) and in South Iceland, while the coppices of North Iceland are of lower growth (Hálsskogur, etc.). I myself have unfortunately seen the coppices of North Iceland only.

The light-conditions in almost all the coppices are favourable enough for lichen-vegetation, in that the foliage of the birch casts a very light shade, and the trees stand a fair distance apart. Lichens are also frequently found on the ground under the trees.

The wood-floor is sometimes occupied by heather-moor, sometimes by grass- or moss-vegetation. But a "herb-vegetation" (i. e. a vegetation in which dicotyledonous flowering-plants are dominant) may also occur.

In Hálsskogur the bottom, which is of fine sand, is covered by a carpet consisting af grass, dwarf-birches, *Vaccinium uliginosum*, *Empetrum*, *Rubus* and *Galium*, with here and there intervening patches bare of vegetation covered with fallen birch-leaves. The trees stand close together, are 1—3 metres high, and the stems are thin, being 8—10 cm. in diameter; the bark is smooth. Both the wood-floor and the trees are devoid of lichens. This is probably due, as regards the bottom, to the too great competition of other plants, while as regards the bark, it is undoubtedly due to its not being sufficiently decomposed.

On the road between Háls and Einarstaðir (North Iceland) I passed by a coppice, quite similar in appearance, where the stems were below or about the height of a man, and devoid of lichens, while the ground, in only one spot, bore some *Cladonia pityrea*.

In some places, according to H. Jónsson's observations, a rich vegetation of lichens occurs on birches, for instance in South Iceland, and probably also in other places, where the birches are old enough to have decomposed bark. Thus, there is frequently found a rich vegetation of

Parmelia olivacea v. aspidota.
Biatora Tornoënsis.
Lecanora symmicta.
Pertusaria xanthostoma.
Lecanora protuberans.

There is also found a rich lichen-vegetation on the dead top shoots of birches.

Deichmann Branth (D. B., 1903, p. 198) has compiled a list of more than 34 species, which have been found on Icelandic birches, namely the following: —

Cladonia pyxidata.
Cetraria sæpincola.
Parmelia olivacea.
Placodium ferrugineum.
P. vitellinum v. octosporum.
Lecanora hypnorum.
Lecanora subfusca (with var. coilocarpa, albella, glabrata, rugosa).
L. varia (with var. symmicta).
L. protuberans.
L. verrucosa.
Pertusaria communis.

Pertusaria xanthostoma.
Urceolaria sophodes v. orbata.
— exigua.
Lecidea vernalis.
— erythrophæa.
— Berengeriana.
— Tornoënsis.
— fuscescens.
— Nylanderi.
Lecidea enteroleuca (with var. Laureri).
Gyalecta Beckhausii.
Buellia myriocarpa.
Arthonia proximella.
Sagedia analepta.
— grisea.
— kentrospora.
Pyrenula micula.

If we compare the birches of Iceland and Denmark with reference to their lichen-vegetation, a characteristic difference will be seen as regards the species. In Denmark *Evernia Prunastri, E. furfuracea, Cetraria glauca, Usnea barbata* and *Ramalina fastigiata* form the dominant feature of the vegetation. In Iceland they do not appear to be of any importance, or are quite absent. The number of the species is greater in Iceland, yet I cannot depend upon this not being due to insufficient investigation of the birches of Denmark.

How the matter stands as regards "mass-occurrence" and "frequency-number" in Iceland and Denmark, I am not prepared to say, because, as I have already mentioned, I myself have not seen lichen-bearing birches in Iceland.

## 2. THE EARTH-LICHEN ASSOCIATIONS.

In the previous pages we have made a survey of the general biology of the earth lichens. Here we shall consider more closely the special Icelandic conditions, viz. the characteristic qualities of the Icelandic soil, and, finally, the lichen vegetation found in the plant-associations.

In a preceding part of this work Professor Thoroddsen has given an exhaustive description of the Icelandic soil, and of its geological and agricultural qualities. To this I refer the reader, and it will suffice here merely to point out such features of it as are of importance to the lichen-vegetation.

As stated by Thoroddsen, the Icelandic soil consists entirely of a finely divided mass, derived from the fundamental rock of the island, or of the same chemical and mineralogical composition as the latter. In other words it is the Basalt, in grains of every possible size, ranging from enormous blocks of rock to particles as fine as dust, which constitutes the soil available to the lichens all over Iceland. The liparite which occurs here and there is, according to Thoroddsen, of no importance as far as soil-formation is concerned.

Consequently, whether the soil is of the one or the other geological origin — glacial soil, or soil deposited in water, or deposited by wind, (aeolian deposits) — its chemical or mineralogical composition is essentially the same in all cases.

The circumstances which are of importance, regarding the soil as a lichen-substratum are therefore essentially the following: — (1) The chemical composition (mineral earth or earth rich in humus), (2) the size of the grains, (3) thermal conditions, (4) the water-contents, (5) drifting soil, (6) burrowing animals, (7) leaf-fall, (8) and the snow-covering.

To these must be added, what is perhaps the most important, (9) competitive relations with other plants.

(1) The chemical composition of the loose soil is, as a whole, somewhat different in Iceland from that in Denmark, as was first pointed out by P. Feilberg (see Thoroddsen, in vol. I, p. 252, of the present work). With regard to the amount of nutrition present, the difference is doubtless of very little consequence as regards lichens. On the other hand, it is indirectly a highly important fact, that the great amount of iron-salts and humus characteristic of the soil of Iceland, conditions a plant-growth which, taken as a whole, is very widely different from that of Denmark, and causes a competition among the plant-species which is highly conducive to the wide distribution of lichens all over Iceland.

(2) The size of the grains (fineness, respective coarseness) of the soil is, as mentioned above, hardly of any direct importance, but no doubt of indirect importance by being the means of bringing about various conditions of heat and moisture in the finer and coarser kinds of soil.

(3) The thermal conditions are far more unfavourable in Iceland than in Denmark, far greater tracts of ground being frozen, during a greater part of the year. As long as the upper soil-layers are frozen, the plant-covering also will frequently be thoroughly chilled, and the lichens will therefore lie dormant. On the other hand, it hardly has a direct influence upon the lichens if the ground is frozen farther down, as they are attached to the ground only very superficially, frequently only a few millimetre at the uppermost part near the surface. Quite another and far greater but indirect rôle is played by the frozen ground, owing to the fact

that the conditions of moisture are essentially dependent upon it. When the ground thaws in spring, there is a time in which the upper soil-layers are, for the time being, very wet, because the melting snow and ice cannot sink into the ground, owing to the sub-surface ice. We may be justified in saying that, taken as a whole, the yearly growth-period as compared, for instance, with that in Denmark, is considerably shortened by the low temperature of the soil. How long this period lasts, upon the whole, as regards the lichens, which, as we know, assimilate as soon as the temperature is above freezing-point, has not been investigated. But I assume that it is far shorter than in Denmark, where it lasts almost all the year round.

(4) The water-contents of the soil in Iceland, owing to the great amount of precipitation and the slight evaporation, are far greater than in Denmark. In the surface features of the landscape this is shown by the frequent occurrence of bogs. But, naturally, there is a great difference in the amount of water contained in the various soils, all conditions being found intermediate between boggy soil saturated with water, and dry sandy soil, and soil fine as dust which is so dry in numerous places that it drifts with the wind at every opportunity. The wettest soil, which is continually saturated with water (the bogs), is devoid of lichens; this is also the case with the driest, drifting soil, not on account of its dryness — for it is well-known that lichens chiefly imbibe directly-precipitated moisture, and are fairly independent of other water-supplies, — but on account of the unstability of the drifting soil. Lichens grow on soil intermediate, with regard to dampness, between these two extremes; they grow in association with other plants, as will be fully described below.

(5) All drifting soil is devoid of lichens.

(6) The rôle which burrowing animals play in Iceland is not known very particularly; it is however in all probability quite insignificant, while in Denmark, as is well-known, it is very great, especially in the woods.

(7) Leaf-fall. The layer of decaying leaves which in Denmark, during autumn, buries all the small plants of the wood-floor, plays, as a matter of course, a similar rôle in Iceland. When the trees or the shrubs (willow, birch) stand very close, the ground is frequently devoid of lichens, and this is no doubt partially due to this leaf-covering.

(8) The snow-covering has a very great influence, especially in the mountains. Where there is a perpetual snow-covering, lichens naturally cannot live. But lichens can live even on soil which is free from snow for only a few weeks during the summer. Thus I observed in several places on the mountains around Öfjord that lichens grew abundantly at considerable elevations, which are not freed of snow until July. Taken as a whole it may be said, that the snow-covering in Iceland, by shortening the annual growth-period, plays a far greater rôle than it does in Denmark.

(9) The competitive relations with other plants are, on the whole, more favourable to the lichens in Iceland than in Denmark, because the higher plants — in consequence of the soil and climate — are not generally of so quick a growth there as in Denmark; but this I must naturally discuss more fully under each particular plant-association. For the present I shall only point out that the lichen-vegetation in Iceland plays physiognomically a more dominant rôle than in Denmark, more particularly because the competition on the part of other plants is not so keen there as it is in the more temperate regions.

The combined result of all the factors, climatic and edaphic, which we have been considering above, shows itself in the form of plant-associations as they occur in nature. I shall therefore go through these one by one, and, as far as our present knowledge of the subject makes it possible, occupy myself more closely with what has given them their appearance.

With regard to the plant-associations of loose soil, it is difficult to carry out any single logical systematization — merely to find proper names for them, such as are characteristic and to the point, is difficult. To do this we can proceed in any one of three essentially different ways: we can (1) name the association after the soil (e. g. "sandy shore," "dunes," etc.), or (2) after the conspicuous, dominant plants found therein (e. g. "beech wood," "birch coppice," etc.), or lastly (3) we may combine these two, as ecologists frequently do, and as people do in common language, naming some associations after the characteristic features of the soil, and others after conspicuous, characteristic plants.

In reality it is extremely difficult to decide upon one of these methods in particular, for the following reasons: If there existed absolute agreement as regards a fixed terminology for the naming of the different kinds of soil, and in addition, if it were possible, out in the field, immediately to identify to which category the soil belonged which supported the association we were just then investigating, then it would be an excellent method consistently to name the association after the soil. But this cannot be done, owing to the nature of the subject. There does not exist, and will hardly ever be created, any descriptive soil-term, which will win universal acceptance. Nor will it ever be possible, out in the field to identify each kind of soil with any certainty. This requires thorough chemical and physical investigations, which must be made in the laboratory.

It appears to be far easier to name the association after the dominant plants, — when such occur. A beech wood is easy to recognize as such, but a "fell-field" (rocky-flat) a "mat-herbage" (herb-flat) which are not characterized by any one individual species, how are we to know them?

Here we find ourselves in reality placed before a fundamental question in ecology, — the definition and naming of the plant-association: partly, how we shall precisely define the individual association, so that it is recognizable wherever it may be met with on the surface of the earth, and may be determined, at any rate, with as great certainty as we determine a systematic species: and partly, how we shall name it, after the soil, or after dominant species of plant, or perhaps after dominant "growth-forms" (see Warming and Raunkiær).

On this question, first and foremost the founder of ecology, E. Warming, and afterwards C. Raunkiær, have contended that the associations ought to be analyzed with regard to "growth-forms," so that we may thereby define them. What we shall afterwards call them is a point of less importance, as different names for the same association may be used synonymously, even although a uniform nomenclature would facilitate the survey considerably when we are occupying ourselves with the systematising of the associations.

Which classification of the growth-forms of the plant-world we are to use, must be dependent on the object we have in view in the investigation of the associations. In itself there is nothing to prevent our using several different classifications in the same investigation, for instance, we could enumerate the "geophytes," "hemicryptophytes," "chamæphytes," etc. (according to Raunkiær's classification), or the "summer-annuals," "cæspitose plants," "creeping-herbs," "shrubs," etc., etc. (according to Warming's classification).

It is in reality a hopeless task to try to describe a plant-association without such an analysis. I have experienced this, time after time, during my studies in Iceland when, in my notes, I was to give a name to an association. I was often uncertain as to how far I was now using the old, long-established terms "heaths," "fell-fields," "mat-herbages," etc., etc., with exactly the same meaning as the creators of these terms themselves gave to them. I did my best to use the correct terms, but I cannot deny that it often occurred to me, that it would have been much easier if the terms had been defined somewhat more precisely. For instance, had the term "heath" been defined as a plant-association in which dwarf shrubs or chamæphytes had a definite degree of frequency, it would have been far easier for me to have recognized the association in question, in the field: also remembering the fact, that the same association may perhaps be named sometimes in one way, and sometimes in another, according as the investigator in question received a more strong, subjective impression of this or the other species: It is possible that a lichenologist would occasionally speak of a "lichen-heath," which a bryologist would call a "moss-heath," and a phanerogamologist an "*Empetrum*-heath"!

I see no other solution of the difficulty than that the investigator — be he bryologist, lichenologist, algologist, phanerogamologist or what else, should define the association, as far as possible, from his own point of view, and then afterwards eventually agree upon how the whole association is to be named, and how the divergent names given by the investigators, may be reconciled with one another.

In the following pages I shall define the associations according to the dominant growth-forms. I shall go through the chief plant-associations, adopting in the main the division briefly given by Thoroddsen in this work (vol. I, pp. 317 et seq.), from which, however, in some points I shall differ.

Besides this analysis of the association as regards the various growth-forms it contains, there are several other matters which will be discussed, first among which comes the mass-occurrence of the different species, or growth-forms, contained in the association.

Various methods have been used for this purpose; they have been described and compared by C. Ferdinandsen (1918). Their value varies greatly, and at the outset we may say that, for an exhaustive description, it is necessary to use several methods. Nature is too many-sided to be described in a few words, or by tabular methods.

Among the chief methods may be mentioned Raunkiær's valency-method (Raunkiær, 1916) which consists in the following: In an association a number of equally large sample-areas (e. g. $^1/_{10}$ square metre) are demarcated, with equally large intermediate spaces between them, and the vegetation in them is investigated. Any plant-species (or any growth-form) which occurs in all the sample-areas is said to have the frequency-percentage (F. $^0/_0$) 100, in half of the samples F. $^0/_0$ 50, etc.

By means of this method an idea is obtained of the frequency of the occurrence of the species (or growth-form) in the association.

Investigators have also tried to express by figures the size of the space occupied by each single species, (or growth-form) in the area of the association; the mode of procedure is similar to that used in the determination of frequency, in so far that samples are taken, the area occupied by every single species in the sample is determined, and on the basis of this, the total amount of area occupied by the species in the whole association, is calculated. Lagerberg, Raunkiær, H. E. Petersen and C. Ferdinandsen recommend and employ this method (see these authors in the Bibliography).

It is evident that it is very much to be wished, that we could give figures, which would be reliable for the areas occupied by the individual species. In the mean time it must be said, that the attempts made by the above-mentioned authors, to make such calculations, have proved an utter failure, and are quite worthless although, unfortunately, we must expect the method to be in vogue for some time, and to be employed by others.

The unreliability of the results obtained by this method, is due to the following fact: Even if we take a sample, ever so small, it is impossible to decide with any certainty how large a part of it is occupied by this or that species, unless it actually happens that only one species occurs in the sample. As soon as there are several species more or less entangled in each other, the conditions pertaining to the space occupied, are incapable of accurate description. How are we to determine, for instance, in a Danish *Calluna*-heath, how much of a sample is occupied by *Calluna,* and how much by the reindeer moss entangled with it. The task is simply impossible, the question cannot be answered. The fact cannot be emphasized too sharply, that the figures which have hitherto been given for the areas occupied, and which have been obtained by the method of the above-mentioned authors, do not at all possess the numerical, the mathematical authority which numbers ought to have in order to be useful for purposes of statistical comparison. They are in short an illusion.

Add to this, that even if the figures for the area occupied could be fixed fairly accurately, that would not give us any great knowledge of the abundance with which the species (or growth-form) in question occurs in an association. A ten-years-old beech-wood will frequently cover as large an area as one of a 100 years, whilst the figures for the area occupied would not give any idea of the enormous difference as regards masses in the two growths. It is true, anything like this need not be demanded of the figure in question, but then they are not very enlightening in any respect, and are therefore superfluous.

In connection with the frequency percentage (F. %) (frequency-number), a far better method can be more advantageously employed, a method which science — as far as I know — has not employed very largely, but which practical men discovered decennia ago. It cannot be employed on excursions, with note-book and squared paper, or on expeditions on horse-back; it requires a sojourn on the spot, and some patience. It is simply this: The mass of a wood is determined by the forester by its timber-contents in cubicmetres (it may be expressed in terms of weight!); the crop of a rye-field may be given in weight (straw and grain); and quite similarly could the natural vegetation of any place be treated by a man of science: but then it would be necessary to reap the plants, the masses of which are wanted to be known.

This method has the advantage that — of course in connection with other descriptive means (frequency-numbers, etc.) — it can be employed to characterize both the whole association, and its individual species. Thus, it is really a valuable piece of information concerning an association, to know, for instance, that on a square metre there grow, on an average, let us say 2 kilograms of plants, while another association perhaps bears 200 kilograms. It must be admitted that this gives quite a striking impression of the plant-producing power in two such localities. I wonder how the tropical rain-forest, and the lichen-covered heaths of Iceland, would appear when thus compared according to relative weights of produce! It would be extremely interesting to ascertain.

But also the luxuriance of the individual species or growth-form in an association, would be able to be characterized by this method. It would be very interesting to see, for instance, the result of comparing a piece of Danish heath with an Icelandic heath, in respect to the lichen-vegetation. How many kilograms of lichens each sample-area contains up there in the North and down here in Denmark.

Unfortunately I have not been able to employ such a "weight" method in my investigations in Iceland, nor had I at that time considered this matter more closely. But I am convinced that we have here an exceedingly valuable means of description, by which to characterize the difference between the masses, be it of the individual species, the growth-form or the whole association; and, as already mentioned, practical men have long ago used it in pursuit of their object.

### a. The Deserts.

Large tracts of Iceland have a desert-vegetation, i. e. a very open vegetation consisting of scattered individuals. Where to draw the boundary line between the desert and the closed vegetations, i. e. vegetations which cover the ground completely, is entirely a matter of opinion, and the boundary can only be an artificial one. We may for instance decide, according to Raunkiær's method, to take a large number of equally large sample-areas, and note down their vegetation separately. It will then be seen that many of the areas are entirely devoid of plants, and such areas may be designated 0 *(nil)*; and then resolve that a tract of land in which 75 % of the sample-areas were devoid of vegetation, should be designated "desert." But, as already mentioned, whether this "percentage of voidness" is chosen, or an entirely different one, for the designation "desert," it is and must be a matter of opinion. Such an analysis of "voidness" would be interesting for purposes of comparison, for instance between the Arctic cold-deserts, and the sub-tropical heat-deserts. But such an analysis has not yet been made, nor have the deserts of Iceland been, as yet, sufficiently investigated in this respect.

In Iceland many different kinds of deserts are found, the best-known are the fell-fields of the plateaux; but others exist also, as for instance vast sandy tracts with drifting sand, both in the highlands and in the lowlands. We shall now consider these deserts more closely, leaving out those with a rock-substratum, which will be discussed elsewhere.

According to the substratum we can divide the deserts into stony, gravelly, sandy and clayey deserts. A division according to the principles of plant-ecology, cannot be undertaken, as the vegetation has not been sufficiently investigated, from a statistical point of view.

Stony Deserts are the stone-covered ridges (holt) of the lowlands, and the talus of fallen blocks and débris (Urd) of the highlands. The lichens growing directly on the stone-substratum, do not concern us here, but between the stones on the ridges there grow as chasmophytes, *Dryas octopetala, Thymus Serpyllum, Silene acaulis, Potentilla verna, Cerastium alpinum, Arabis petræa, Saxifraga cæspitosa, Juncus trifidus, Luzula spicata, Achimilla alpina, Poa glauca, Elyna Bellardi,* and a number of less frequent species (according to Jónsson). Interspersed in the moss-carpets occur (according to Jónsson's list in "Vegetationen paa Snæfellsnæs," p. 41) the following species: —

Cladonia rangiferina (podetia-wandering fruticose lichen).
Thamnolia vermicularis —
Cladonia uncialis —
Sphærophorus coralloides —
Cetraria aculeata —
Sphærophorus fragilis —
Cladonia pyxidata (hypothallus-wandering fruticose lichen).
— cornucopioides —
Cetraria islandica (erect foliaceous lichen).
Peltigera canina (horizontal foliaceous lichen).
— rufescens —
— aphtosa —

Jónsson does not mention having found any crustaceous lichens, therefore these will hardly occur in conspicuous abundance, whilst it may be expected that, on future investigations, some or other of the small, inconspicuous species may be found, at any rate on decaying moss.

Jónsson also mentions the fact that here and there *Cladonia* and *Sphærophorus* spp. may occur as dominants in a sub-vegetation of mosses, in addition to more sparsely occurring *Gramineæ.*

The taluses of fallen blocks and débris (Urd) in the highlands, are either very poor in, or entirely devoid of, phanerogams, and between the stones mosses *(Grimmia hypnoides)* chiefly occur, in part together with lichens; this will, however, be discussed more fully under the vegetation of the moss-carpets of the island.

The Gravelly flats in the lowlands bear a scanty vegetation of herbs, (see e. g. Thoroddsen in vol. I, p. 326 of the present work; Jónsson's lists are exhaustive, but, like Thoroddsen, he makes no mention of finding lichens).

In river-gravel in the lowlands *Chamœnerium* is common. The river-flats are occasionally inundated in spring, and are devoid of lichens.

The gravelly flats of the plateau are "the parts of the rocky flat poorest in plants" (Jónsson). Here and there grow *Luzula spicata, Oxyria digyna, Cerastium alpinum, Silene acaulis, Arabis petrœa, Galium silvestre, Saxifraga cœspitosa,* etc. Moss-cushions *(Dicranum falcatum)* occur also, and, — as "collars" around larger stones, — small carpets of *Grimmia hypnoides* intermixed with lichens *(Cetraria islandica* and *Cladonia)* and phanerogams; this will be mentioned more fully under the moss-vegetation. The gravelly flats which I traversed just below the summit of the mountain "Sulur," near Eyjafjördur, were still, on the 5th of July, supersaturated with the down-trickling snow-water, and were quite bare of vegetation.

Sandy flats. Several kinds of sandy flats of various geological origin occur, partly in the lowlands, and partly in the highlands. Many of them are quite bare of plant-growth along such great tracts, that days intervene before a few individuals are again met with. The commoner types of sandy flats are: beach-sand (with a halophilous herb-vegetation), which is devoid of lichens (owing to its contents of chloride of sodium); Jökul-sand (which is often inundated by Jökul-rivers) either devoid of, or with a very poor, herb-vegetation, and without lichens (on account of inundations possibly followed by drifting sand); and lastly tracts of blown sand (Sander) of various origin, but more or less wind-affected on the surface by frequent and violent sand-storms. The different kinds of sand mentioned here are devoid of lichens, owing to three essentially different reasons: (1) the occurrence of chloride of sodium in the soil (beach-sand), (2) frequent inundations (the sandy tracts below the Jökuls) or (3) drifting sand, (in the sandy tracts of the plateaux and elsewhere).

I traversed, in several places, such extensive sandy tracts, as for instance Hólasandr (north of Mývatn), the "Sanders" in the delta of the Jökulsá (at the head of Axarfjörðr), and the dunes between Mývatn and the Jökulsá.

The first of these tracts (Hólasandr) consists of black sand, in which are numerous stones with worn edges. It is very poor in vegetation; there occurred however, scattered uniformly over the entire surface, some grass, in tufts, at stated intervals of about $^1/_3$—$^1/_2$ metre. All other kind of vegetation was absent, for instance — owing to the strong sand-drifts prevailing everywhere — not a single moss or lichen was found.

As mentioned above, the stones were highly worn by the action of sand, and bore no mosses and hardly any lichens; scarcely a hundred out of the thousands of stones I passed by during a two-hours' ride, bore any vegetation at all, and even that of these few stones was extremely scanty. The following species were found: —

Stereocaulon spp. (fruticose lichen).
Parmelia lanata (foliaceous lichen).
Gyrophora arctica —
— erosa —
Lecidea pantherina (crustaceous lichen).

The dune terrain east of Mývatn bore in numerous places a scattered vegetation of *Elymus arenarius*, which looked very remarkable against the dark background of black sand. Here also strong sand-drifts prevailed, and the ground was, in consequence, quite devoid of lichens.

As regards their vegetation and other external conditions, the blown-sand areas in the delta at the mouth of the Jōkulsá, greatly resemble, for instance, Hólasandr. The sand, which is mixed with stones with worn edges, drifts very much. In stormy weather it was not possible for us to see even a few hundred metres in front of us on account of the sand-clouds, which filled the air near the ground.

In this place, a little grass, some *Silene acaulis,* and a few other phanerogams, formed an extremely poor and scattered vegetation. Mosses and lichens were totally absent, on account of the drifting sand.

Desert-like, clayey-flats with a poor or scattered vegetation, have been described more fully by Jónsson from East Iceland, Snæfellsnæs and South Iceland. They are, however, frequently more luxurious, and can bear a vegetation which forms a kind of transition to heath-vegetation. An instance of this is also given below under the description of heaths (Type III).

We shall elsewhere — under the description of Iceland's moss-carpets and their lichens, — have an opportunity of discussing the competition between moss and lichen. Here it will suffice to state, that lichens, in the loose soil of mountain-hights, in mountain-deserts, rarely occur on quite bare, purely inorganic soil. They show a peculiar tendency to seek company with mosses or other plants, without its being always possible to state precisely, which have been the first to arrive on the spot.

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The species which appear to be most common on loose soil in mountain-deserts are the following: —

Cladonia turgida (fruticose lichen), frequently sterile.
— pyxidata — — , on humus.
— rangiferina — —
— coccifera — —
Stereocaulon denudatum — —
Alectoria nigricans — —
Thamnolia vermicularis — , sterile.
Cetraria hiascens (foliaceous lichen), frequently sterile.
— islandica — —
— Fahlunensis — —
— aculeata (fruticose lichen), —
Solorina crocea (foliaceous lichen), —
Pannaria microphylla —
Peltigera aphtosa — —
— lepidophora — —
Dermatocarpon hepaticum — , on moor-soil.
Lecanora tartarea (crustaceous lichen), fertile; on moss, moor-soil and lichens.
Bacidia flavovirescens (crustaceous lichen), often sterile; on purely inorganic soil.
Pertusaria oculata (crustaceous lichen), often fertile.
Buellia parasema —
v. papillata, fertile; on moor-soil.
v. triphragmia, fertile.
Rinodina mniaræa (crustaceous lichen)
v. cinnamomea, fertile; on moor-soil.
Lecidea assimilata (crustaceous lichen), fertile; on dead moss.
Caloplaca Jungermanniæ — , fertile; on moor-soil.
Psoroma hypnorum — , fertile; on moss.
Lecanora castanea — , fertile; on moor-soil.
Bæomyces byssoides — , often sterile; on moor-soil rich in mineral.

This is by no means an exhaustive list of the earth-lichens of the plateau; it must be supplemented by several other species, the occurrence of which is not known very accurately, and also by some which will be mentioned under the description of the moss-carpets of Iceland; these, as we know, partially extend upwards into the most desolate wastes of mountain heights, and are there found interspersed with various species of lichens.

### b. Lichen-heaths

of wide extent do not appear to occur in Iceland. In the above a couple of instances have been mentioned showing that lichens can, in patches, dominate the physiognomy of a *Grimmia*-carpet or of a poorly-developed chamæphyte-heath. But beyond this, no lichen-heaths proper are known, as they are described from other places in Arctic Regions.

### c. Moss-vegetations.

Whilst chamæphyte-heaths, grass-areas and coppices all have their own fairly distinct horizontal limits, this is not the case as regards the moss-areas. These are found at all altitudes, right up to the snow-limit, both in the low land and in the highest plant-bearing high land. The moss-vegetation itself has been exhaustively described elsewhere in this work (Hesselbo, 1918). I shall therefore occupy myself exclusively with those parts of it which are of importance to lichen-growth.

Mosses differ (in a higher degree than do lichens) in their requirements as regards moisture, in that several are hydrophytes (*Fontinalis*, *Sphagnum* spp., etc.), whilst others suffice with intermittent supplies of water, and some are distinctly xerophytic.

The vegetation of all areas of perpetual water-containing mosses, (in bogs and the like) is always devoid of lichens.

Here therefore, only that vegetation will be discussed which, during a shorter or longer period of the year, is dry and contains lichens. This refers, consequently, almost exclusively to the *Grimmia*-vegetation in both the high and low land. But before mentioning these more closely I shall say a few words about the *Philonotis*-bogs on the mountain slopes. They are seen in the landscape as bright-green patches on mountain declivities, where springs appear on the surface of the ground, and are extremely common everywhere along the sides of the fjords. Owing to their great water-contents they are always devoid of lichens.

*Grimmia*-heaths are found, as mentioned, at all altitudes right up to the snow-line, but differ somewhat according to the altitude.

The substratum which supports the *Grimmia*-carpet is sometimes solid rock, sometimes loose soil. My own observations are derived almost exclusively from carpets upon lava.

On mountain heights (fell-fields) the carpets are often small in extent, but further down in the low land they may cover large continuous tracts.

The plant-carpet is a few centimetres high and the moss-shoots stand erect. Whatever may be the nature of the deeper-lying substratum, at the bottom of the carpet there is always found, as a matter of course, a peat-formation consisting of the dead remains of the mosses, as soon as the moss-covering is only a few years old. The deeper-lying soil is evidently of no direct importance, or concern to the lichens; they are connected with the peat and the dust-particles, which always occur on it, and amongst the mosses.

With regard to the amount of water contained amongst the mosses, very little is mentioned in the literature. It may, however, be taken for granted that all *Grimmia*-vegetation in Iceland is dry enough to bear lichens. My own observations show this distinctly enough. For the rest, there is, as usual, the great defect, that we have no fixed method to indicate the degree of dampness of the plant-association, as far as emergent associations are concerned. We are constantly reduced to the entirely relative, and consequently almost useless terms, "dry," "damp," etc., without any fixed statement as regards measured amount.

Jónsson states that there is an essential difference in the accompanying phanerogams in high and in low land, in that only a few occur on the rocky flat, whilst they are found far more numerously further down. He states, in addition, as a general fact, that lichens are found more abundantly in the *Grimmia*-carpets of the rocky flat, than in those of the low land. How far this is quite right can only be proved by frequency-numbers, and statements of mass-occurrences (in weight), and such are not found in sufficient numbers. I must, however, say that Jónsson's statement sounds very reasonable, and is supported by Hesselbo. It can undoubtedly be explained by the fact that the climatic conditions are more unfavourable to the mosses in the high land, and relatively more favourable to the lichens. Whether the absolute amount of lichens (in weight per unit of area) is really greater in the high land than in the low land is perhaps doubtful. But there is nothing to prevent the assumption that the amount, in proportion to the mosses, is greatest at a high altitude, not because the climate of mountain-heights is favourable to lichens, and is more agreeable to them than the climate of the low land, but because it is more inimical to the mosses than to the lichens, and thereby causes the latter to grow in apparently greater luxuriance. It is absolutely necessary to warn against a too strong belief in one's first-hand and direct impression as regards this matter; only actual measurements can give real information.

As an instance of a decided *Grimmia*-heath I shall describe more fully a stretch of land near Havnefjord (South-west Iceland).

The substratum is an older lava-field consisting of highly vesicular and porous post-glacial lava, the surface of which varies greatly, in that there occur level plains of small-sized lava-débris, strewn here and there with a little soil, large blocks of rock of varied appearance, vertical faces of rock, and caves, all mixed together in great confusion.

The *Grimmia*-carpet extends chiefly over the level plains covered with lava-débris. An enumeration of the characteristic plants gave the following results: — *Grimmia* occurred in all the sample-areas (F % 100), crustaceous lichens (F % 65), fruticose lichens (F % 15), bare ground (F % 10), grass (F % 65), *Galium* (F % 60), and some *Silene acaulis*.

The numbers may lead us to believe that crustaceous lichens highly dominate the plant-physiognomy of the carpet; this is, however, not the case.

The following species of lichens have been found: —

| | |
|---|---|
| Cetraria aculeata, fruticose. | Pertusaria corallina, crustaceous. |
| Cladonia coccifera, — | Sterile crustaceous lichens. |

But several other species may occur. If we enumerate all the species which have hitherto been recorded, we get the following: —

| | |
|---|---|
| Alectoria ochroleuca v. cincinnata, | podetia-wandering fruticose lichen. |
| Cladonia rangiferina, | — |
| Thamnolia vermicularis, | — |
| Cladonia uncialis, | — |

Stereocaulon denudatum, podetia-wandering fruticose lichen.
Sphærophorus fragilis, —
— coralloides —
Cetraria aculeata, —
Cladonia pyxidata, hypothallus-wandering fruticose lichen.
— gracilis, —
— cornucopioides, —
Cetraria islandica, erect foliaceous lichen.
Peltigera canina, procumbent foliaceous lichen.
— rufesceus, —
— aphtosa, —
Solorina crocea, —
Pertusaria corallina, crustaceous lichen.
Sterile crustaceous lichens.

Altogether about 18 species. Quantitively, as far as it appears, the fruticose lichens are decidedly dominant in some places. Thus, Jónsson has seen them in such abundance amongst *Grimmia*, that he calls them "indicative of Lichen-heaths." But this appears to be only true of patches here and there. I myself have not met with this phenomenon. In Denmark we have nothing that can be compared with the Icelandic *Grimmia*-carpets, as regards superficial extension. Where we, here and there, find *Grimmia*-bogs scattered in our heaths, they are generally small, and appear to be wetter at the bottom, than are those in Iceland, and are consequently practically devoid of lichens. The difference no doubt chiefly depends on the fact, that in Denmark the *Grimmia*-bogs usually occur in damp hollows, where stagnant ground-water furnishes them with the necessary moisture, whilst the *Grimmia*-carpets in Iceland are, in a higher degree, directly furnished with this by rain. The *Grimmia*-carpets in Denmark have, as a rule, undoubtedly a quicker vertical growth, and deeper peat-substratum, which explains the characteristic paucity of lichens in our *Grimmia*-carpets, and the lichen-wealth in those of Iceland. It is consequently, in the first instance the competition which is stronger and more inimical to lichens in Denmark than in Iceland.

Besides this, it is strange that the Iceland *Grimmia*-carpets can contain quantitively, such an abundance of crustaceous lichens, whilst ours are quite devoid of them.

A Table will render the difference plain: —

| | Fruticose lichens | Foliaceous lichens | Crustaceous lichens | Number of species |
|---|---|---|---|---|
| Icelandic *Grimmia* carpets .. | 61 % | 28 % | 11 % | 18 |
| Danish — — .. | 100 % | 00 | 00 | 5 |

I have no means of determining with certainty the quantitive difference, frequency and mass-occurrence (in weight). But a first-hand, direct consideration shows clearly enough, that the Danish bogs are very poor in lichens, whilst the lichen-wealth is far more considerable in Iceland.

### d. The Grass Vegetation.

The majority of the grasses of Iceland belong probably to the same growth-form and are hemicryptophytes. The grass-covered areas — the grass-vegetation — may consequently be defined as areas containing a hemicryptophyte-vegetation with a very high frequency-percentage, in favourable cases — perhaps even most frequently — with a grass-frequency percentage (F %) 100. But consequently the areas contain many other plants besides grasses, for instance a larger or smaller number of chamæphytes, mosses, lichens, etc.

The grass-vegetation occurs abundantly everywhere on the island; no horizontal limit (compare wood-limit) towards the Arctic regions occurs.

On the other hand, there is a vertical limit, which, however, I cannot state precisely in metres, as I myself have not any definite measurements, nor have I seen any in the works of other authors. This much however is known, that it is chiefly the low-lying parts of the mountains and the lowlands which can support grass-carpets, while the high land is devoid of continuous grass-carpets.

With regard to the relation between the grassland and the ground-water level, the investigations published are not exhaustive enough to be able to give us a clear view on the subject. It is known, for instance from H. Jónsson's investigations, that low-lying, clayey sea-shores are in many cases covered with *Glyceria maritima* provided the ground is occasionally inundated by the sea.

Such a Glycerietum is often abundantly mixed wlth *Agrostis alba* and as regards growth-form, is consequently, on the whole, a grassland, but differs in many respects so widely from the other grass-areas inland, that its associates are very different from those of these inland grass-areas.

This example is mentioned here merely to emphasize the commonly-existing rule which I demonstrated several years ago, that soil containing chloride of sodium is devoid of lichens. Not only would the presence of this substance, poisonous to lichens, but also the very high level of the ground-water undoubtedly, in itself, suffice to exclude lichens.

When the ground-water is fresh (lakes, etc.) a fixed succession of associations is no doubt developed in Iceland as with us in Denmark; those of Denmark are excellently set forth in Mentz's (Mentz, 1913) work on the recent vegetation of the Danish bogs, in which he demonstrates the transition from reed-swamp through mud-meadows to grass-bogs or *Paludella*-bogs and on to other vegetations (*Sphagnum*-bogs, etc.). With regard to Iceland we have not as yet such exhaustive descriptions; it is however already known that reed-swamps occur, passing into wet *Cyperaceæ*-meadows, etc., and thence transitional forms to grassland.

But whether the ground-water is fresh or salt, it must be emphasized as a common feature, that lichens are absent everywhere where the ground-water, even during a shorter period of the year only, stands up to the level of the plant-covering or even above it, as in Denmark. I have observed such extensive meadows, devoid of lichens, in several places near Eyjafjördur and elsewhere.

The drier, lichen-containing grassland will be treated more fully in the following pages.

There exist no statistical investigations of the frequency-number of the grass species which occur in the grass-carpets, from which the various types of grass-areas could be designated or named. It is mentioned in the literature on the subject that the list of species from the different substrata (level land, mountain sides, home-fields, etc.) differs, but an exhaustive statistical verification is still wanting, and is also difficult to obtain, as the grasses are usually closely grazed by sheep so that it is a difficult or at any rate a slow work to determine them in the field. But even now an orientation may be had. It is for instance known that not only highly mixed carpets of both *Gramineæ* and *Cyperaceæ* are found, but also purer carpets of sometimes one, sometimes another species; for instance, as Jónsson has shown, there often occurs a fairly pure vegetation of *Nardus* on slopes (Lier); also a rather pure *Agrostis (vulgaris)*-vegetation, and *Nardus-Agrostis*-slopes (Lier).

Consequently, it is not possible to give a more detailed division according to associations, but from a lichen-ecological standpoint this is of no consequence, because the different species of grass differ only slightly as competitors with lichens, and can therefore very well be treated collectively.

On the other hand, we have good knowledge of the substrata which support the grass, which is usually divided into associations according to the substrata — at least partially.

Thoroddsen discusses this exhaustively and instructively (vol. I, pp. 335—36), stating that

Grass-slopes (Græs-li) occur on sloping ground with loose soil and a level surface (not knolly) at the foot of mountains, both when the mountain is tuff and when it is basalt.

Knolly grassland (Græs-Mo) is extremely knolly, clayey ground, intermixed with humus.

A third type ("dry uncultivated grassland" loc. cit. p. 337) is without knolls and has a sandy, gravelly or pebbly substratum and an open plant-covering.

Home-field (Tun) is the cultivated, manured grassland around the farm-buildings.

The conditions afforded the lichens in the grass-vegetation are chiefly characterized by the fact that the plant-carpet is quite low, being only a few centimetre high; besides this the shoots, and especially the leaves, frequently stand more or less erect, so that abundant light usually falls between them. The amount of light is very favourable to lichens even in the most luxuriant carpet; on the other hand, the vertical direction of growth of the grass is a very grave hindrance to the crustaceous earth-lichens, which cannot of course force their way athwart this. On the other hand, as regards the fruticose and the erect foliaceous lichens this hindrance is of no great importance. Consequently, it will be easily understood, that crustaceous lichens can occur in abundance only in places, where the grass-carpet is open, so that they can grow directly on the surface of the ground, or here and there, where the grass is closely cropped (by grazing sheep, etc.), they can grow across the tufts.

As examples of lichen-vegetation in grass-carpets, I shall mention a few observations which are typical: —

On sloping ground on the sides of Reyðarfjörður (East Iceland) heaths and grass-carpets grow mixed with one another. The latter, seen from a distance, have a light greyish-green colour and consist mainly of *Festuca ovina* mixed with a small amount of *Calluna, Empetrum, Dryas, Silene acaulis, Cassiope hypnoides, Betula nana*, some mosses and *Lycopodium*. When I visited the place the grass was very short (3—6 centimetres), being closely grazed by sheep whose dung was found everywhere. Here and there was an extremely small number of lichens, which played a very subordinate part both as regards abundance and degree of frequency.

The degree of frequency was determined neither here nor in any other of the grass-carpets investigated by me, because the lichens were so exceedingly unevenly distributed that, in order to obtain a fairly reliable frequency-number, a far larger number of sample-areas would be required, than I had time to investigate.

The following species were found: —

Stereocaulon coralloides.
— tomentosum f. campestre.
— incrustatum.
Cladonia pityrea.
— uncialis.
Cladonia fimbriata.
Thamnolia vermicularis.
Cetraria aculeata.
Peltigera canina.
— aphtosa.
Bacidia flavo-virescens.

In quite similar localities, and in an exactly similar vegetation, I found near Seyðisfjörður the same scanty lichen-vegetation supplemented by a few other species, viz.

Psoroma hypnorum.
Dermatocarpon hepaticum.
Collema spp.

I found on extensive, very knolly grassland, on mountain-slopes on each side of Eyjafjörður, a somewhat different vegetation, in that the top of the knolls bore *Dryas, Betula nana* or *Empetrum* — an indication of heath-vegetation. Upon these dwarf-shrubs and the dead portions of the grass-tufts on the top of the knolls, occurred masses of *Lecanora tartarea*, and here and there a solitary *Cetraria aculeata*. The former crustaceous lichen is, as is well-known, extremely common on the stunted plant-carpets of the Arctic regions, for instance in Lapland and Greenland.

I found near Eyjafjörður, just below the summit of Sulur-mountain, extensive flats covered with heaths, knolly grassland, bogs and *Cyperaceæ* bogs.

The grass-flats contained a great quantity of lichens, very unevenly distributed, but in great numbers and well-developed specimens. The following species were found: —

Alectoria ochroleuca.
Cladonia turgida.
Sphærophorus fragilis.
Cetraria aculeata.
Peltigera aphtosa.
— malacea.
Leeanora subfusca v. hypnorum.
— tartarea.
Pertusaria oculata.
Lecidea clæochroma v. muscorum.
Coenogonium ebeneum.
Sterile crustaceous lichens.

The lichens occurred not only on the top of the knolls, but also on their sides. On the other hand, quite flat grass-areas (consisting of *Nardus, Anthoxanthum* and some *Carex* spp.) were quite devoid of lichens and very bright-green; they were probably too damp for lichens.

The species which have hitherto been found in grass-areas are the following: —

Alectoria ochroleuca (fruticose).
Cladonia turgida —
— pityrea —
— uncialis —
— fimbriata —
Thamnolia vermicularis —
Sphærophorus fragilis —
Stereocaulon coralloides —
— tomentosum f. campestre (fruticose).
— incrustatum —
Cetraria aculeata —
Peltigera canina (foliaceous).
— aphtosa —
Peltigera malacea (foliaceous).
Collema spp. —
Dermatocarpon hepaticum —
Coenogonium ebeneum (crustaceous).
Lecanora tartarea —
— subfusca v. hypnorum (crustaceous).
Psoroma hypnorum —
Pertusaria oculata —
Lecidea elæochroma v. muscorum (crustaceous).
Bacidia flavovirescens —
Sterile crustaceous lichens.

Consequently, in all, 24 species: 11 fruticose lichens (46 %), 5 foliaceous lichens (21 %) and 8 crustaceous lichens (33 %).

Here, as in the case of the heath, is a want which has not yet been supplied; the mass-occurrence (given in weight) of the lichens has not been determined. Nor is the average frequency-number known, for reasons which have been mentioned above. It is therefore difficult to give any comparison between the lichen-vegetation of the grass-areas of Denmark and Iceland, as regards quantity, so far as this is manifested by mass-occurrence and frequency-number. As regards quality, i. e. with respect to growth-form and systematic species, a comparison can more easily be made.

It must be borne in mind that Iceland is peculiar owing to its great abundance of natural, free-growing pastures, both damp meadows, devoid of lichens, and drier lichen-bearing areas, whilst Denmark is almost devoid of uncultivated pastures, for damp meadows are frequently more or less cultivated (drained, etc.), and most of the other grasses are under intensive culture, entering into the regular rotation of crops. Consequently, the lichen-bearing areas in Denmark are very small and contain, according to my observations, only about 16 lichen-species, viz. 12 fruticose *(Cladonia rangiferina, C. rangiformis, C. uncialis, C. furcata, C. gracilis, C. squamosa, C. pyxidata, C. fimbriata, C. Floerkeana, C. coccifera, Cetraria aculeata,* and *Stereocaulon paschale),* 2 foliaceous *(Cetraria nivalis* and *Peltigera canina)* and 2 crustaceous *(Sphyridium byssoides* and *Lecidea uliginosa).*

The relationship according to percentage is consequently as follows: —

| | Fruticose lichens | Foliaceous lichens | Crustaceous lichens |
|---|---|---|---|
| Danish lichen-bearing grass-areas (in dunes, etc.) | 75 % | 13 % | 13 % |
| Icelandic — — .............. | 46 % | 21 % | 33 % |

As seen from the lists, the species are not the same, although several are common to both countries. But the most conspicuous difference is that which has regard to the growth-forms, Iceland having a very great number of crustaceous lichens — which appear to play rather an important part as regards the plant-physiognomy — viz. 33 %. This undoubtedly indicates that the competition between grass and lichen results rather in favour of the lichens in Iceland, than of those in Denmark; that is to say, the presence of the great number of crustaceous lichens is not due either to climate or soil, but to a less keen competition.

Consequently, if we are to sum up in a few words a comparison between the lichen-vegetation of the Danish and Iceland grass-areas, we must say, that Iceland has the greater number of species, 24 as against 16 Danish, Iceland has 11 fruticose lichens, 5 foliaceous lichens, and 8 crustaceous lichens, while Denmark has 12, 2, 2 respectively. The numerical preponderance as regards Iceland is due to the foliaceous and especially the crustaceous lichens.

The mass-occurrence (in weight) in both countries is unknown, as is also the frequency-number in both countries. For a first-hand and direct consideration the difference does not appear to be great in these two respects, but we ought not to remain standing at this point.

## e. Heaths.

Under this name I include all such associations as are identified in the field by the fact that all, or at any rate almost all, the sample-areas contain chamæphytes, mainly dwarf-shrubs. A phanerogamologist will hardly suffice with so short and summary a characteristic, and it is his task to investigate partly which growth-forms the heath contains, and what percentage of each (chamæphytes, hemicryptophytes, etc.) and partly what frequency-degree each of these growth-forms has. A vegetation of which some of the sample-areas contain *Empetrum* only, others *Calluna* only, and others again a mixture of both is, according to the diagnosis used here, a heath as entirely as a vegetation which contains exclusively *Calluna* in all its sample-areas, because *Calluna* and *Empetrum* belong to the same growth-form. When I here mention as a kind of diagnosis, the characteristic that all or almost all the sample-areas must contain some or other chamæphyte, this should not be regarded as an analysis of the phanerogamic growth-forms of the Iceland heath -- such will no doubt be given elsewhere in this work — but it is simply an easily recognizable feature whereby one can perhaps in the future recognize such Icelandic vegetations, of which the lichen-vegetation has been investigated by me and will be described more fully later on in this paper; in a similarly summary manner phanerogamologists describe lichen-vegetations, moss-vegetations, etc. in associations which interest them for the sake of the phanerogams. It is in addition a diagnosis of quite similar character as the diagnosis that a w o o d is an association in which every sample-area contains a tree or parts of a tree — a diagnosis which does not involve anything whatever as to the entire biological aspect of the wood, when all its species are enumerated according to their growth-form.

I must add, that in the investigation of the heath-associations, I took, in the majority of the localities, sample-areas of 2 square decimetres (dm.²) with intermediate spaces of equal size, viz. about 1 metre.

The majority of the heaths, regarded as landscapes, are easily recognizable in Iceland by their greenish-brown tone of colour, which makes them conspicuous even at a fairly long distance. They occur on mountain-sides up to a height of about 400 metres. It is stated that on slopes (mountain-sides) the ground and hence also the plant-covering is flat, whilst they are knolly and uneven on a horizontal substratum. These features agree exactly with my observations.

In the following I shall give some examples of the more frequent facies of the heath and their lichen-vegetation.

Type I. Dry heaths on level (not knolly) ground.

(a) Heaths rich in phanerogams but either poor in or devoid of lichens.

Near Háls parsonage in Fnjoskádalur (North Iceland) I noted down that there occur extensive heaths the character plants of which are *Empetrum*, *Betula nana* and various *Glumifloræ*, mostly grasses. Each of these occur in all the sample-areas, i. e. they have the frequency-percentage 100. The ground, which is gently sloping, consists of fine, reddish sand, and is covered by a continuous carpet of the above-mentioned character-plants and by a few others which have a lesser frequency-degree, e. g. *Dryas*, *Silene acaulis*, etc.

Both the open ground and the birch-clusters are devoid of lichens.

The reason of this phenomenon merits fuller discussion. As mentioned above, we can, on the whole, point out eight essential factors which determine the presence or absence of earth-lichens in a particular association, viz. the chemical composition of the soil, the size of its grains, thermal conditions, water-contents, drifting soil, burrowing animals, a layer of decaying leaves, snow-covering, and competitive relations with other plants. Among these eight factors we must consider more fully the layer of decaying leaves and the competitive relations with neighbours. It is impossible to believe that all the other factors mentioned above, could have an injurious influence on a lichen-covering on the heath-areas in question. But the two powerfully acting factors just mentioned are without doubt instrumental in the existing want of lichens. The fact is, that dwarf-birches, where they form dense growths, are fairly high in growth, cast rather a deep shade, and shed a considerable number of leaves which cover and choke such lichen-germs as might possibly fall on the plant-carpet and try to hold their own there.

The frequency-percentage (100 %) of the dwarf-birch in this association does not, as a matter of course, give us any idea of the fact that it dominates the area to such a high degree and has such an exclusive influence as regards the lichens. It has not for instance a higher frequency-number than have the *Empetrum* and *Gramineæ* in the same association. Yet we shall see further on that both *Empetrum* and *Gramineæ* in purer growths — i. e. not at all or only slightly mixed with birches — are far more hospitable towards the lichens than is the association described here, whose want of lichens must therefore undoubtedly be attributed to the presence of the dwarf birch.

In itself it is a drawback of the method in question, that this quality cannot be deduced from the frequency-number — that the latter expresses so imperfectly the area covered by the species present; but I fear that this drawback will ultimately be found to be insurmountable, whatever method should be adopted. The word-description of the association must here supplement the statistical figures.

I found heaths of this kind or of very much the same composition on extensive tracts between the farms of Háls and Einarstaðir, lower down on the mountains; especially in Fljótsheiði, a locality near the latter farm, I noted down a vegetation of dwarf-birches (F % 95), i. e. frequency-number 95, *Empetrum* (F % 90), *Glumifloræ* (F % 85), *Vaccinium uliginosum* (F % 65), *Dryas* (F % 45), *Salix lanata* (F % 30) and *Calluna* (F % 10). The dwarf-birch was consequently somewhat less frequent and a little less dominant there. A few other species grew scattered in the plant-carpet, and there occurred also a small quantity of lichens, F % 20 (10 % crustaceous lichens, 0 % foliaceous lichens, 10 % fruticose lichens) and a small quantity of mosses (F % 5).

The lichens in question were *Alectoria ochroleuca* and *Thamnolia vermicularis,* both podetia-wandering fruticose lichens, and a few crustaceous lichens which were not determined more closely.

In large, extensive tracts of land along the left bank of the Jökulsá, and between the farms of Svinadalur and Ás, I observed heaths somewhat more luxuriant in composition and characterized by an abundant mixture of *Salix lanata.* The other species were *Betula nana* (F % 100), *Glumifloræ* (F % 100), *Empetrum* (F % 95), *Vaccinium uliginosum* (F °/o 80), *Salix lanata* (F °/o 60), *Geranium silvaticum* (F °/o 26), *Betula pubescens* (F °/o 20), *Salix* spp. (F °/o 20), *Equisetum* (F °/o 20), a little *Calluna* (F °/o 7), a little *Lycopodium* (F °/o 7) and some mosses (F °/o 13). Consequently, these heaths contain considerable quantities of high, well-grown shrubs, viz. *Salix lanata*, some *Betula pubescens*, etc. The vegetation was very close and luxuriant, and the floor was entirely covered with decaying leaves. In correlation with this lichens were totally wanting in these heaths.

We have now seen some different examples of how both the lower and taller shrubs, which shed an abundance of leaves every year, are simply through this peculiarity inimical to the growth of lichens. The more frequently low-growing trees occur on a heath, the more difficult do the life-conditions of the lichens become. It cannot be doubted that there is correlation between the occurrence of these two growth-forms.

Type I. (b) Dry heath with drifting soil; devoid of lichens.

In the mountains between Fnjoskádalur and Öfjord (North Iceland) I noted in some places a *Dryas*-heath on which the characteristic plants were *Dryas* (F °/o 100), *Glumifloræ* (F °/o 100), dwarf-birch (F °/o 50), *Empetrum* (F °/o 40), *Salix lanata* (F °/o 20), and *Vaccinium uliginosum* (F °/o 20). Peculiar to this heath was the total absence of lichens, which was evidently due to the shifting soil of the place in question, strong winds causing it to drift. It was evident that the plant covering and other conditions were not detrimental to the lichens, which in other places throve excellently among the same competitors which occurred here.

Thus we have seen two essentially different factors which may be instrumental in excluding a lichen-vegetation from heaths; (1) certain shade-casting, deciduous chamæphytes and Nano-phanerophytes which may dominate so highly that lichen-growth is made impossible, and (2) drifting soil which may play exactly the same part, even if the plants present are not in themselves any hindrance to lichen-growth.

Type I. (c) Heaths poor in phanerogams and rich in lichens.

Other heaths may be rich, even very rich, in lichens. We shall now mention some specimens of them.

In the heaths near Einarstaðir (Aðalreykjadalr in North Iceland) were found scattered larger and smaller areas of Dryas-grass-heaths which were easily discernible even from a considerable distance owing to their light greyish-green tone of colour. Their character-plants were *Dryas* (F % 100), *Glumifloræ* (F % 100) and *Empetrum* (F % 90), besides less important quantities of dwarf-birches (F % 10) and *Silene acaulis* (F % 10). As indicated by the names, the plant-covering is rather low; the soil was stable (not drifting) and no abundantly leaf-shedding plants were predominant in it.

Such areas were peculiar by the vegetation being — also physiognomically — highly dominated by lichens, especially crustaceous lichens, for lichens, taken as a whole, were found in all the samples (F % 100). Fruticose lichens (F % 100), do not play any dominant part physiognomically, in spite of their high frequency-percentage (F % 100), that is to say, they are not very conspicuous as masses. This is in a way also true of the foliaceous lichens (F % 33), whilst crustaceous lichens (F % 100) are dominant to an unusual extent. This is a very peculiar feature, as it must be remembered that crustaceous lichens, taken as a whole, have very great difficulty in holding their own amongst other competiting plants, for they are very easily choked by being even very slightly covered over by larger neighbours. Taken as a whole, the association just described may be regarded as a characteristic Arctic association, poor in phanerogams and rich in lichens.

The following species occurred: —

| | Fruticose lichens | Foliaceous lichens | Crustaceous lichens | F % | Fertile | Sterile |
|---|---|---|---|---|---|---|
| Cetraria aculeata | + | | | 100 | | + |
| Alectoria ochroleuca | + | | | 100 | | + |
| Thamnolia vermicularis | + | | | | | + |
| Cetraria islandica | | + | | 20 | | + |
| Solorina saccata | | + | | 10 | + | |
| Leptogium lacerum | | + | | | | + |
| Peltigera lepidophora | | + | | | | + |
| Lecanora tartarea | | | + | 100 | | + |
| Bacidia flavovirescens | | | + | | | + |
| Caloplaca pyracea | | | + | | + | |

Consequently, 3 sterile fruticose lichens, 4 foliaceous lichens (of which 1 sterile) and 3 crustaceous lichens (of which 1 sterile).

In the districts around Mývatn about Hliðarfjall I noted similar *Dryas*-heaths covering large tracts alternating with bare sand. Here the characteristic plants were also *Dryas* (F % 100), *Empetrum* (F % 100), *Glumifloræ* (F % 100) and abundance of dwarf-birches (F % 70) and *Vaccinium uliginosum* (F % 50). What has been said above about the factors which conditioned the life of the lichens in the heaths near Einarstaðir holds also good as regards these heaths. A fairly rich lichen-covering occurred (F % 100), viz. fruticose lichens (F % 100), foliaceous lichens (F % 50) and crustaceous lichens (F % 90); but, as may be seen, the larger species preponderate slightly, perhaps in correlation with the fact that dwarf-birches are more dominant here and determine the character of the lichen-vegetation.

The following species were found: —

| | Fruticose lichens | Foliaceous lichens | Crustaceous lichens | F % | Fertile | Sterile |
|---|---|---|---|---|---|---|
| Cetraria aculeata | + | | | 100 | | + |
| Alectoria ochroleuca | + | | | 90 | | + |
| Thamnolia vermicularis | + | | | 100 | | + |
| Alectoria nigricans | + | | | 60 | | + |
| Cladonia rangiferina | + | | | 10 | | + |
| Cetraria nivalis | | + | | 30 | | + |
| — islandica | | + | | 20 | | + |
| Lecanora tartarea | | | + | 90 | + | |

Consequently, 5 fruticose lichens, 2 foliaceous lichens and 1 crustaceous lichen.

The species of lichens are not everywhere the same, but they do not vary greatly. In the neighbourhood of Mývatn I traversed large tracts of heath, still poorer in phanerogams, where the frequency-percentage of the lichens was very great (F % 100) and where the landscape displayed dark patches of blackish-brown lichens (*Cetraria islandica, C. nigricans* and *C. corniculata*). Here we might perhaps be justified in speaking of "lichen-heaths," but I think that their contents of *Dryas*, F % 100, make such a name superfluous.

I shall describe one more specimen of a *Dryas*-heath which I investigated near Einarstaðir. The ground was slightly inclined and partially bared in many places. The plant-covering was 8—10 cm. high and consisted of *Dryas* (F % 100), *Empetrum* (F % 100), grasses (F % 100), dwarf-birch (F % 64), *Azalea procumbens* (F % 24), *Vaccinum uliginosum* (F % 16), *Polygonum viviparum* (F % 12) and *Thalictrum alpinum* (F % 4). In this low-growing, open vegetation a quantity of lichens was growing (F % 100), fruticose and foliaceous lichens and *Lecanora tartarea*. The species were: —

Alectoria ochroleuca (fruticose lichen).
— nigricans —
Cetraria nivalis (foliaceous lichen).
— aculeata (fruticose lichen).
Thamnolia vermicularis (fruticose lichen).
Lecanora tartarea (crustaceous lichen).

The types of heath described above are characterized by their level, partially sloping substratum, their open and low-growing vegetation, and chamæphytes and hemicryptophytes with slight leaf-fall which dominate, both physiognomically and ecologically. Consequently, the conditions are favourable to the lichens, and their frequency-percentage is everywhere 100 or thereabout, sometimes crustaceous lichens (mostly *Lecanora tartarea*), sometimes fruticose lichens dominating.

Type II. Dry, knolly heaths with phanerogams on the horizontal surface of the knolls, lichens on the sides of the knolls, and mosses, etc., in the narrow depressions or ruts between the knolls.

A third type of heath which is common in Iceland is the Knolly heath; it has fewer lichens than has the low-lying, level *Dryas-Empetrum*-grass-heath.

I noted some examples of this type of heath from different areas in North Iceland between Einarstaðir (in Aðalreykjadalur) and Mývatn, on Reykjaheiði (south of Axarfjörður, between the Jökulsá and the Laxá), along the left bank of the Laxá (which runs out into Skjalfandi) and in a few other places.

As already mentioned it is peculiar to these heaths that the ground is very knolly, i. e. it consists of mounds with deep intervening depressions. The heaths appear usually or perhaps exclusively to develop on level (not sloping) ground.

Between Einarstaðir and Mývatn (in the valley of the Laxá) heaths were found composed of *Empetrum* (F % 100), grasses (F % 100), dwarf-birch (F % 80), and a few other phanerogams with a considerably less frequency-degree and physiognomical dominance. Lichens were found in all the samples (F % 100), but nevertheless played physiognomically a less considerable part than in the level *Dryas*-grass-*Empetrum*-heath. They all occurred on the sides of the knolls, while the horizontal surfaces of the knolls were covered by phanerogams.

The following species occurred: —

| | Fruticose lichens | Foliaceous lichens | Crustaceous lichens | F % | Fertile | Sterile |
|---|---|---|---|---|---|---|
| Alectoria ochroleuca | + | | | All the species taken together constitute a frequency-percentage 100. The species were not determined on the spot. | | + |
| Stereocaulon paschale | + | | | | | + |
| Cladonia rangiferina | + | | | | | + |
| — sp. | + | | | | | + |
| Thamnolia vermicularis | + | | | | | + |
| Cetraria aculeata | + | | | | | + |
| — islandica | | + | | | | + |
| — nivalis | | + | | | | + |
| — Fahlunensis | | + | | | | + |
| Peltigera rufescens | | + | | | | + |
| — lêpidophora | | + | | | | + |
| Solorina saccata | | + | | | + | |
| Caloplaca vitellina | | | + | | + | |
| Lecanora tartarea | | | + | | | + |

*Alectoria ochroleuca* and *Lecanora tartarea* constituted the most conspicuous features of the landscape, while reindeer moss, which is so common in Danish heaths, was of very little importance there.

On a knolly heath, in the district around Ásbyrgi, sitting on the knolls themselves, I also noted down the following species: —

Cladonia fimbriata (fruticose lichen; sterile).
— cariosa ( — ; fertile).
— pityrea ( — ; sterile).
Leptogium lacerum (foliaceous lichen; sterile).
Peltigera venosa ( — ; fertile).
Bacidia flavo-virescens (crustaceous lichen; sterile).
Psoroma hypnorum ( — ; fertíle).
Lecidea assimilata ( — ; fertile).

Upon the above-mentioned Reykjaheiði, over considerable tracts of land, I also observed a very knolly heath, with high mounds (reaching to the knee and upwards). Between the knolls there were deep, narrow depressions.

The vegetation of the knolls consisted of dwarf-birch (F % 100), *Vaccinium uliginosum* (F % 100), *Empetrum* (F % 100), *Juniperus* (F % 60), grasses (F % 60) and small quantities of *Salix lanata* and *Calluna* and a few other less dominant species.

Mosses and lichens were found to be equally abundant upon the knolls themselves, viz. about frequency-percentage 40 of each.

As for the rest, each individual knoll showed a characteristic vertical grouping of the species, in that the horizontal surface of the knolls was covered by *Empetrum*, dwarf-birch and *Vaccinium*, whilst *Calluna* grew further down towards the depressions. All the lichens occurred on the sides of the knolls, none upon the horizontal surfaces.

In the depressions between the knolls, a vegetation was formed consisting of an equal mixture of *Empetrum*, mosses and grasses, whilst lichens were practically absent. The shade was very deep in the depressions, and this is no doubt the reason why lichens were almost absent there.

On this very characteristic heath, I noted down the following lichens: —

| | |
|---|---|
| Cladonia fimbriata | (fruticose lichen; sterile). |
| — uncialis | ( — ; — ). |
| — rangiferina | ( — ; — ). |
| — gracilis | ( — ; — ). |
| Alectoria ochroleuca | ( — ; — ). |
| — nigricans | ( — ; — ). |
| Stereocaulon paschale | ( — ; — ). |
| Sphærophorus fragilis | ( — ; — ). |
| Cetraria aculeata | ( — ; — ). |
| — islandica | (foliaceous lichen; sterile). |
| Peltigera rufescens | ( — ; — ). |
| Lecanora tartarea | (crustaceous lichen; fertile). |
| Psoroma hypnorum | ( — ; — ). |
| Petusaria xanthostoma | ( — ; — ). |
| Bæomyces byssoides | ( — ; sterile). |
| Buellia scabrosa | ( — ; fertile). |
| Bacidia umbrina | ( — ; — ). |

In a locality on the left bank of the Laxá, and not far from where it flows into Skjalfandi, I observed a similar tract of heath with large, high knolls (about 60—70 cm.) and with a vegetation similar to that in Reykjaheiði. The dominant phanerogamic vegetation upon the knolls consisted of *Empetrum*, grass and *Calluna*, together with small quantities of dwarf-birch, *Arctostaphylos uva ursi, Betula nana, Vaccinium uliginosum* and *Dryas*. On the sides of the knolls were found lichens with a frequency degree 80, viz.

| | | |
|---|---|---|
| Cladonia pityrea | (fruticose lichen; | sterile). |
| — coccifera | ( — ; | — ). |
| — rangiferina | ( — ; | — ). |
| Peltigera rufescens | (foliaceous lichen; | — ). |
| Cetraria islandica | ( — ; | — ). |
| Pertusaria oculata | (crustaceous lichen; | fertile). |
| Psoroma hypnorum | ( — ; | — ). |
| Lecidea assimilata | ( — ; | — ). |
| Bacidia flavovirescens | ( — ; | sterile). |
| Lecanora tartarea | ( — ; | — ). |

The depressions between the knolls were covered with grasses, mosses, *Calluna*, etc., but lichens were absent.

In a locality a few miles from the heath just mentioned a very knolly heath occurred on a lava substratum, with the same phanerogams as that just mentioned, and the lichens also almost exclusively covering the sides of the knolls; only about 15 F % lichens occurring upon the horizontal surface. The species were: —

| | | |
|---|---|---|
| Alectoria ochroleuca | (fruticose lichen; | sterile). |
| Cladonia pityrea | ( — ; | — ). |
| Peltigera venosa | (foliaceous lichen; | sterile). |
| Pannaria brunnea | (crustaceous lichen; | fertile). |
| Psoroma hypnorum | ( — ; | — ). |
| Lecidea helvola | ( — ; | — ). |
| Lecanora tartarea | ( — ; | — ). |
| Bæomyces byssoides | ( — ; | sterile). |

Consequently, it is common to the Knolly heaths we have been considering here, to have a very uneven substratum with an essentially different vegetation upon the knolls and in the depressions between them. Lichens occur in a highly varying frequency-degree (40—80—100 F %) and almost exclusively on the sides of the knolls.

Type III. Wet Mountain-heaths.

Still another type of heath is found in Iceland on mountain heights, in places where the snow-covering lasts a long time. I investigated more closely some such heaths, for instance on the mountains east of Eyjafjörður on Vadlaheiði, on July 3rd, 1913. The snow had just disappeared from the greater part of the heath, but it was still lying in many small patches in the depressions. It was evident that both climate and soil here were distinctly wetter and colder than in those places where the heath-types discussed above, usually develop.

The substratum was very knolly moraine soil, with knolls reaching up to the knees, and with deep, narrow moss-grown depressions between the knolls. Lichens were abundantly present; they occurred chiefly on the sides and on the horizontal surface of the knolls. The latter phenomenon I have only met with on this type of heath, and it is no doubt to be explained as a result of the fact that, owing to the difficult conditions of vegetation, well-developed phanerogams do not occur on the top-surfaces of the knolls, as they occurred on the heaths situated on lower levels on the mountains.

The following phanerogams occurred on the knolls: — Dwarf-willow (F % 90), *Cyperaceæ* (F % 90), *Polygonum viviparum* (F % 90), *Empetrum* (F % 40), *Silene acaulis* (F % 70), *Cassiope hypnoides* (F % 40), *Salix lanata* (F % 20), and lastly there occurred, also on the knolls, 100 F % of lichens (i. e. 90 F % of crustaceous lichens, 60 F % of foliaceous lichens and 60 F % of fruticose lichens).

In the depressions between the knolls there grew dwarf-willows (F % 100), *Polygonum viviparum* (F % 100), a small amount of *Empetrum* and grasses (F % 40), a small amount of *Cyperaceæ*, large quantities of mosses (F % 100), but no lichens.

The reason of this absence of lichens must undoubtedly be sought in the fact that the depressions keep very wet during the short period of summer in which the heath is free from snow: this creates unfavourable conditions for the lichens.

The following lichens were found upon the knolls: —

| | |
|---|---|
| Stereocaulon paschale | (fruticose lichen; sterile). |
| Cladonia turgida | ( — ; — ). |
| — coccifera | ( — ; — ). |
| — pyxidata | ( — ; — ). |
| — fimbriata | ( — ; — ). |
| — rangiferina | ( — ; — ). |
| Cetraria islandica | (foliaceous lichen; sterile). |
| — hiascens | ( — ; — ). |
| Dermatocarpon hepaticum | ( — ; fertile). |
| Peltigera aphtosa | ( — ; sterile). |
| — rufescens | ( — ; — ). |
| — lepidophora | ( — ; — ). |

Solorina saccata (foliaceous lichen; fertile).
Psoroma hypnorum (crustaceous lichen; fertile).
Lecidea elæochroma v. muscorum (crustaceous lichen; fertile).
Bæomyces byssoides (crustaceous lichen; sterile).
Lecanora tartarea ( — ; sterile and fertile).
Buellia parasema v. muscorum (crustaceous lichen; fertile).
Caloplaca Jungermanniæ (crustaceous lichen; fertile).
Lecidea vernalis ( — ; — ).
— assimilata ( — ; — ).
Rinodina mniaræa v. cinnamomea (crustaceous lichen; fertile).

In all, 9 crustaceous lichens, 7 foliaceous lichens and 6 fruticose lichens.

I observed a similar damp mountain-heath, but smaller in extent, on Husavíkrfjall near Skjalfandi (North Iceland). Here also the phanerogamic vegetation consisted mainly of *Empetrum* (F °/o 100) and *Cyperaceæ* (F °/o 100), as also of *Vaccinium uliginosum* (F °/o 80), *Azalea procumbens* (F °/o 80), *Salix* spp. (F °/o 40), grasses (F °/o 20), and some *Alchemilla alpina*, — also lichens (F °/o 100). Here also the heath was knolly, and all the lichens occurred upon the knolls. The crustaceous lichens were dominant.

The following species occurred: —

Stereocaulon denudatum (fruticose lichen; sterile).
Cetraria hiascens (foliaceous lichen; sterile).
Peltigera lepidophora ( — ; — ).
— aphtosa ( — ; — ).
Psoroma hypnorum (crustaceous lichen; fertile).
Lecanora tartarea ( — ; sterile).
Bacidia flavovirescens ( — ; — ).
Lecidea assimilata ( — ; fertile).
Bæomyces byssoides ( — ; sterile).
(An undeterminable, sterile crustaceous lichen).
(Lepraria).

There still remains to be mentioned a small tract of very wet heath which was observed on Vaðlaheiði, on the mountains between Eyjafjördur and Fjoskádalur, where the plant-growth on the 3rd of July, 1913 had recently been bared of snow and was just coming into leaf.

The soil was wet, peaty and springy from the roots of the plants, and was partially covered with *Cyanophyceæ*. The phanerogamic vegetation, which was very low in growth and poorly developed, consisted of dwarf willows (F °/o 95), *Cyperaceæ* (F °/o 85), *Cassiope hypnoides* (F °/o 45), *Alchemilla alpina* (F °/o 25) and a few others which were not very conspicuous (e. g. *Azalea procumbens*, species of *Salix*, etc.); there occurred also a small amount of mosses (F °/o 20), and some lichens (F °/o 45).

It was distinctly seen, that here all vegetation, both phanerogamic and cryptogamic, was greatly retarded by the long-lasting snow-covering, and by the fact that the soil was very wet and cold during the growth-period.

The following species occurred: —

Stereocaulon spp. (poorly developed) (fruticose lichen; sterile).
Peltigera rufescens (foliaceous lichen; sterile).
— aphtosa ( — ; — ).
— lepidophora ( — ; — ).
Leptogium lacerum ( — ; — ).
Psoroma hypnorum (crustaceous lichen; fertile).

In order to obtain a general view of the subject, some typical tables are given here in which the different kinds of heaths are presented in tabular form. They are resumés of the preceding text.

## Type I a.

(Dry heaths on level (not knolly) ground; rich in phanerogams; devoid of, or poor in, lichens).

### Ex. 1. Heath near Háls parsonage (North Iceland).

| | | | |
|---|---|---|---|
| Dwarf birch | F °/o 100 | Dryas | (a small amount) |
| Empetrum | F °/o 100 | Arctostaphylos | (a small amount) |
| Grasses | F °/o 100 | Lichens | F °/o 0 |

### Ex. 2. Heath between Svinadalr and Ás (North Iceland).

| | | | |
|---|---|---|---|
| Dwarf birch | F °/o 100 | Salix spp. | F °/o 20 |
| Glumifloræ | F °/o 100 | Equisetum | F °/o 20 |
| Empetrum | F °/o 95 | Calluna | F °/o 7 |
| Vaccinium uliginosum | F °/o 80 | Lycopodium | F °/o 7 |
| Salix lanata | F °/o 60 | Mosses | F °/o 13 |
| Geranium silvaticum | F °/o 26 | Lichens | F °/o 0 |
| Betula pubescens | F °/o 20 | | |

### Ex. 3. Heath near Einarstaðir (North Iceland).

| | | | |
|---|---|---|---|
| Dwarf birch | F °/o 95 | Dryas | F °/o 45 |
| Empetrum | F °/o 90 | Salix lanata | F °/o 30 |
| Glumifloræ | F °/o 85 | Calluna | F °/o 10 |
| Vaccinium uliginosum | F °/o 65 | Lichens | F °/o 20 |

### Type I b.

(Dry heaths with drifting soil; devoid of lichens).

#### Ex. 1. Heath on mountains between Fnjoskádalur and Eyjafjörður (North Iceland).

| | | | |
|---|---|---|---|
| Dryas | F % 100 | Salix lanata | F % 20 |
| Glumifloræ | F % 100 | Vaccinium uliginosum | F % 20 |
| Dwarf birch | F % 50 | Lichens | F % 0 |
| Empetrum | F % 40 | | |

### Type I c.

(Dry heaths on level (not knolly) ground; heaths poor in phanerogams, but rich in lichens).

#### Ex. 1. Heath near Einarstaðir (North Iceland).

| | | | |
|---|---|---|---|
| Dryas | F % 100 | Dwarf birch | F % 10 |
| Glumifloræ | F % 100 | Silene acaulis | F % 10 |
| Empetrum | F % 90 | Lichens | F % 100 |

#### Ex. 2. Heath near Mývatn (North Iceland).

| | | | |
|---|---|---|---|
| Dryas | F % 100 | Dwarf birch | F % 70 |
| Empetrum | F % 100 | Vaccinium uliginosum | F % 50 |
| Glumifloræ | F % 100 | Lichens | F % 100 |

### Type II.

(Dry, knolly heaths with phanerogams on the horizontal surfaces of the knolls, lichens on the sides of the knolls, mosses, etc., in the depressions between the knolls).

#### Ex. 1. The vegetation of the knolls on the heaths near the Laxá (North Iceland).

| | | | |
|---|---|---|---|
| Empetrum | F % 100 | Dwarf birch | F % 80 |
| Grasses | F % 100 | Lichens | F % 100 |

#### Ex. 2. The vegetation of the knolls on the heaths near the Laxá, near Skjalfandi.

| | | | |
|---|---|---|---|
| Calluna | F % 100 | Dryas | F % 40 |
| Empetrum | F % 100 | Dwarf willow | F % 20 |
| Grasses | F % 100 | Cyperaceæ | F % 20 |
| Arctostophylos | F % 80 | Alchemilla alpina | F % 20 |
| Dwarf birch | F % 80 | Mosses | F % 60 |
| Vaccinium uliginosum | F % 80 | Lichens | F % 80 |

#### Ex. 3. The vegetation of the knolls on Reykjaheiði (North Iceland).

| | | | |
|---|---|---|---|
| Dwarf birch | F % 100 | Salix lanata | (a small amount) |
| Vaccinium uliginosum | F % 100 | Calluna | (a small amount) |
| Empetrum | F % 100 | Mosses | F % 40 |
| Juniperus | F % 60 | Lichens | F % 40 |
| Grasses | F % 60 | | |

### Type III.

(Wet mountain heaths; level or knolly; snow-covering of long persistence; on the whole rich in lichens).

Ex. 1. Vaðlaheiði; the vegetation upon the knolls (North Iceland).

| | | | |
|---|---|---|---|
| Dwarf willow | F % 90 | Cassiope hypnoides | F % 40 |
| Cyperaceæ | F % 90 | Salix lanata | F % 20 |
| Polygonum viviparum | F % 90 | Mosses | F % 100 |
| Empetrum | F % 40 | Lichens | F % 100 |
| Silene acaulis | F % 70 | | |

Ex. 2. Vegetation upon the knolls on a heath on Husavíkrfjall (North Iceland).

| | | | |
|---|---|---|---|
| Empetrum | F % 100 | Salix spp. | F % 40 |
| Cyperaceæ | F % 100 | Grasses | F % 20 |
| Vaccinium uliginosum | F % 80 | Alchemilla alpina | F % 20 |
| Azalea procumbens | F % 80 | Lichens | F % 100 |

Ex. 3. Not knolly, level heath on Vaðlaheiði (North Iceland).

| | | | |
|---|---|---|---|
| Dwarf willow | F % 95 | Alchemilla alpina | F % 25 |
| Cyperaceæ | F % 85 | Lichens | F % 45 |
| Cassiope hypnoides | F % 45 | | |

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As may be seen from the above description, the conception "heath" is rather comprehensive, in that many kinds of vegetation of fairly different physiognomy can be comprised under this name. Heaths however — as defined by me here — have one feature in common: they are all dominated by chamæphytes (about F % 100), in that sometimes one, sometimes another chamæphyte predominates, and sometimes they occur fairly equally mixed. In the meantime all chamæphytes are not equally hospitable towards lichens, for some, e. g. *Salix lanata*, dwarf birches and a few others, sometimes when they are well-developed, cast a deep shade and cover the ground abundantly with fallen leaves, and so they prove detrimental to the lichen-vegetation. Consequently the latter, partly from this reason and partly from others, vary as regards frequency-degree and mass-occurrence without its being possible to understand this fact by simply regarding the frequency-number (F %) of the chamæphytes in the tables. Other peculiarities, viz. the special specific peculiarities (high or low growth, small-leaved or large-leaved, etc.), luxuriant or stunted growth and similar features, cannot at all be expressed by means of the frequency-numbers. Therefore, properly regarded, these prove to be nothing else but a diagnosis whereby to identify the association in nature, in the same way as the systematical description of species serves to identify the systematical species.

The frequency-number, however, affords some guidance to the attainment of an idea of the physiognomy of the association. But certainly much more than this is necessary. An exhaustive word-description, conceɪning all the features which cannot be explained by the frequency-number, is quite indispensable. This applies more especially to the mass-occurrence of the individual growth-forms, where the freqency-number is a very imperfect means of description.

As the heath is defined here, it is defined by its characteristic, dominant phanerogams.

Instead of treating the lichens found in every single plant-association already-known, I could have proceeded along other lines, and have classified the lichen-associations exclusively according to the characteristic lichens found in them, putting aside all accustomed considerations with regard to the phanerogams. Lichenologists will perhaps reproach me for not having taken this course. But I regard it as fully justifiable to make use of the conceptions already familiar regarding associations and to widen these by setting forth what lichen-studies teach us regarding them, in addition to what we have already learned from the phanerogam-studies. If I were to start in a one-sided way along lichen-ecological lines, then, as a matter of course, the conception "heath" could not be maintained, for no mass-occurrence, no frequency-number nor any other means of definition enables us to define the conception "heath" lichenologically. We have seen that the frequency-number for the lichens of heaths ranges from 0 to 100, — consequently, a heath cannot be defined by the frequency-number. Neither will it be possible to do so by a statement of the abundance of lichens, nor by any other means can the term "heath" be defined lichenologically.

When I maintain the conception "heath," it is exclusively a phanerogamic conception which I maintain, because it is old-established and because the heath is easily recognizable in nature when it is defined as I have done it here (F % 100 chamæphytes), and because, everything considered, it is more particularly the phanerogams of the heath which are of importance as regards the luxuriancy or the reverse of the lichens.

The following species have been found on the heaths of Iceland: —

| | | |
|---|---|---|
| Alectoria ochroleuca | (fruticose; | podetia-wanderer). |
| — nigricans | ( — ; | — ). |
| Thamnolia vermicularis | ( — ; | — ). |
| Cladonia rangiferina | ( — ; | — ). |
| — uncialis | ( — ; | — ). |
| — gracilis | ( — ; | hypothallus-wanderer [usually]). |
| — turgida | ( — ; | — — ). |
| — fimbriata | ( — ; | — ). |
| — cariosa | ( — ; | — ). |
| — pityrea | ( — ; | — ). |
| — coccifera | ( — ; | — ). |
| Stereocaulon paschale | ( — ; | podetia-wanderer). |
| — denudatum | ( — ; | — ). |
| Sphærophorus fragilis | ( — ; | — ). |
| Cetraria aculeata | ( — ; | — ). |
| — islandica | (foliaceous; | erect). |
| — nivalis | ( — ; | — ) |
| — Fahlunensis | ( — ; | procumbent). |
| — hiascens | ( — ; | erect). |
| Peltigera aphtosa | ( — ; | procumbent). |
| — venosa | ( — ; | — ). |
| — rufescens | ( — ; | — ). |
| — lepidophora | ( — ; | — ). |
| Dermatocarpon hepaticum | ( — ; | — ). |
| Solorina saccata | ( — ; | — ). |
| Leptogium lacerum | ( — ; | — ). |
| Lecanora tartarea | | (crustaceous). |
| Psoroma hypnorum | | — |
| Pertusaria xanthostoma | | — |
| — oculata | | — |
| Caloplaca pyracea | | — |
| — Jungermanniæ | | — |
| — vitellina | | — |
| Pannaria brunnea | | — |
| Rinodina mniaræa v. cinnamomea | | — |
| Bacidia flavovirescens | | — |
| — umbrina | | — |
| Baeomyces byssoides | | — |
| Buellia scabrosa | | — |
| — parasema v. muscorum | | — |
| Lecidea vernalis | | — |
| — helvola | | — |
| — elæochroma v. muscorum | | — |
| — assimilata | | — |
| Lepraria | | — |

To these must probably be added almost all the other species which have been found, some by me on the ground in other plant-associations, and some by others on Icelandic soil without closer notification of the association. There is hardly a single Icelandic earth-lichen which avoids the heath; they certainly all occur there occasionally, although those enumerated in the above list doubtless form the nucleus of the lichen-vegetation of the heath.

As may be seen, there have been found 9 fruticose podetia-wanderers, 6 fruticose hypothallus-wanderers, 3 erect and 8 procumbent foliaceous lichens, and 19 crustaceous lichens.

But, as already mentioned, to these must probably be added all the other earth-lichens, viz. 12 fruticose, 16 foliaceous and 48 crustaceous species.

It is much to be desired that we could compare the lichen-vegetation of the Icelandic heaths with that in other countries, for instance in Denmark. Our knowledge of the lichens from heaths in other parts of the globe, is practically *nil.* As we know, lichen-ecological observations have, up to the present date, played a very subordinate part in scientific work.

Some of the most conspicuous points which there could be reason to compare are the agreements or disagreements as regards (1) systematic species, (2) growth-forms, (3) frequency-degree and (4) mass-occurrence.

With regard to systematic species there is a very conspicuous difference between the Danish and the Icelandic heaths. Whilst the Danish heaths — as far as they contain lichens at all — are entirely dominated by *Cladonia rangiferina,* the Icelandic heaths are not dominated by any single species. It is true, reindeer moss occurs, but only in small quantities. Of far more frequent occurrence are *Alectoria ochroleuca, Thamnolia vermicularis, Cetraria islandica* and *Lecanora tartarea.* Thus the Icelandic heaths cannot be characterized by any single species. We shall not, however, go further into details as regards the systematic species, it will suffice to refer to the list of the Danish Heath-lichens in "Danske Licheners Økologi" (p. 305) and, as regards the Icelandic lichens, to the list of species given above.

The growth-forms are not exactly the same on the heaths of Iceland and Denmark. Whilst Denmark has 21 fruticose lichens (57 °/₀ of the heath-lichens), 3 foliaceous lichens (8 °/₀) and 13 crustaceous lichens (35 °/₀), in Iceland the proportions of growth-forms are distributed as follows: — 15 are fruticose lichens (33 °/₀), 11 are foliaceous lichens (24.5 °/₀), and 19 are crustaceous lichens (42 °/₀).

The Growth-forms of the Heath-lichens.

| | Fruticose | Foliaceous | Crustaceous | Number of species |
|---|---|---|---|---|
| Danish heaths ............. | 57 % | 8 % | 35 % | 37 |
| Icelandic heaths............ | 33 % | 24.5 % | 42 % | 45 |

Of these numbers the Danish will scarcely be altered to any extent, whilst the Icelandic, through more numerous and more detailed investigations, will probably undergo a very radical alteration in favour of the crustaceous lichens. On riding across the heaths in Iceland it strikes one that the crustaceous lichens are more dominant there than in Denmark. This agrees closely with the fact that the chamæphytes are, as a rule, obviously poorer and less well-developed there than on Danish heaths, and are consequently more hospitable towards lichens, than are the taller, well-grown species.

With respect to the frequency-number of the lichens, none are to hand from Denmark. Those from Iceland are given above. Judging from what I remember, and compared with what I wrote on the subject in "Danske Licheners Økologi" (p. 301 et seq.), I am, however, inclined to believe that in Denmark all possible frequency-numbers occur, from 0 to 100, as in Iceland, in that we have in Denmark *Calluna*-heaths, which are sometimes very rich in lichens and sometimes almost devoid of them. In this respect there is scarcely any difference worth mentioning between the Danish and the Icelandic heaths.

It is as difficult or, properly speaking, still more difficult to state anything about the mass-occurrence of the lichens in Denmark compared with Iceland. I must, however, enter somewhat more closely into this question, as it is, in addition, of more far-reaching ecological importance.

If we are briefly to compare Iceland and Denmark as regards their lichen-vegetation on heaths, as far as this can be done on the basis of the investigations hitherto made, which in a high degree require to be more detailed as regards both countries, especially with reference to the mass-occurrence of the species, it may be stated that: —

The heaths of Iceland and Denmark, regarded from the point of view of a landscape, resemble each other as regards their whole physiognomical feature, besides which there is a great similiarity as regards the frequency-degree of the lichens (as far as this can be decided by a rough estimate). The difference as regards mass-occurrence (stated in weight) is not known (but at a rough estimate it would not seem to be great; the mass-occurrence is greatest perhaps on the Danish heaths). With respect to growth-forms the similiarity also appears to be rather great, but it will probably, on a closer investigation, be lessened by the fact that more crustaceous lichens will be found on the heaths of Iceland, than on those of Denmark. The systematic species of the two countries differ by no means slightly from each other.

It may therefore be said generally, that the conception "heath," as we know it from Denmark, does not undergo any great fundamental change through a closer investigation of the Icelandic heaths.

After having thus dwelt upon the appearance of the lichen-vegetation, it now remains for us briefly to point out the conditions which the lichens find on the heath and which have a determining influence as regards whether they thrive or do not.

The following are the most essential: —

(1) Nowhere on the heaths did I observe, that the chemical composition of the soil had a detrimental influence on the lichen-vegetation — but in other localities, for instance near Solfataras, etc., the conditions were very unfavourable to them.

(2) Thermal conditions and water contents are so closely connected with each other, that it is usually difficult to separate them. Damp, cold soil is generally unfavourable to many lichens (compare Bogs), whilst desiccation is not detrimental to them in a climate where the precipitation is as great as it is in Iceland. The greatest degree of moisture which permits the growth of heath-vegetation (i. e. F % 100 chamæphytes) is however also favourable to lichens (mountain-heaths at higher altitudes).

(3) Loose, drifting soil frequently bears heath-vegetation, when the soil does not drift very greatly. But such heaths are devoid of lichens.

(4) Leaf-fall, which covers the lichens, does not hamper them greatly on the heaths; luxuriant dwarf-birch growths and in some degree a few other larger species may, however, by this means prevent the appearance of lichens.

(5) The snow-covering in some localities has a not unfavourable influence provided it disappears for a few weeks every summer without leaving too great masses of water behind it (in which case mosses and algæ gain the upper hand). The heaths of mountain heights are sometimes rather rich in lichens.

(6) Conditions concerning the *niveau* of the ground, appear to be of fairly great importance, inasmuch as knolly ground, in most cases, bears lichens on the sides of the knolls, whilst the horizontal surfaces of the knolls are covered with lichens in damp heaths only. The depressions between the knolls frequently bear mosses and no lichens at all or only a minute quantity. Here, it is most probably, the conditions of moisture that make themselves felt.

(7) The plant-covering (the competitors) plays essentially the part of contending against the lichens by covering them with decaying leaves (see above) or by overshadowing them. Both these drawbacks occur on Icelandic as well as on Danish heaths, where the higher plant-growth is more luxuriant. But experience shows that the growth and luxuriance of the chamæphytes themselves is not great enough on all heaths to exclude lichens.

### f. Coppices.

These, the only phanerophytic birch-vegetation of Iceland, are, as elsewhere mentioned in this work (see vol. I, p. 312 et seq.), widely distributed over the whole of the island, — but may, however, possibly be absent from a narrow strip of North Iceland. They do not extend upwards on the mountains beyond a height of about 550 metres, and the majority of them are situated at lower levels. Everywhere the coppices consist, to a certain extent, of rather poorly developed individuals, the height of which ranges from that of a low-growing shrub to a height of several metres (8—9). (The most frequent height is 1—2 metres). The density of the tree-trunks varies considerably, which consequently results in a fairly varying ground-vegetation.

The soil is often knolly clay, and rests on gravel or also on rock, but sometimes there is a stony bottom, and sometimes the bottom is boggy soil (Thoroddsen, p. 342). According to H. Jónsson the most common ground-vegetations are: heather-moor (of *Empetrum nigrum, Arctostaphylos uva ursi* and *Vaccinium uliginosum*), grassland (of *Agrostis vulgaris, Aira flexuosa, Anthoxanthum, Festuca rubra*), herb-flat (of *Angelica silvestris, Spiræa Ulmaria*, etc.) and moss-vegetation (of *Hylocomium proliferum, H. triquetrum, H. squarrosum, H. parietinum* and *Climacium dendroides*).

In Hálsskogur I noted a vegetation consisting of various grasses, of *Arctostophylos,* dwarf birches, *Vaccinium uliginosum, Equisetum, Rubus saxatilis, Empetrum* and a few other plants. The ground was in part covered with decaying birch-leaves, forming a layer of about 2—6 cm. in depth, and the trunks had an average height of about 3 metres. The ground there was quite devoid of lichens as were also the trunks.

The information contained in the literature on the subject, as regards the ground-vegetation of coppices, is not very exhaustive, and does not give much information with regard to how far lichens occur or not. One must, however, expect that coppices, the floor of which is occupied by heath-vegetation, can also harbour lichens, but nothing concerning this is mentioned in the literature on the subject, and I myself have not seen any coppices with an actual ground-vegetation of heath. Nor is there any information to hand as to how far grassland, mat-herbage or moss-carpets, when occurring as ground-vegetation, shelter lichens.

It is, however, certain that earth-lichens may occur here and there, but even in the most favourable cases, they are but few in number and physiognomically little dominant.

H. Jónsson mentions for instance "Cladonia-species" (which?) as occurring near Breiðibolstaðir (South Iceland) and says that they occur there "abundantly, but are far from playing so important a part and from being so widely distributed, as in South Greenland."

I myself only once found a small tuft of *Cladonia pityrea.*

I do not doubt that, on the whole, the floor of the coppices may be regarded as poor in, or devoid of, lichens and the reason for this is undoubtedly to be found as usual, in the want of light and in the leaf-fall.

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Nor does the ground-vegetation of willow-coppices appear to include lichens.

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The epiphytic flora will be mentioned elsewhere, so I shall not enter into the subject more fully here, where only the earth-lichens of the plant-associations are being discussed.

## 3. ROCK-LICHEN ASSOCIATION.

By far the greater part of the rocky substratum of Iceland consists of basalt, but recent lava and liparite occur also, the latter, however, in a small quantity only. All these three kinds of rocks are fine-grained volcanic rocks. Considered from a chemical point of view, lipartite differs distinctly from the other two, in that it is of the same mineralogical composition as granite, and is consequently rich in silica.

How the lichens penetrate into these substrata with their hyphæ has not been investigated even in the case of a single species.

The same applies also to the Icelandic tuff — cemented volcanic ashes of a similar chemical composition as lava, but of quite different physical qualities.

We shall now consider more fully the individual substrata and their vegetation.

### a. Basalt.

On this kind of rock there occur, as on many others, lichen-vegetations which vary greatly. They may be classified according to different principles exactly as is the case with vegetations on loose soil. I consider it best — as in the case of earth-vegetations — to take the plants themselves as a guide in the classification, and shall therefore treat the associations in three main groups, viz. associations of crustaceous, foliaceous and fruticose lichens respectively; under the last group there are two essentially different sections, viz. erect and pendulous lichens.

With regard to these associations it may be said in general that: —

Crustaceous-lichen-associations grow on rocks of all possible angles of declivity — on horizontal surfaces, on vertical or sloping rock-faces, and on roofs of caves.

Foliaceous lichens grow in a similar manner to crustaceous lichens on horizontal surfaces, on vertical or sloping rock-faces, and in caves.

Erect fruticose lichens are found only on horizontal and on gently inclined surfaces, because they are as a rule very slightly attached to the substratum, in fact, they are generally attached to other plants which in their turn are anchored to the substratum, they are not themselves immediately attached to the rock-substratum. They are absent from vertical rock-faces and from the roofs of caves

Pendulous fruticose lichens can be found on rocks of all degrees of inclination: horizontal surfaces, vertical and sloping rock-faces, etc.

The associations may be — as in the case of the phanerogams — divided into formations, facies or whatever we may choose to call them, and they may be named after the one or more species which dominate the community.

In addition to the chemical and physical qualities of the rock and the degree of inclination of the substratum, there are other conditions which play a part as regards the physiognomy of the vegetation, primarily conditions pertaining to moisture, and the competitive relations between the species themselves.

Thus the same vegetations are not found on rocks wetted with spray, on submerged rocks and on dry emergent rocks. The quality of the water also — salt, fresh or distilled (rain) water — plays an essential rôle here. Moreover, it is of no slight importance, whether the rocks are frequently manured by birds or whether this does not take place.

We can, as already mentioned, divide the associations, which are produced by the action of each of these complexes of life-conditions, in very different ways: we may speak of "nitrophilous associations" (Sernander), of halophilous associations, associations of hollows, associations of horizontal surfaces, etc., according to our knowledge of the factors which determine the association. But this mode of naming them appears to me to be extremely unpractical, because we may very often be at a loss with regard to the group to which we are to refer the association in question. It is in reality not at all possible to draw a decided line between a nitrophilous and a non-nitrophilous association: all lichens are in fact nitrophilous to some degree.

It is the same difficulty with which the ecologists have had to contend as regards the soil-associations, but in this department order is appearing owing to the fact that the association is not named after factors — as a rule imperfectly known — which condition its well-being ("sand-vegetation," "rock-vegetation," "xerophilous coppice," etc.), but after the plants themselves (phanerophyte-vegetation, chamæphyte-vegetation, etc.).

Whether one choose the one or the other mode of procedure is by no means a matter of indifference. The associations living in nature are naturally the same, whether we give them the one or the other name, but for the sake of synonymy it is necessary to have simple and easily definable conceptions, and this is best done by naming the association after the dominant plant-growth-form.

With regard to lichens we will therefore employ as the principle of main division the grouping indicated above, viz. that of crustaceous, foliaceous and fruticose lichens, and, as far as possible, follow them on each rock-substratum.

The Crustaceous-lichen-association is widely distributed on all kinds of basalt. Several types (formations) may be distinguished, e. g. mixed crustaceous-lichen-formations, *Staurothele*-formations, *Caloplaca*-formations and *Verrucaria*-formations.

Mixed crustaceous-lichen-formations are widely distributed especially on the almost vertical faces of basalt rocks along the fjords.

The plant-density is often rather slight, in that the individuals are not in contact with each other, i. e. they leave the rock-surface visible between them. In such places, therefore, there is no actual competition between the species, and the community is consequently analogous to the desert-vegetation of loose soil.

In other places the plants may be closely in contact with each other, and struggle for space. In this case competition arises, where sometimes the one and sometimes the other plant predominates, but all the circumstances concerning this interesting struggle have not been investigated and are not known.

Many interesting observations could undoubtedly be made as regards the frequency-number and mass-occurrence of the single species under different conditions, but all this requires both a long sojourn and also patient investigations on the spot. I presume, that among other things, we should thereby acquire a closer knowledge of the life-necessities of each species, and that we should be able to sub-divide the "mixed crustaceous-lichen-associations" into perhaps as many formations as the number of the systematic species. But this the future must decide.

To this association almost all the crustaceous lichens of Iceland must undoubtedly be referred, i. e. somewhat above 100 species. There are, however, some which occur repeatedly and which ought to be enumerated as characteristic of the association, viz.

| | |
|---|---|
| Lecanora cinerea. | Lecanora intricata. |
| — pallescens. | — frustulosa. |
| — atra. | — sordida v. glaucoma. |

Lecidea pantherina.
— cyanea.
— erratica.
— speirea.
— lapicida.
— elæochroma.
Lecidea elata.
Rhizocarpon geographicum.
— geminatum.
Caloplaca vitellina.
Physcia aipolia.

Occasionally there also occur mixed with the above: *Racodium rupestre, Polyblastia hyperborea, Acarospora Heppii, A. fuscata, Catillaria athallina* and a few foliaceous lichens *(Parmelia lanata, Gyrophora cylindrica* and *G. erosa).*

This association grows from the coast — where it begins a short distance above the *Verrucaria*-belt — to far up the mountains, where it stops at the snow-line. As regards its luxuriancy at various heights above sea-level, very little is known, but it appears to be least developed at great altitudes. I myself had a distinct impression of this for instance from my observations on the mountain Sulur near Eyjafjörður and the mountains near Húsavík (on the north coast), and H. Jónsson states the same as regards the conditions on Snæfellsnæs; he writes: "The same is the case with the crustaceous lichens as with the phanerogams; they occurred extremely sparsely on the stones in the upper part of the rocky flat." The association is quite absent from the pebbles on the shore; it cannot endure inundation by salt water.

The Staurothele-association occurs almost exclusively by waterfalls, where it forms black crusts on the rocks in all places where the spray from the falling water reaches. It is extremely characteristic of all such localities. Mixed among the slender, black thalli of *Staurothele* occur crust-like thalli of various *Cyanophyceæ,* so that it is often difficult to decide which of them is the more abundant. I have never found any other species of lichen directly connected with this association, which therefore contains only the one species *Staurothele clopima.*

The Caloplaca-association *(Placodium stramineum, P. alphoplacum* and *Caloplaca murorum),* which on Bornholm (Denmark) is so common on the shore above the *Verrucaria*-belt, is very little developed in Iceland. I found only slight indications of it in Seyðisfjörður. Helgi Jónsson records it from West Iceland.

The Verrucaria-association, formed by *V. maura* and an inconsiderable quantity of *Lichina confinis,* which is well-known from Bornholm and from all the other rocky coasts of the North, is also found in Iceland, where it borders the sea-shore from high-water level as far upwards as the spray of the waves reaches. I have seen it developed very distinctly for instance on the sides of Seyðisfjörður, Reyðarfjörður, Eyjafjörður and in several other places. Its natural history is in all respects a repetition of what we know from Denmark, Finland, etc. Therefore, there is no special reason to dwell upon it more fully here.

Foliaceous-lichen-associations are found here and there, fairly well-developed, especially in the low land, where they frequently consist of *Parmelia saxatilis, P. lanata, P. stygia* or of species of *Gyrophora (G. cylindrica, arctica, erosa).* Sometimes the one, sometimes the other species predominates, whereby several formations may be distinguished ("*Parmelia*-formation," "*Gyrophora*-formation," etc.). As far as my observations go these communities are most luxuriantly developed in places where it is light and damp. For instance, they are found well-developed by the waterfalls at the head of Seyðisfjörður and by Dettifoss (North Iceland).

The density of the plants is as a rule high and consequently the competition is keen, but regarding this point no detailed investigations have been made. The crustaceous lichens are however mercilessly exterminated when *Parmelia saxatilis* puts in its appearance; in many places this process of extermination may be observed in various stages.

It is more rare for the *Gyrophora* spp. to dominate so decidedly; I did not see them as pure growths, as they may be found in Arctic countries.

The Fruticose-lichen-association. Helgi Jónsson records that *Ramalina cuspidata* often occurs abundantly on the rocks of South-west Iceland. He does not, however, state more explicitely whether it actually forms carpets. I myself never saw it occur in such abundance as to make it justifiable to speak of *Ramalina*-carpets, like those found on the shores of Bornholm. Nor did I come across such a feature on the coastal rocks of Iceland.

*Usnea melaxantha* may sometimes be found in tolerable abundance near the snow-line on mountain heights, but I did not see this species either actually form carpets.

Therefore it appears that Iceland has no continuous carpets of pendulous fruticose lichens which are attached to the rock-substratum itself like those we have in Denmark.

Erect fruticose lichens (*Alectoria, Stereocaulon, Cladonia, Cetraria aculeata,* etc.) are frequently found covering the rock-substratum at almost all altitudes. But it must be remembered that all the lichens belonging to this group, are more or less dependent upon the presence of other plants, for — as I have fully explained in my "Danske Licheners Økologi" — they always follow an initial vegetation of other lichens (crustaceous or foliaceous lichens) or of mosses and live so actually on the soil formed by them that they are not even attached to the rock-substratum, but on the contrary, in some cases die away at the base. This circumstance has also been considered more fully in the present treatise under the heading "Earth-lichens" and will not be discussed further here.

An exception to this rule is formed, it appears, by *Stereocaulon denudatum*, which at least appears to be able to live upon the rock itself. I have not found it, however, upon basalt, but in great abundance upon recent lava, and shall treat of it under the heading "Lava."

### b. Lava.

The post-glacial lava is black, with many small cavities and vesicles, and sometimes of an appearance similar to cokes. When it gradually becomes covered with vegetation, this usually consists of *Grimmia*-carpets, which again can develop into heaths, etc. But those areas which do not immediately become moss-covered, frequently become first lichen-covered. The lichens may occur on the rock-substratum itself, at first crustaceous lichens, then foliaceous and fruticose lichens. The latter are, however, probably most frequent in places where moss had first been growing.

I have not had the opportunity of seeing lava at all altitudes, and therefore I am not prepared to say how far it supports *Verrucaria*- and *Caloplaca*-associations near the sea-shore, which it is evidently able to do. My observations are made from lava-streams in rather low-lying land, up to a height of about 300 metres above sea-level, and there I found the following associations: —

Crustaceous-lichen association. By way of example I quote such associations from a lava-field near Havnefjord. I found growing here, on sloping surfaces, a vegetation which consisted mainly of crustaceous lichens; in 90 % of the sample-areas were found a few foliaceous lichens (1 %), fruticose lichens (40 %) and moss (90 %). The latter did not cover the rock to such an extent, as might be expected, judging by the high frequency-number. On the whole, the substratum was visible everywhere between the lichens. The following species were found: —

| | |
|---|---|
| Lecanora atra, | crustaceous lichen. |
| — badia, | — |
| — varia, | — |
| — tartarea, | — |
| — pallescens, | — |
| Caloplaca vitellina, | — |
| — ferruginea v. obscura, | — |
| Acarospora Heppii, | — |
| — fuscata, | — |
| Hæmatomma coccineum, | — |
| Lecidea elæochroma, | — |
| — auriculata, | — |
| — convexa, | — |
| — panæola, | — |
| — pantherina, | — |
| — cinereoatra, | — |
| Buellia myriocarpa, | — |
| Rhizocarpon geographicum, | — |
| Sterile crustaceous lichens, | — |
| Lepraria, | — |

Parmelia saxatilis, foliaceous lichen.
Ramalina subfarinacea, pendulous fruticose lichen.
Stereocaulon denudatum, erect fruticose lichen.

In a locality, close to the one described above, there occurred on a vertical lava-face a crustaceous-lichen growth, poor in individuals; fruticose and foliaceous lichens were quite absent from it; and all the sample-areas showed bare rocky substratum, whilst not even all of them contained crustaceous lichens, which were found only in 76 % of the samples. All other plants were absent.

A Foliaceous-lichen-association was observed by me, for instance near the farm Reykjahlið, near Mývatn (North Iceland). The dominant species were: —

| | |
|---|---|
| Parmelia saxatilis, | foliaceous lichen. |
| Physcia stellaris, | — |
| Xanthoria lychnea, | — |
| Stereocaulon denudatum, | fruticose lichen. |
| Lecanora saxatilis, | crustaceous lichen. |
| Caloplaca elegans, | — |
| — vitellina, | — |
| Lecidea confluens, | — |
| — assimilata, | — |
| — paupercula, | — |
| — pantherina, | — |
| Rhizocarpon geographicum, | — |
| — geminatum, | — |

I had not time to determine the frequency-numbers of the crustaceous, foliaceous and fruticose lichens, but even on a superficial view, it was evident that foliaceous lichens were in the majority, and that the vegetation was fairly dense, so that competition existed amongst the individuals.

Fruticose-lichen-association, very vigorously developed, was observed by me on lava in another locality near Mývatn. Here I traversed a large tract of country, which was entirely covered by a thick, well-developed carpet, consisting almost exclusively of *Stereocaulon denudatum*, which formed a very dense, pure and fine growth, without any intermixture of other species worth mentioning. This species of *Stereocaulon*, as long as it is young, is able to grow on bare (but of course weathered) rock. Afterwards its podetia die away at the base, and form a peaty layer; as a consequence it gradually becomes an earth-lichen. But, at any rate to begin with, it can occur as a rock-lichen, i. e. it does not require a preceding growth of mosses to which to attach itself. But from this it does not follow that, when occurring as a carpet, it has always been the first species to arrive. In fact, I have observed it growing upon moss.

Consequently, we have here to do with a form intermediate between an earth-lichen-association, and a rock-lichen-association.

Another fruticose-lichen-association on lava is formed by *Ramalina subfarinacea*, which lives immediately attached to the rock-substratum, and never develops into an earth-lichen. I found this species near Havnefjord, where it grew on the top of a mass of lava, mixed with some crustaceous lichens (F % 100), which, although they occurred in all the sample-areas, were evidently on the point of becoming overgrown, and killed by the *Ramalina*.

How many species in all are found on lava, is not known, but a list is given above of those which occur most frequently on it. I am, however, inclined to believe that, practically, all the rock-lichens found in Iceland can grow both on lava and on basalt; partly because the two kinds of rock are in the main of the same chemical composition, and partly because it appears that lichens are very partial to lava as a substratum. From a superficial point of view, the vegetation of the lava appears to be considerably richer in quantity, than that of the basalt; for instance, I never saw such immense quantities of *Stereocaulon* on the latter, as on lava. But it is desirable that the conditions concerning masses, by the method of weight, and the number of the species, may be investigated more thoroughly.

### c. Tuff.

On the tuff-deposits of Iceland, lichens occur very sparsely. The tuff consists of rather loosely-connected ash-particles, and is naturally stratified like other æolian sedimentary deposits. Its chemical composition comes very near to that of the basalt and the lava, but its physical conditions, as a plant-substratum, differ very essentially, since, in the first place, its porosity causes all the water which falls upon it, to be absorbed and retained, as in a piece of blotting-paper, so that the lichens are deprived of this water; and in the second place it has, in all probability, quite different thermal qualities, inasmuch as it no doubt gets heated far more slowly than the two other kinds of rock.

Taken as a whole, it may be said that tuff is a very unfavourable lichen-substratum. But then I must acknowledge that I saw it only in a few places, partly as a shore-rock, where it was quite devoid of lichens, since both *Verrucaria*- and *Caloplaca*-vegetation were totally absent; and partly in the interior of the country, where, in a few places, I saw old crater-cones (extinct) consisting of tuff, where the vegetation was so scanty that everything but lichens was wanting, consequently both mosses and phanerogams, whilst the lichen-vegetation was restricted to a few specimens, which, if the frequency-number had been determined, would hardly have amounted to one individual per 1000 sample-areas (à 2 dm.²).

Not far from the farm Ljósavatn, between Háls and Einarstaðir (North Iceland) I found specimens — perhaps 50 in all — of a sterile, undeterminable, crustaceous lichen. On tuff in Reyðarfjörður (East Iceland) I found a few specimens of

Lecanora Hageni,
— calcarea,
Arthonia ruderalis.

Such paucity of lichens as this on porous rock, is known almost nowhere else but in Denmark in the case of the chalk. It is possible that the cause of this is the same in both cases, viz., the unfavourable conditions with regard to moisture. I can express no opinion as to whether the tuff occurs anywhere on the island, under conditions which permit it to bear lichens, but, in the literature on the subject, I have not found any allusion made to anything of the kind.

### d. Liparite.

This rock is not widely distributed in Iceland, and therefore plays a very inferior part in the physiognomy of the country. In chemical respects it is of the same composition as granite, since it is the corresponding volcanic rock.

I have only had an opportunity of investigating its vegetation in very few localities, viz., in Hliðarfjall, near the farm Reykjahlið, close to Mývatn, and near Geysir. I am therefore not prepared to state anything about the vegetation it supports, when it stands in salt water, nor what the conditions on it may possibly be, when we find it as a lofty mountain.

Near Geysir, on the mountain situated close to the spring itself, I found a very scanty vegetation consisting of crustaceous lichens (F % 100), a few foliaceous lichens (F % 36) and a little moss (F % 16). The mountain was far from being covered, consequently, the vegetation was desert-like, and all the specimens were small, and only slightly developed. The following species were found: —

| | |
|---|---|
| Lecanora pallescens, | crustaceous lichen. |
| — varia | — |
| Lecidea auriculata, | — |
| Sterile, undeterminable, | — |
| Rhizocarpon geographicum, | — |
| Gyrophora erosa, | foliaceous lichen. |
| — cylindrica, | — |

On Hliðarfjall near Mývatn, at the base of a solitary mountain-summit, which rises above the surrounding country, there is a mighty talus of large fallen blocks, and of débris. Upon the blocks, and upon the mountain itself, there occurred a scanty vegetation — open and desert-like — of various foliaceous and crustaceous lichens. The following species were found: —

| | |
|---|---|
| Lecanora polytropa, | crustaceous lichen. |
| — (Aspicilia) alpina, | — |
| — impavida, | — |
| Rhizocarpon geographicum, | — |
| Parmelia lanata, | foliaceous lichen. |
| Gyrophora erosa, | — |
| — cylindrica, | — |

Gyrophora arctica, foliaceous lichen.
— hyperborea, —
Stereocaulon denudatum v. pulvinatum, fruticose lichen.

Taken as a whole, the liparite impresses one as being a very poor substratum for lichens. This fact is curious, considering that granite, which has the same chemical composition as liparite, is so rich in lichens. It must therefore be presumed, that the difference is due to physical conditions.

# V. THE VERTICAL DISTRIBUTION OF THE LICHENS.

Thoroddsen, in vol. I of this work, has given an account of the little which is, as yet, known as regards the vertical distribution of the phanerogams. It must unfortunately be admitted, that our knowledge of the lichens is, in this respect, still more scanty. The object which it was desirable to attain, viz., a thorough knowledge of the occurrence of each single species, from sea-level upwards on the mountains, is still unattained, but something is known on the subject.

It is not known with certainty, as regards any single species, how far it has any other upper limit on the mountains, than the snow-line, with the sole exception of the decidedly maritime species *Verrucaria maura* and *Lichina confinis*, which are connected only with localities washed by the spray of the waves.

Nor is it known with any certainty as regards a single species, how far it has any other lower limit than the sea-level; several species are, however, known, regarding which it is, at any rate, probable that they are associated with cold mountain heights, and avoid the milder climate of the low land. This is the case, for instance, with *Usnea melaxantha* and *Solorina crocea*, which hardly ever descend anywhere into the lowlands, without its being possible to give a tolerably definite lower limit.

In order, however, to give a small contribution to our knowledge regarding this point, I shall proceed to enumerate the lichens found in a few localities situated on high ground: —

On Hliðarfjall, which is mentioned under the rock-lichen-associations, under "Liparite," there grows a scanty vegetation consisting of the following species: —

| | |
|---|---|
| Rhizocarpon geographicum. | Gyrophora cylindrica. |
| Lecanora polytropa. | — arctica. |
| — alpina. | — hyperborea. |
| Gyrophora erosa. | Parmelia lanata. |

The mountain is 790 metres high. The species found there were not, however, collected on the summit itself — which is almost inaccessible — but yet not far below it.

On Sulur, near Eyjafjörður (height about 1400 metres), I found the steep mountain summit free from snow on July 5th, 1913. The summit itself was almost devoid of lichens; there occurred only a few specimens of: —

Lecanora polytropa.
— varia.
— (Aspicilia) gibbosa.
Caloplaca vitellina.
— elegans.
— pyracea.
— cerina.
Lecidea auriculata.
Lecidea fuscoatra.
— Siebenhaariana.
Rhizocarpon geminatum.
— geographicum.
Parmelia lanata.
Gyrophora erosa.
— arctica.
Usnea melaxantha.

On detached blocks of rock and on smaller rock-fragments immediately below the summit, there occurred: —

Lecidea lapicida.
— confluens.
— subconfluens.
— panæola.
Lecanora gibbosa.
— varia.
— polytropa.
— badia.
Rhizocarpon geographicum.
Caloplaca vitellina.
Pertusaria oculata.
Parmelia lanata.
— saxatilis.
Cetraria Fahlunensis.
Gyrophora cylindrica.
— erosa.
— hyperborea.

On loose soil there occurred a scattered desert (rocky-flat-) vegetation, consisting of a few plants of *Dryas, Silene acaulis* and some other species *(Ranunculus glacialis, Saxifraga oppositifolia)* and a little moss; intermixed with this vegetation occurred some lichens, which grew exclusively on the mosses, and were quite absent from the purely inorganic soil. The following species were found: —

Lecanora tartarea.
— castanea.
Pertusaria oculata.
Caloplaca Jungermanniæ.
Psoroma Hypnorum.
Lecidea assimilata.
Bacidia flavovirescens.
Buellia parasema (v. papillata and triphragmia).
Rinodina mniaræa v. cinnamomea.
Pannaria microphylla.
Dermatocarpon hepaticum.
Peltigera aphtosa.
Solorina crocea.
Cetraria Fahlunensis.
— aculeata.
— islandica.
Alectoria nigricans.
Cladonia turgida.
— pyxidata.
— rangiferina.
— coccifera.
Thamnolia vermicularis.
Stereocaulon spp.

The species here enumerated, which occur on rock and on earth, consequently represent what may be called the nival lichen-flora of Iceland; they are the most hardy species, and ascend far above the coppices, heaths and grass-carpets, right up to the snow-line. With regard to the majority of them it may be asserted — as already mentioned — that they also descend far into the low land; only *Solorina crocea* and *Usnea melaxantha* can with certainty be regarded as exclusively mountain-height plants.

But in addition to the species mentioned here, various others will no doubt be found in the future, when more mountain summits and the interior plateau of Iceland have been better investigated.

In the above, when discussing the earth-lichens, those species have been mentioned, which are found in the common earth-plant-associations, as far as these, taken as a whole, bear lichens. The lists of species given there, are consequently also illustrative of the vertical distribution of the lichens, inasmuch as the heath with its lichens ascends to about 300 metres up the mountains, the birch coppices to about 550 (more frequently less), the willow-coppices (which do not appear to be very widely distributed and are almost unknown as regards their lichens) to about 800 metres, the grass-vegetation, with the upper limit of which I am not acquainted, and the desert-vegetation up to 1000—1400 metres; then comes the ice-region.

If we now go through the lists, which are given above for each individual association — grass, heath, moss, coppice, etc. — we shall find that they do not include all the earth-lichens of Iceland, inasmuch as they do not contain all the numerous species, which have in part been found by other collectors without their having stated more closely in which association they were collected. Consequently, here is a large field left for future investigations, i. e. an elucidation with regard to the particular association in which each single species lives and — together with this association — at what sea-level.

With regard to the mass-occurrence of the earth-lichens at various altitudes, very much is likewise wanting to our possession of reliable data as regards the heights, which are most favourable to them. This much can only be said as a general fact, that (1) close to the sea no lichens live on the earth, if the ground-water reaches to the surface of the earth; and (2) from these low altitudes, and upwards, the mass-occurrence of the lichens appears to be essentially dependent on local conditions, i. e. conditions pertaining to soil, competition with other plants, etc., as has been more fully mentioned under the individual association.

The main question — whether the differences in the climate, which prevail at various altitudes, have any other importance than that which they have by indirectly exposing the lichens to the competition of sometimes the one and sometimes the other plant-species (in heaths, coppices, grass, etc.) — is best answered by investigating the vegetation at higher levels. Or to put the question more simply: Can any connection be shown to exist between the character of the climate and the mass-occurrence of the lichens? To this we must reply with a fairly certain "Yes." It is to be expected that, when all competition with other plants is absent, and the soil is of suitable composition, the lichens must be abundantly present in great masses, in other words: mountain heights must necessarily be very rich in lichens. Now there is no doubt at all that the lichens, at higher altitudes, are more conspicuous in the landscape, than at lower levels, but on the other hand, neither can it be doubted that the lichens are far, very far, from covering all the soil on mountain-heights, which is bare of all other competitors. There can, on the whole, be no doubt at all that, both as regards number of species and mass-occurrence, the mountain-height manifests a poverty, which cannot be due to soil and competition, but must largely be a result of the more severe climate.

With regard to the rock-lichens, the list of the hardy mountain-height-species is given above. With respect to mass-occurrence it can likewise be said that the mass is evidently smaller on that ground, which lies highest even though, as in the case of the earth-lichens, more reliable determinations concerning mass-occurrence are still wanting. It is, however, evident even from a superficial survey, that both as regards number of species and mass-occurrence the highest mountains are poorer than the lower.

With the Epiphytic lichens the matter is quite simple: they are solely connected with coppices and cease at the alpine limits of the latter, i. e. they are entirely absent from mountain-heights.

# VI. THE ABUNDANCE OF LICHENS IN ICELAND.

In my work "Forberedende Undersøgelser til en almindelig Liken-Økologi" (1813) I have made a preliminary attempt towards characterizing the various zones of the globe, as regards their abundance of lichens. I shall now mention in short the problems pertaining to this department, which require to be solved more particularly as regards Iceland.

The abundance of lichens in a country may be characterized in various ways, but those that, as a rule, will interest us most, are (1) the abundance of species and (2) the abundance of individuals (mass-occurrence) in a country.

Let us firstly regard the abundance of species of the various climate-belts and the method by which to determine this numerically.

This task is very comprehensive and cannot in reality be worked out with the aid of the floristical works, which we have at our disposal at present, and this for various reasons. The principal of these are the following two: — (1) The floras comprise, as a rule, politically — not with regard to climatology — limited areas, and (2) as a rule they give no information as regards the distribution of the species in a vertical direction above sea-level in the "Region."

But let us suppose these wants supplied at some future time by laborious and protracted investigations in the field. We shall then by that time be able to give the abundance of species of the various climate-belts in absolute figures — so many in the whole of the Arctic, respectively temperate, sub-tropical and tropical belts.

I have reason to assume — as I have more fully shown in my "Forberedende Undersøgelser til en almindelig Liken-Økologi" — that the abundance of the various climate-belts given in such absolute figures will show that the Arctic-belt is poorest in the northern hemisphere. The mutual relationship of the other belts, in this respect, is somewhat doubtful.

But let us now also suppose, that at some future time we shall succeed in deciding the absolute number of species for each climate-belt; there will nevertheless be highly important and interesting details to investigate as regards these numbers: first and foremost the mean number of species of the climate-belts, that is the number of species per unit of area.

For in itself it is very probable that a relatively small territory as, for instance, the Antarctic region has a very small number of species, whilst, for instance, the Tropical region, the superficial measure of which is many times larger than that of the Antarctic, has a great number of species. If we compare the area of the climate-belts with their number of species, dividing the number of the species by the superficial measure (for instance, in geographical square miles), we get fractions which give us a clear idea of the abundance of species in proportion to the area of the climate-belt. For if we imagine a climate-belt investigated, square mile after square mile, and new species are constantly found, over and over again, in every such small area, the sum total for the entire belt would become very great. On the other hand, if we find in another belt, a certain number of species in the square mile first investigated, and thereafter the same species over and over again in the areas subsequently investigated, the sum total for the whole climate-belt would become rather small. It is exactly this circumstance which will be recorded in the fraction, which results from the division of the number of the species of a climate-belt by its area (e. g. in geographical square miles or kilometres). This fraction expresses the greater or lesser monotony of the area as regards the occurrence of the species.

A third valuable means, wherewith to compare the abundance of species of various climate-belts, is to take equally large (preferably very large) areas characteristic of the belts (that is to say areas which contain all the plant-associations contained in each single belt) and add up the number of their species, which then directly indicates the comparison of them with regard to abundance of species. This method is the most elucidatory of all three and has therefore been made the subject of a fuller discussion in my "Forberedende Undersøgelser" (1913). In itself it is immediately evident, that no other means of comparison is equal to this as regards reliability; this, which is simply a special lichenological employment of a geographical principle commonly employed in almost all other possible circumstances.

If we want to compare the abundance of species of a certain limited area, for instance, that of Iceland with that of other areas within the same climate-belt or in others we must naturally first and foremost employ just this last method, that is, we must take for comparison areas equal in size to Iceland.

It is in the nature of the matter, that such investigations involve considerable difficulties and, in fact, they have not yet been made at all. But before they may happen to be made, we must help ourselves with less valuable and easier methods, which can give us hints with regard to the questions which we wish to have solved, and which will presently be more fully discussed.

If we wish to compare the abundance of species of the various plant-associations with one another, several methods can naturally be employed, but already here the absolute figure for the species is very elucidatory. Thus, for instance, it is very interesting to ascertain the difference between the number of species in a grass-field and in a heath in Iceland (see above). But here also it is naturally still more valuable to determine the number of species of a certain unit of area in one association, and compare it with an equally large area of another association, for instance the number of species, let us say in one square mile of heath, compared with one square mile of forest, etc.

But in the main, these statistical investigations are as yet tasks for the future, — much still remains to be done in this respect, but what we already know for certain as regards Iceland will be recorded here.

Iceland has, according to the list given here, about 285 species; a few more may probably be added to this number by latter investigations, but judging from what is known — only few.

Now does this figure represent many or few species in proportion to the area of the island?

Let us first compare it with some countries from the Arctic regions: Greenland has 287 and Spitzbergen 207 species. In proportion to its area, Spitzbergen — the smallest of the three countries — has consequently the greatest number of species; then comes Iceland and — as the one poorest in species — that immense Greenland, which has, within its domain, an almost equally great absolute number of species as Iceland, which is about 22 times smaller. These figures are in themselves striking enough, but they give no information concerning the equality of the distribution of the species in the areas of these three countries occupied by the lichens. We know, it is true, from other sources, that all three countries have a larger or smaller area covered with inland-ice, which however, in proportion to the entire area of the country, is most strongly developed in Greenland. Even this alone naturally brings about a heterogenous lichen-colonization in these countries. But even if we do not take this into consideration, but only regard the areas which are free from ice, the figures do not state anything about the equality of the distribution of the lichens: whether we can meet with all the species of Greenland, of Iceland or of Spitzbergen within every lesser area or whether the distribution is quite otherwise. We have in this respect a small hint from Greenland, where at least the north-eastern area, which has been investigated by the "Danmark Expedition," gives only about 100 species, which with tolerable certainty can be taken as an indication of the fact, that the difference between South and North in this country of great length is of importance. But a reliable comparison of the distribution within the three countries in question, cannot be obtained until equally large areas from each of them have been compared with one another, which has not yet been done.

On comparing the number of species from Iceland with those from Denmark — to take a well-investigated area from another climate-belt — we find that Denmark, on her 38000 square km., has 397 species against Iceland's 285 species on 104000 square km., or 0.0021 species per square km. in Iceland and 0.0104 species per square km. in Denmark. Nor do these figures give any insight into how the species are distributed within each country. In this case also it will be necessary to compare equally large areas of the two countries (taking their characteristic plant-associations into consideration).

But until such a comparison has been made, it must suffice to substantiate the fact, that the abundance of species in the whole of Iceland is less than in the whole of Denmark, in spite of Iceland being $2^1/_2$ times the size of Denmark. In the same way it may be said that Greenland is far poorer in species than is Denmark, although it is many times the size of Denmark, whilst, for instance, Germany, France and Great Britain, with their greater stretch of country, have also many more lichens than has Denmark, viz. 1100—1400 species.

On the whole it holds good, as a general rule, as has been stated and more fully proved in my "Forberedende Undersøgelser," that the Arctic countries and Iceland are poorer in species, even considerably poorer, than are the temperate or the subtropical countries. The cause of this fact may be disputed, but the fact itself cannot be denied.

And yet it has been denied! For instance when discussing verbally with men of science in my own department, I have heard the assertion advanced, that exactly the Arctic regions, in contradiction to what I maintained, were comparatively rich in species! In this respect they have referred to the results arrived at by Nylander in his "Synopsis methodica lichenum." Nylander there shows that the Arctic regions are comparatively rich in species! But it should be noted that he arrives at this conclusion by comparing the number of phanerogams (!) with the number of lichen-species.

I have previously (Forberedende Undersøgelser, 1913) mentioned the figures given by Nylander and his comments on them. They are I presume correct — both the figures and the comments — only they do not at all affect the circumstance which I am endeavouring to elucidate, viz., the abundance of species in relation to area; and therefore they cannot at all be used as a corrective of my results. And yet, in verbal discussions, I have more than once come across this entirely erroneous view.

I have shown that the Arctic regions — as also Iceland — is poor in lichen-species in proportion to their area, far poorer than the temperate regions.

But there are many details in this connection which require to be more fully discussed, and for that reason we will regard the separate biological groups of lichens more closely: Bark, Epiphyllous, Earth and Rock-lichens, in order, if possible, to arrive at some explanation with regard to the cause of the phenomenon.

Bark-lichens. We must *a priori* expect the bark-lichens to be greatest in number in places where there is the greatest abundance of substratum for them, i. e. many species of trees, and in great number of individuals. Iceland is badly off in this respect, having on the whole, only one species of tree, which bears lichens somewhat abundantly, viz. the birch.

If we regard the bark-lichens in the various belts, it is seen that there are many in the Tropics, that for instance tropical Africa has almost 500 bark-lichens, already known, which form 65 % of all its lichens, Italy 508 (about 32 %), Denmark 165 (about 39 %) and Iceland 59 (about 15 %, inasmuch as Iceland's 285 systematic species constitute 337 biological forms, as several of the species occur sometimes as earth- and sometimes as rock-lichens, etc.). Now the areas which have here been compared with one another, are far from being all equally large and therefore do not give any figures, which are useful for purposes of direct comparison. But, at any rate, they give an indication of the fact that bark-lichens are comparatively more numerous in countries rich in trees than in Iceland; and they give the very important-information that Iceland, although it is much larger than Denmark, has only 59 species, whilst Denmark has 165! Whether this circumstance is solely due to want of necessary tree-substratum is not easy to decide. For instance, whether the bark-lichens of Denmark would be able to thrive in Iceland, if, by way of experiment, we removed them thither, together with the stems upon which they occurred, or whether the climate alone would kill them, we do not know. But that the paucity of species is due to the climate — directly or indirectly — is evident enough.

Epiphyllous lichens. These occur, as is well-known, on evergreen leaves only. 24 species are known to occur in tropical Africa and 3 in Italy. From the climate-belts north of Italy they are practically absent, and in Iceland, with its deciduous birches and willows, they are totally wanting. The same consideration which applies to the bark-lichens may be extended to the epiphyllous lichens, viz., that the climate is, directly or indirectly, a hindrance to their growth in Iceland.

Earth-lichens. We must expect *a priori,* that regions with a luxuriant vegetation of phanerogams and other good-sized plants are not favourable to earth-lichens. From the whole of that immense, tropical Africa (outside its alpine regions) only some 50 lichens are known! (about 5—6 %), from Italy 275 (about 17 %), from Denmark 86 (about 20 %) and from Iceland 121 (about 36 %). As may be seen, the percentage of the earth-lichens becomes greater and greater, the farther we proceed northwards to the cold regions. This is without doubt correlated with the fact, that the number of the competitors of the lichens decreases towards the north, the ground becoming more destitute of other plant-growth.

But the absolute number itself is greater for Iceland than for Denmark! Does this imply that the climate up there in the north is more favourable to lichens than down here in Denmark? Does not this contradict our general assumption, that lichens are more abundant in temperate countries than in Iceland? Anything of this kind cannot be deduced from the aforesaid fact. Considering the particularly favourable conditions which Iceland can offer the earth-lichens as regards competition, the number 121 in proportion to the 104 000 square km. of country is very modest compared with Denmark's 86 on 38 000 square km.

Still more interesting conditions become apparent when we regard the sub-divisions of the earth-lichens: the crustaceous, foliaceous and fruticose lichens. It is then seen that Denmark and Iceland have the following earth-lichens: —

| | Crustaceous | Foliaceous | Fruticose |
|---|---|---|---|
| Denmark | 34 | 21 | 31 |
| Iceland | 67 | 27 | 27 |

These figures are most peculiar, inasmuch as they show that Iceland's predominance as regards the number of earth-lichens, is due to a greater number of crustaceous lichens, inasmuch as both countries have about the same number of foliaceous and fruticose lichens, taken collectively, whilst Iceland has very nearly twice as many crustaceous lichens as Denmark. Remembering, that this growth-form in particular, in order to be able to live at all, demands either a very moderate competition, or none whatever, on the part of other plants, it is easily to be understood, that an Arctic country in particular, with a slightly developed phanerogamic vegetation, offers the crustaceous lichens the most favourable conditions possible, as regards competition. In reality there is so much unoccupied ground, free from other plants, that we might expect a much greater number, offering an analogy with the fact, that much tree-vegetation (for instance in the Tropics, in Italy, etc.) serves greatly to increase the number of species of tree-lichens. When in spite of the very slight competition, the number of earth-lichens is so limited, this can only be regarded as a direct result of the climate.

Rock-lichens. With regard to these it can be stated that tropical Africa has 182 species (24 %), Italy 729 (46 %), Denmark 169 (39—40 %) and Iceland 157 (47 %). The figures indicate that the sub-tropics are rich, and the purely tropical regions poor, in species; whilst the temperate and Arctic regions are less rich in species than are the sub-tropics.

On comparing more particularly Denmark with Iceland, we find that the number of species is greatest in Denmark, although Iceland is much larger in area. Remembering, moreover, that Iceland has bare rock-substrata, the superficial extent of which is so great that in Denmark we can form no conception of it, whilst our Danish species are limited to the very modest granite-surfaces on Bornholm, and to the loose stones found scattered about in fields and in fences, the small number connected with Iceland appears extremely elucidatory. It is impossible to explain this as anything else than a direct result of the climate, because Iceland has so many kinds of rock-substrata, that there would be plenty for the lichens to choose among, if the climate had otherwise been favourable to them.

We can consequently briefly sum up the above in the following few sentences: —

(1) Iceland (as also the Arctic countries) has on the whole a lichen-vegetation poor in species in proportion to its area, poorer than have the temperate and sub-tropical countries.

(2) The Bark-lichens meet with the most favourable conditions in the tropics — that is to say, they are rich in species there — in the Sub-tropics and in the Temperate regions they are poorer, whilst in the Arctic countries and in Iceland they are poorest of all; this should probably be correlated with the abundance of substrata present.

(3) The Epiphyllous lichens find the most favourable conditions in the Tropics, less favourable in the Sub-tropics, and least favourable of all in the Temperate regions; in the Arctic countries and in Iceland they are entirely wanting.

(4) The Earth-lichens meet with very unfavourable conditions in the Tropics, better in the Sub-tropics, better still (probably) in the Temperate regions, and best of all in the Arctic regions — as regards conditions concerning competition. The climate, on the other hand, appears to be directly unfavourable to them in the Arctic regions and in Iceland.

(5) The Rock-lichens meet with very unfavourable conditions

in the Tropics, better in the Sub-tropics, better still in the Temperate countries, and best of all in the Arctic countries and in Iceland — as regards conditions concerning competition. The climate, on the other hand, appears to be directly unfavourable to them in the Arctic regions and in Iceland.

This is best shown in a Table: —

| | Bark-lichens | Epiphyllous lichens | Earth-lichens | Rock-lichens |
|---|---|---|---|---|
| Tropical Africa....... | 498 (65 %) | 24 (3.2 %) | 45 (5.8 %) | 182 (24 %) |
| Italy ................ | 508 (32 %) | 3 (0.2 %) | 275 (17 %) | 729 (46 %) |
| Denmark ............ | 165 (39 %) | — | 86 (20 %) | 169 (39 %) |
| Iceland .............. | 59 (15 %) | — | 121 (36 %) | 157 (47 %) |

These figures have been commented upon more fully in the above, both the actual figures and the percentages.

But the other side of the matter still remains to be discussed, viz., the valuation of the wealth of the various regions as regards the mass-development, as far as this is manifested by frequency numbers and masses (given in weight per unit of area). Hitherto we have been exclusively dependent upon a superficial valuation of this, and we are as yet hardly beyond the very rudiments as regards this point, but it need not continue to be so in the future. I shall record here the little that is known and may be discerned, but, firstly I shall dwell a little on the precautionary measures which must necessarily be taken in order to be able to judge somewhat correctly.

The cause which chiefly leads us to judge erroneously, is the fact, that we are involuntarily deceived by the size of the phanerogams compared with the lichens. Thus, we may very easily be struck by the abundance of lichens on mountain heights, in places where phanerogams are either totally or almost wanting, and on the other hand, underrate the abundance of lichens where the larger phanerogams are more numerous. This is in itself so common and significant a source of delusion when forming an estimate of the abundance of lichens, that as a rule we must be very cautious about relying on the results which the botanist in question puts forward, if we do not know beforehand his conception of this circumstance. But even if the botanist happens to judge quite correctly, yet he has no other descriptive means with which to express his judgment than the terms "abundant," "less abundant," etc., merely relative expressions, which have no relation to any fixed and invariable unit.

It must therefore be absolutely recommended, in future, to determine the abundance of lichens in a country, a plant-association, a zone, etc., by still two other means, viz., frequency-number and mass-occurrence (in weight per unit of area) — in addition to its number of species.

In the present treatise I have as regards some of the Icelandic associations — as far as travelling-conditions permitted — given some frequency-numbers, which may be obtained, for instance by demarcating small sample-areas (1 or 2 square decimetres each) with equally large, intermediate spaces between them — in some places it is practicable to employ the smaller unit, whilst in other places the larger unit is preferable — and by noting whether they contain lichens. This method, as already mentioned, is Raunkiær's for phanerogams, and is also very good for lichenological purposes. In that way it is possible to determine almost all possible frequency-numbers in detail, to investigate for instance the frequency-number for crustaceous-lichens only, foliaceous-lichens only, etc., or the frequency-number for lichens taken collectively. If it be a question of wishing to know, for instance, how frequently lichens, as compared with phanerogams, occur in the sample-areas one can just take, say 100—200 or 1000 sample-areas, according to what may be considered necessary in order to obtain a reliable impression of the conditions, and note down in which areas lichens occur and in which phanerogams (mosses, algæ, etc.). If lichens occur in all the samples, then the frequency-number of the lichens is F % 100 (F % stands for the frequency-percentage); if they occur only in 50 out of 100 sample-areas, then the frequency-number is F % 50, etc. — All this has been treated of above to some extent, but here it is explained more fully. — In the case of phanerogams, mosses, etc. exactly the same method is employed.

If one should wish to determine how frequently crustaceous, foliaceous and fruticose lichens occur among themselves, one must note down, with regard to each of these little sample-areas, which of these growth-forms occur in it. For instance, in a series of samples, crustaceous lichens may be found in 50, fruticose lichens in 100, and foliaceous lichens in 20 sample-areas. The frequency-number is then F °/o 50, F °/o 100 and F °/o 20 respectively, all of which has already been known and employed for several years in ecology, with regard to phanerogams.

This frequency-number serves to indicate how equally the lichens are distributed in an association or similar limited area. This has the great advantage, that even non-specialists, who have a general botanical training, can note down various facts with regard to the distribution of special groups of plants (lichens, earth-algæ, mosses, etc.) in the associations, without knowing the name of a single species found.

A specialist, when he has time at his disposal, will be able to go more into details, and even determine the distribution of a single species within a certain area.

The determination of the mass-occurrence of lichens has never yet been undertaken; it has been mentioned under the treatment of the heath-lichens. For this determination it is necessary to reap everything that grows on each sample-area, and weigh it. By this means one obtains figures, which are directly useful for purposes of comparison, as regards the relative extent of mass-occurrence of the plant-association in question. This method is useless as regards the crustaceous lichens, but in their case it is possible to state, with some certainty, the size of the area covered by them.

If we are to compare the abundance of the lichens of the various countries, according to the methods which have been briefly treated here, and, by means of these methods, try for instance to answer the general question: "Where are the lichens to be found in greatest abundance, in Iceland or in Denmark?" This question must be further detailed, in order to be answered, and cannot, upon the whole, be answered as yet. The Icelandic heaths can be compared with the Danish, the Icelandic grasslands with those of Denmark, etc., as has been done above, by way of experiment, in the special sections, with regard to frequency-number and mass-occurrence (in weight per unit of area). But a thorough comparison cannot yet be made, as it requires many more investigations in the field, than have hitherto been undertaken.

It is, however, my impression, as it has been the impression of other botanists, already in former times, that as regards frequency number and abundance the Arctic regions and Iceland appear to be richer than other regions, no doubt chiefly on account of the slight competition to which the lichens are subjected. It must, however, be remembered that the cold mountain heights in Iceland appear to be less rich in lichens, than are the more low-lying parts, and are remarkably poor when the fact is considered that the competition on the part of other plants is only slight, or altogether wanting; so that one is led to the conclusion that the climate, as such, is not favourable.

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