NATIONAL MUSEUM MELBOURNE

Journal and Proceedings

OF

The Royal Society of Western Australia.

PATRON: H.M. THE KING.

Volume II.
1915 - 1916.

Published June, 1917.

The Authors of Papers are alone responsible for the statements made and the opinions expressed therein.

PRICE: Five Shillings.

Perth:
Wholly set up and printed in Australia by V. K. Jones & Co. Ltd.,
859 Hay Street, Perth, Western Australia.

1917

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STUDENT MEMBERS.

Montgomery, S. K., 30 Richardson Street, West Perth.

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* Including those who have not signified their intention of becoming Ordinary Members.

RECORD OF PROCEEDINGS

of

THE ROYAL SOCIETY OF WESTERN AUSTRALIA, FOR THE SESSION 1915-1916.

August 10, 1915.—The President (Mr. A. Gibb Maitland) in the Chair. Messrs. H. McKail and W. H. Taylor were elected Ordinary Members. Prof. A. D. Ross delivered a lecture on Gyrostatics, with experimental illustrations; a short discussion followed.

September 14, 1915.—Prof. A. D. Ross, Vice-President, in the Chair. The Secretary reported that two successful excursions had taken place since the last meeting.

Mr. Alexander exhibited a living specimen of the small headed Toad (*Myobatrachus gouldi*), stated to have been found in a rock at West Guildford. Miss Creeth exhibited specimens of Spider Orchids (*Caladenia Patersoni*) from Darlington, and Mr. Hall, a number of paintings of Wild Flowers from the neighbourhood of York. Mr. Allum delivered a lecture on "The Principles of Currency."

October 12, 1915.—The President (Mr. Gibb Maitland) in the Chair. Mr. C. Hedley was elected a Corresponding Member; Dr. W. E. Blackall and Mr. W. H. Shields were elected Ordinary Members. Presentations of various publications to the Society were announced.

Mr. J. T. Jutson read a paper prepared by Mr. E. S. Simpson and himself, on Notes on the Geology and Physiography of Albany; a general discussion followed.

November 9, 1915.—Prof. A. D. Ross, Vice-President in the Chair.

Mr. A. O. Watkins exhibited a Tray invented by him, and in use at the Royal Mint, for recharging Cupels in Assaying, without withdrawal from the furnace, and demonstrated its use. Mr. A. Montgomery gave an account of recent observations concerning the superficial beds of the Collie Coalfield, and exhibited specimens of *Glossopteris* from the Premier Mine. Mr. W. B. Alexander exhibited a specimen of a white flocular substance, which fell from the atmosphere in the South-West of the State on the 5th October, supposed to be Spider Gossamer. Prof. Ross delivered a short lecture on "Gambling" as viewed from a mathematical stand-point.

December 14, 1915.—Exhibition and Conversazione.

Exhibits:—Color photography; Cinematograph camera; Electric cables, and Optical phenomena (Pro. Ross). Stages in Embryology of the Chicken; Head of Mosquito (Prof. Dakin). Fossils from the Collie Coalfield (Mr. A. Montgomery). Electrolytic break for X-Rays, Wireless, etc. (Mr. McKail). Plant Diseases and Examples of Fasciation (Dr. Stoward). Samples of Wheat, Healthy, and Diseased (Mr. Grasby). Photographs of the Moon (Mr. Curlewis). Tracing illustrating the Meteorites (complete series); examples of Tectites (Mr. Simp-
Meteorites (complete series); examples of Tectaties (Mr. Simpson). Native Weapons and Musical Instruments (Mr. Glauert). Adults, Young, and Eggs of the Cuckoo Family and their Hosts, also North American Birds of Parasitic Habits (Mr. Alexander).

RECESS.

March 14, 1916.—The President (Mr. Gibb Maitland) in the Chair, referred to the loss of the Society through the death of Sir J. Winthrop Hackett; it was resolved that a letter of condolence be sent to Lady Hackett.

Mr. A. Montgomery gave an account of recent observations made by him on the geology of the Yalgoo district. Mr. W. B. Alexander exhibited varieties of Phasmidae, some of which bore a remarkable resemblance to vegetable products in their general appearance. Mr. R. H. B. Downes read a short paper on "Mirage"; a discussion followed.

April 11, 1916.—The President (Mr. Gibb Maitland) in the Chair, announced the change of the Society's headquarters to rooms in the Museum. Mr. J. S. Clarke was elected an Associate.

Mr. Alexander exhibited (for Mr. M. A. Browne), some yellow spider's silk from Ravensthorpe; also nests of two species of leaf cutter Bees, found by Mr. Mathews and Simpson respectively. Prof. Dakin gave an account of the Whale Fishery on the South Coast of Western Australia, illustrated by lantern views.

May 9, 1916.—The President (Mr. Gibb Maitland) in the Chair. Mr. W. H. Mathews was elected Ordinary Member.

Mr. Alexander exhibited a nearly white specimen of the Black Moorhen (*Gallinula tenebrosa*), recently shot at Wanneroo; also two Cuttle fish from Garden Island, one, a large example of *Sepia longimanus*; the other undetermined. Mr. Montgomery read part of a paper on "The Significance of some Physiographical Features of Western Australia.

June 13, 1916.—The President (Mr. Gibb Maitland) in the Chair. New Rules were adopted in substitution for old Rules Nos. 3 and 4, on the routine of election of Officers.

Mr. Alexander exhibited the following:—Old-man schnapper from the Swan River; Flute Mouth (*Fistularia petimba*) from Fremantle, a new record for W.A.; Serjeant-fish (*Rachycentron canadum*) from Fremantle, a new record for W.A.; Blow-fish (*Tetradon armilla*) from Cottesloe, a new record for the west coast; Giant herring (*Eops saurus*) from Shark's Bay; Frost-fish (proposed name, (*Evoxymetopon Anzac*) from Fremantle, new species, a short paper with technical description was laid on the table; Nest of the Darter (*Anhinga novaehollandiae*) containing two young birds, from Bremer Bay. Mr. Alexander also presented a "List of the Orthopterous Insects hitherto recorded from Western Australia, including species in the collection of the W.A. Museum, not previously recorded from the State." Mr. Montgomery read the concluding portion of his paper on "The Significance of some Physiographical Features of Western Australia," and a discussion upon the latter paper followed.

July 11, 1916.—Annual General Meeting. The President (Mr. Gibb Maitland) in the Chair. Mr. H. P. Woodward and Acting Professor Tomlinson were elected Ordinary Members.

The Annual Report and Financial Statement were read and adopted. The following Officers for the ensuing year were declared elected, viz.:—President, Prof. A. D. Ross; Vice-Presidents, Messrs. A. Montgomery, and W. J. Hancock; Secretary, Mrs. Dakin; Treasurer, Mr. F. E. Allum; Librarian, Dr. F. Stoward; other Members of Council, Messrs. E. S. Simpson, R. H. B. Downes and H. McKail. A vote of thanks for his services was accorded to Mr. Alexander, the retiring Secretary.

Prof. Dakin exhibited pure cultures of the Bacterium, the causal agent of Cerebro-Spinal Meningitis, also stained specimens of the same under the microscope, describing the diagnosis of the disease and method of isolation of the germs. Mr. McKail exhibited a map of Garden Island drawn up by the Sea-Scouts. Mr. Alexander exhibited a fine specimen of the Cocoa-nut Robber Crab (*Birgus latro*); shells of the Paper-Nautilus (*Argonauta*) and specimens of foliage, buds and flowers of the *Eucalyptus lehmanni*. The President then delivered his address "Some Problems of Western Australian Geology," illustrated with the lantern. Mr. Gibb Maitland then vacated the Chair in favor of the new President, Prof. A. D. Ross, and a vote of thanks to the retiring President was heartily recorded.

ANNUAL REPORT OF THE ROYAL SOCIETY OF WESTERN AUSTRALIA FOR THE SESSION 1915-1916.

Ladies and Gentlemen,—

Your Council beg to submit the Annual Report and Financial Statement for the year ended June 30, 1916.

The number of members on the roll is now 87, as against 85 last year. Of these 59 are Ordinary Members, 19 Associates, 1 a Corresponding Member, and 8 Honorary Members. During the year 8 Members, 2 Associates and a Corresponding Member were elected; 1 Member and 2 Associates resigned, and the name of 4 Associates were removed from the list in accordance with Rule 12. The Council have also to record with deep regret the deaths of two members. Lieut. A. J. Robertson, M.Sc., was killed in action at Gallipoli on August 6, 1915, and the Hon. Sir J. Winthrop Hackett, L.L.D., M.L.C., K.C.M.G., died on February 19, 1916.

The Council has met 15 times during the year, and the attendance of its members has been as follows:—Mr. Allum, 15; Mr. Simpson, 14; Mr. Alexander, 14; Mr. Montgomery, 13; Mr. Hancock, 13; Mr. Maitland, 12; Prof. Ross, 11; Mr. Curlewis, 10; Mr. Sutton, 10; Mr. Watkins, 10; Prof. Dakin, 8; Dr. Stoward, 8.

The Ordinary Meetings of the Society have been regularly held, and the following members have contributed papers or given addresses:—Profs. Ross and Dakin, and Messrs. Allum, Simpson, Jutson, Downes, Alexander, and Montgomery. The December meeting, as last year, took the form of a conversazione, at which a number of interesting exhibits were on view.

In April, the problem of finding suitable accommodation for the Society, which had for a long time past occupied the attention of the Council, was solved by the kindness of the Trustees of the Museum, who granted the Society the use of the old lecture-room and a small adjoining room in the basement of the Museum. At the same time the Council purchased new bookshelves, so that the Society's library is now adequately housed, and available for reference. Many loose volumes however, urgently need binding.

During the year, the Council arranged to undertake the work of cataloguing all scientific papers published in the State for the International Catalogue of Scientific Literature, and those published during 1914 and 1915 have been dealt with by members of the Society having special knowledge of the different subjects, and cards despatched to London.

Owing to a most unfortunate series of misunderstandings, the Council regret that Volume 1 of the Society's Journal which was almost ready for publication last August, has still not appeared. It was found necessary to obtain the sanction of the State Treasurer to the further expenditure necessary for its completion, and this was at length granted in April last. Since then the work has been recommended, and the Council hope that the volume will be ready for distribution before the August meeting.

The Society's finances are in a satisfactory state, there being a credit balance at the end of the year of £10 4s. 6d. as against a debit balance of £20 16s. 10s. a year ago.

A. GIBB MAITLAND,
President.

W. B. ALEXANDER,
Hon. Secretary.

July 11, 1916.

FINANCIAL STATEMENT.

"The Treasurer's Financial Statement for the year ending 30th June, 1916, which disclosed a satisfactory position, was received and adopted."

LIST OF DONORS TO THE LIBRARY.

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Geological Survey of Western Australia.
Western Australian Museum and Art Gallery.
Royal Society of South Australia.
Department of Agriculture of Victoria.
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National Herbarium of Victoria.
National Museum, Melbourne.
Royal Society of Victoria.
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OBITUARY.

SIR J. WINTHROP HACKETT.

By the death of Sir J. Winthrop Hackett, K.C.M.G., D.C.L., which occurred at his residence in Perth, on the 19th of February, 1916, the Society lost one of its oldest members, and Perth, a citizen who has always been to the front in matters of education in this State.

Sir Winthrop Hackett was born in 1848 at Lordello in the County of Dublin, the eldest child of the Rev. John Winthrop Hackett, M.A. He was called to the Irish Bar in 1874, and in the following year having come out to Australia, was admitted to the Bar in Sydney, but soon turned his attention to journalism; in 1882 he came to West Australia, shortly after which he entered into partnership in the West Australian newspaper, of which he retained the management up to the day of his death. He was a Governor of the High School, Perth, and was one of the most prominent, if not the most prominent of the founders of the University of Western Australia, of which he was the first Chancelor, and in which he endowed a Chair of Agriculture. He was also prominent in the affairs of the Public Library and Museum, and presided over the Zoological Gardens and Acclimatisation Society; he was also an active supporter and contributer to the National Art Gallery.

Sir Winthrop left a wife, a son and four daughters to mourn his loss. He was one of the earliest members of the Natural History and Science Society of Western Australia, the parent of the present Society, and he remained a member of the Royal Society of Western Australia up to the time of his death, but was prevented by his various interests from taking any very active part in its operations.

THE JOURNAL

OF

THE ROYAL SOCIETY

OF

WESTERN AUSTRALIA.

VOL. II.

SOME PROBLEMS

OF

WESTERN AUSTRALIAN GEOLOGY.

Presidential Address to the Royal Society of Western Australia.

By

A. Gibb Maitland, F.G.S.

(Delivered on the 11th July, 1916.)

"The greatest and noblest pleasure which men can have in this world is to discover new truths, and the next following this is to shake off old prejudices."

Usage prescribes that the work of the Royal Society shall be brought to a close by an address from the Presidental Chair, though the choice of a fitting subject is oftimes a source of considerable anxiety to its occupant.

In this year 1916, it is almost impossible to forget, that European nations have for well nigh two years past, been utilising the combined resources of science for the purpose of carrying on the most gigantic struggle of which there is any historical record. This fact suggests that the present and future relationships between war and science, i.e., its present use as "aids to the "lightening the burdens of humanity by the mastery of natural" "forces—the transformation of inanimate power to relieve mankind" "from arduous work, the conquest of pain and disease, and by no" "means least the enlargement of the human mind," as a fitting subject with which to conclude my allotted term as your presiding officer.

As a geologist, I however, may, along with the astronomer, lay some claim to that privilege of "belonging to a branch of science which has nothing to do with War," unless indeed those violent tremors in the region of the Mediterranean, ascribed by ancient mythology to the quiverings of that hundred armed giant, Typheus, while endeavouring to escape from his fiery prison, are indicative of internal warfare in what Hamlet calls "this goodly frame the earth," may be held to disprove the claim.

After some deliberation I have chosen to address you on a subject of my own particular science, rather than to wander as a comparative stranger into other fields.

Coming therefore to the subject of my address, I purpose departing somewhat from established custom and instead of looking backwards, will endeavour to look into the future, and point out some problems of Western Australian geology which provide abundant opportunities for collective and individual research.

Fig. 1.
Scarplike face of Darling Range.

The southern half of Western Australia affords perhaps no more striking feature than the scarp-like face of what is generally known as the Darling Range, and which forms the western rim of the Plateau of the Interior. (Fig. 1). This rim of crystalline rocks rises to heights about 1,000 feet above the broad, comparatively flat expanse known as the Coastal Plain.

The boundary between this Plateau and the Coastal Plain is virtually constituted by a nearly straight or at least a gently curving line, and forms part of a long zone in which faulting is the most important structural feature. What may be called offset faults.

may in some cases, be held to explain the want of continuity in the scarp-like face of the plateau. (Fig. 2).

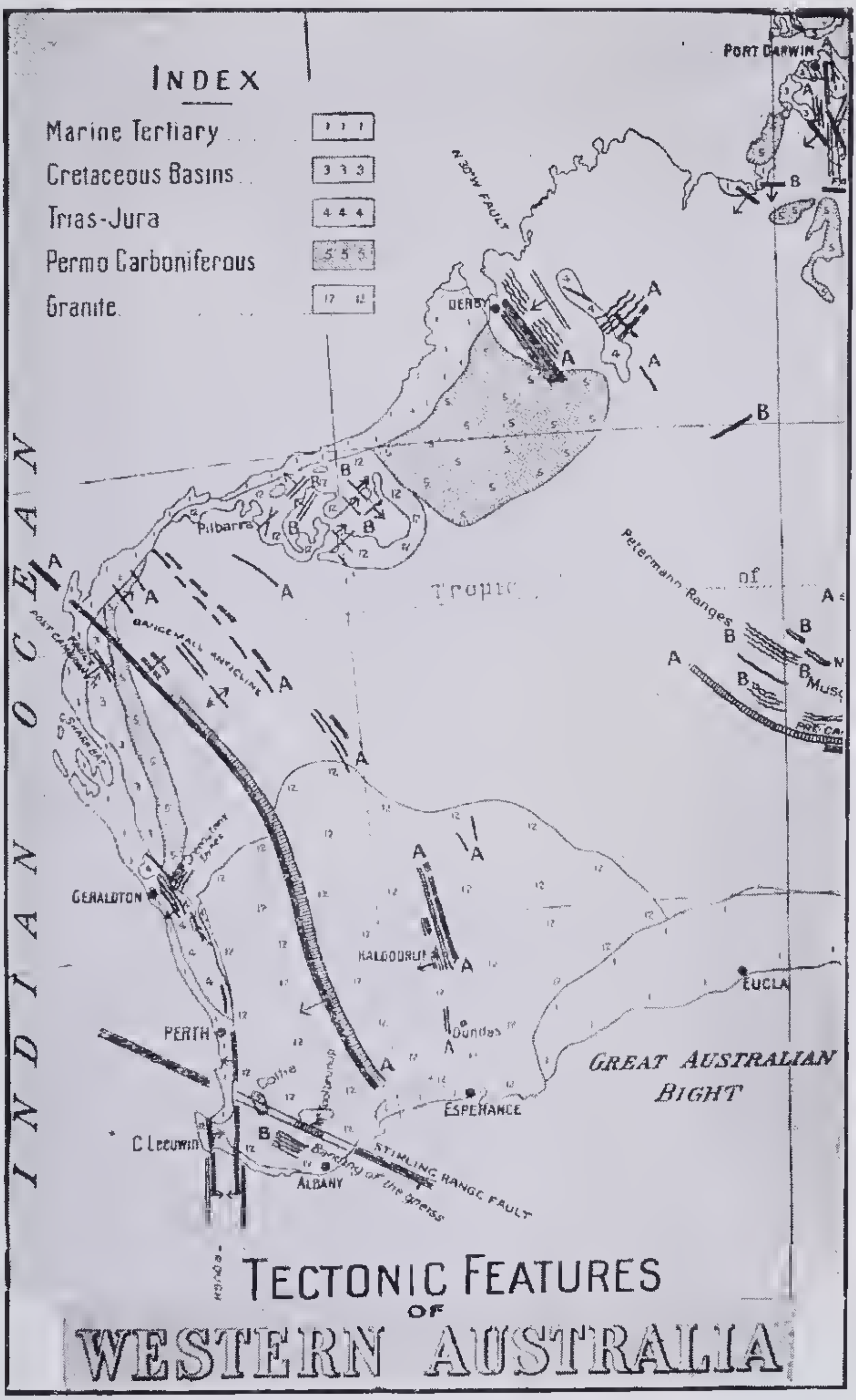

Fig. 2.

Map showing the Tectonic Features of Western Australia.

When viewed *en bloc,* this plateau presents a fairly even surface, which rises to no very great elevation above sea-level (Fig. 3); it has a very restricted and limited rainfall, and is drained by

Fig. 3.
Lake Way, East Murchison Goldfield.

Fig. 4.
Brockman Creek and Lake Carnegie.

intermittent water-courses (Fig. 4), which debouch into shallow basins, generally known as "Salt" or "Dry Lakes." (Fig. 5).

Wind erosion is the predominating denuding agent which tends to keep the plateau level. In many places the rocks have been scored by the sand-blast action. The potency of wind-scour or sand-blast may be noticed in the frosting of those heaps of discarded bottles, which in certain districts, are pretty well the sole relics of departed greatness.

Fig. 5.
Lake Dundas, Norseman. Dundas Goldfield.

It is my purpose therefore to deal briefly with some of the problems which the rocks of the old plateau present, the solution of which offers a peculiarly interesting subject for enquiry. It is not however, intended to deal with the more recent and fascinating branch of geology which concerns itself with the origin, structure, and formation of the surface features of the State.

The rocks of which the plateau is made up present a bewildering variety of lithological types. which bid fair to make this portion of Western Australia a classic field for petrological research. Portions of the plateau have been examined during very many hasty traverses, which individually yield somewhat limited information, although collectively give a good general idea of the geological structure. The rocks of the plateau have been most closely investigated in those districts in which the probability of economic development has necessitated detailed geological surveys. These localities are very widely separated, and it is now becoming imperatively necessary to link up these districts by a study of the intervening areas, though many portions being masked by residual and other deposits, the geological structure of these areas will, it is to be feared, in the absence of systematic boring, carried out under scientific guidance or extensive underground mining operations, remain more or less the subject of speculation and inference.

The oldest known rocks of Western Australia comprise a great group which almost everywhere constitute the foundation of the State; to the whole of these rocks however, observers have invariably assigned an Archaean age, but this is rather inferred than proved.

I propose to retain the term Archaean for that great basement complex of schists, gneisses and allied rocks, but although this is done, it is not meant to imply that the rocks so designated in the Northern Hemisphere and elsewhere are exactly contemporaneous.

As may be seen by a glance at the geological sketch map (Fig. 6), the great bulk of the interior plateau is granite and gneiss, the remainder being formed of the metamorphic rocks, the whole forming th foundation upon which the Palaeozoic and more recent super-structure has been built.

Fig. 6.

In the absence of any other evidence, it has been found convenient to separate these rocks into two great lithological groups, viz., (a) the gneissic and granitoid rocks, and (b) the crystalline schists.

The crystalline schists of which there are at least two distinct groups, which there is some reason to believe differ considerably in geological age; these are (1) phyllites, quartzites, conglomerates and arkoses, which have been designated the Mosquito Creek Series, and (2) an older, mica-quartz schist and marble group, associated with basic rocks which have been at times converted into greenstone schists. These rocks have been more or less irregularly folded and compressed concertina-fashion, along high.., inclined axial planes; the folding is meridional, the prevalent strike being generally north-west and south-east. The broad geological structure of the western half of the State across some of these bands is shown in the section (Fig. 7), and will serve perhaps to make this clear. The dotted lines indicate the former extension of the strata. Some however, of the hornbendic rocks associated with these rocks may possibly represent original gritty beds made up of epidote and chlorite. In some instances quartzites in which original argillaceous impurities have re-crystallised as felspar and mica, render them easily mistaken for granite and its allies.

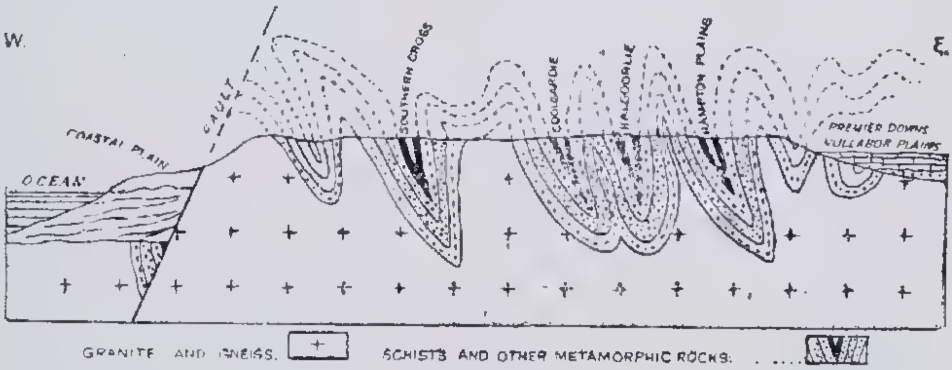

Fig. 7.

Generalised section across Western Australia from the Coast to Premier Downs.

A most noticeable feature in these crystalline schists is constituted by these bands of cherts and brilliantly coloured jasper (which often contain oxide of iron to such an extent as to warrant their being classed as iron ores). These extend as roughly parallel bands, which owing to their serrated ridges stand out in bold relief (Fig. 8), and are very much in evidence in certain districts. These bands do not always occur in straight lines, but as they have also been subject to earth movement since their formation, they are often thrown into a series of gentle curves, which vary locally in general direction.

Fig. 8.
Banded Chert, Mt. Hunt, East Coolgardie Goldfield.

One very great and important problem in connection with our Pre-Cambrian or Archaean Rocks is their division into series which may be correlated from district to district, and during the working out of the stratigraphical relationship of these, the problem is not really so hopeless as it may at first sight appear.

It is only by the application of stratigraphical methods (using this term in the widest scientific sense) to these ancient crystalline schists, that a classification quite as satisfactory as that of the rocks much higher on the geological column, can be arrived at.

These crystalline schists have been invaded by huge masses and veins of granite, which occupy some hundreds of square miles in parts of the State. The intrusion of the granite is perhaps, from the economic point of view, the most important geological event at this perod, in as much as most of the gold deposits, which places Western Australia in the front rank of mining countries in the British Empire, bear some genetic relation thereto.

The mining centre of Tambourah (Fig. 9) in the Pilbara Goldfield is one in which the intrusive nature of the granite may be readily studied, here the country is very nearly destitute of soil, and the rocks lie ready for inspection anywhere. At this locality the granite may be seen to have wandered through the schists, in addition to having engulphed and floated off extensive masses along its margin.

These granite rocks constitute composite batholiths occupying hundreds of square miles, and there seem some geological reasons for believing them to have digested and replaced very large masses of sediments. When considered in the light of their metamorphic

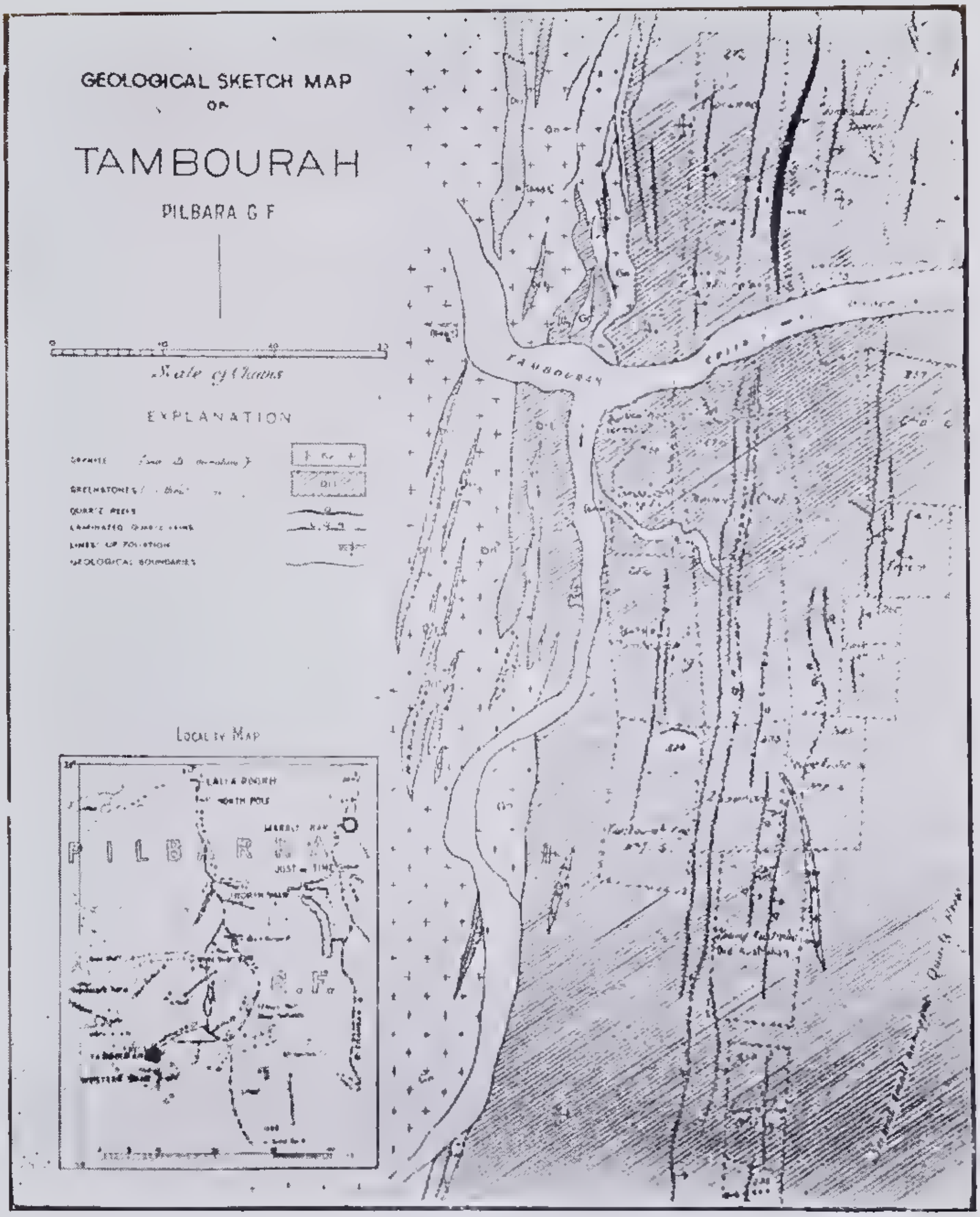

Fig. 9.

effects, these great intrusive granite masses, constitute a great significant and outstanding feature of the Western Australian goldfields geology.

Owing to the physiographic features of the Central Plateau, erosion has not yet penetrated to any depth, hence it cannot be said that the anatomy of these masses has yet been thoroughly understood.

These granites are traversed by many large ice-like quartz reefs (Fig. 10) which can be traced across country for miles; the mode of occurrence, etc., of these large quartz masses point to their being of igneous origin, representing the final product of the differentiation of a granite magma—its ultra-acid portion.

Fig. 10.
Quartz Reef, Erlstoun, Mt. Margaret Goldfield.

A great deal has been written during the last decade or two on the matter of ore deposits, mostly however, on more or less isolated occurrences, which detract very considerably from the value they would otherwise have had, and many of the later day theories on ore deposition have been based not so much upon the results of careful observation, as upon speculation, which has resulted in one eminent scientist giving utterance to the dictum that "Mining prophesies are proverbially erroneous." Very few mines present data sufficient to enable a true mental picture of the real nature of an ore deposit to be obtained, such can, however, only be arrived at by careful investigation into the geological structure and stratigraphy of wide stretches of country, where all the ore deposits are perhaps genetically connected and capable of throwing light one upon another.

Since the days of Daubree work in experimental geology has fallen somewhat into desuetude. A wide and almost untrodden field (in Australia at any rate) is open for laboratory research and experimental work, in connection with the genesis of minerals and the rock types of which they form an integral part. Work of this kind, owing to the light which the results when properly interpreted, would tend to throw on the peculiarities of the distribution of metalliferous ores, etc., can readily be seen to be of considerable economic importance. The recent experimental work upon silicate mixtures, carried out in the geophysical laboratory at Washington may be cited as evidence of the value of such investigations in connection with the two most important problems with which the geologist has to deal, viz., (a) the differentiation of silicate magmas into various rock types, and (b) the nature and order in which minerals crystallise when the molten magma has congealed into solid rock.

THE NULLAGINE FORMATION.

Resting with a violent unconformity upon these older rocks, which so far as may be judged, formed a broad continental mass, or at any rate, a group of more or less closely related islands or archipelago, is a great thickness of sedimentary rocks, which has been designated the Nullagine Formation.

This formation is made up in very large part of material derived from the denudation of the earlier continental land surface. It is impossible in the present condition of our knowledge to determine the exact amount of erosion to which this land surface has been subject prior to Nullagine time. This must have been enormous and the debris from it doubtless formed that great thickness of sediments, ranging from the Cambrian to the most Recent, which go to make up the beds forming the relatively narrow belt in the maritime districts of the State.

The Nullagine Formation is perhaps the most widely spread of any of the rock systems exposed in Western Australia, and in some respects one of the most important. The formation has been followed from the Oakover River, across the upper reaches of the Nullagine, the Coongan and the Shaw Rivers, and from thence without a break to Roebourne and southwards to the Fortescue River. The same series of constitutes the Hamersley Range, which contains Mount Bruce, one of, if not actually the highest summit of the State, it also makes up that rough tableland which divides the waters of the Lyons from those of the Ashburton River. The southernmost boundary of this large exposure is in the neighbourhood of Mount Russel, in south latitude 26deg. 30lat., not far to the south of Lake Way. In its lithological characters, its behaviour and general aspect, the Nullagine Formation bears a very striking resemblance to those beds which constitute one continuous series in that tableland, which extends from Wyndham to Mount Hart, a prominent summit near the southern face of the King Leopold Plateau, in the Kimberley Division.

The Nullagine Formation makes a very prominent feature in the landscape in those regions in which it is developed, presenting as it does a plateau-like appearance, owing to certain of the harder beds standing out in bold relief, and forming mural faces at different levels as at Mount Margaret in West Pilbara. (Fig. 11).

Lithologically the strata consist of a group of sedimentary rocks, sandstones, quartzites, conglomerates, and dolomitic limestones. Associated with these beds, igneous rocks are specially abundant, and according to their mode of origin they are readily divisible into two classes, some were formed from congealed molten

Fig. 11.
Mt. Margaret, Hamersley Range, West Pilbara Goldfield.

matter, crystallising as dolerite, which forced its way either along the planes of bedding or across the strata in the form of intrusive sheets, sills or dykes. The others were contemporaneous with the deposition of the associated sedimentaries and include outpourings of lavas, ashes and other volcanic ejectmenta.

The results of field investigation extending over ten years, in the enormous area occupied by this formation and its equivalents, have shown it to be of absorbing interest to the petrographer, and the student of volcanic geology, as it was without any doubt the most active centre of eruptive energy, to be found in Western Australia during this geological epoch. The gold-bearing character of the basal members of the formation has given additional scientific interest to the series, and added considerably to its otherwise economic importance.

As our exploratory field work has proceeded, coupled with detailed mapping in certain economically important localities, the true character and significance of the Nullagine Formation has been gradually unfolded. Its systematic study opens up a field which bids fair to offer a rich harvest, and when the crop has been gathered, it will be found that valuable additions have been made to the sum total of our knowledge of the igneous rocks and phenomena of Western Australia.

In the neighbourhood of Nullagine from which the formation takes its name, the violent unconformity separating the series from the underlying beds is to be seen. The basal member of the Nullagine Formation is a massive layer of coarse conglomerate made up of rounded ellipsoidal, or sub-angular fragments of the underlying beds. The conglomerate often includes boulders which reach lengths of 4 to 5 feet, though the bands containing the large fragments are merely local. Figure 12 shows a portion of this

Fig. 12.
Auriferous Conglomerate, Grant's Hill, Nullagine. Pilbara Goldfield.

conglomerate at the entrance to one of the mine workings, reef quartz identical in character with that forming the auriferous deposits in the underlying strata, being a very common constituent. The pebbles are imbedded in a matrix, which is principally sandy, though sometimes aluminous. Limonitized pyrites up to two inches in length, often forms an important constituent of the conglomerate or consolidated shingle; owing to the climatic conditions these pseudomorphs offer very great resistance to atmospheric influences and retaining the exact form of the original pyrites, crystals accumulate in fairly large quantities on the surface.

The flats in the neighbourhood of Nullagine are covered with a heterogeneous collection of boulders and blocks, derived from the disintegration of the basal conglomerate, of which a good view may be seen in Fig. 13.

Considerable interest attaches to the nature of portions of the basal conglomerate as exposed in the vicinity of Kadgebut Spring, a watering place some miles to the south of Nullagine township, where the conglomerate is seen to contain some flattened and striated pebbles of rocks identical with those forming the underlying strata. The special interest attaching to these striated pebbles lies in the fact that a glacial origin had been assigned to them by my

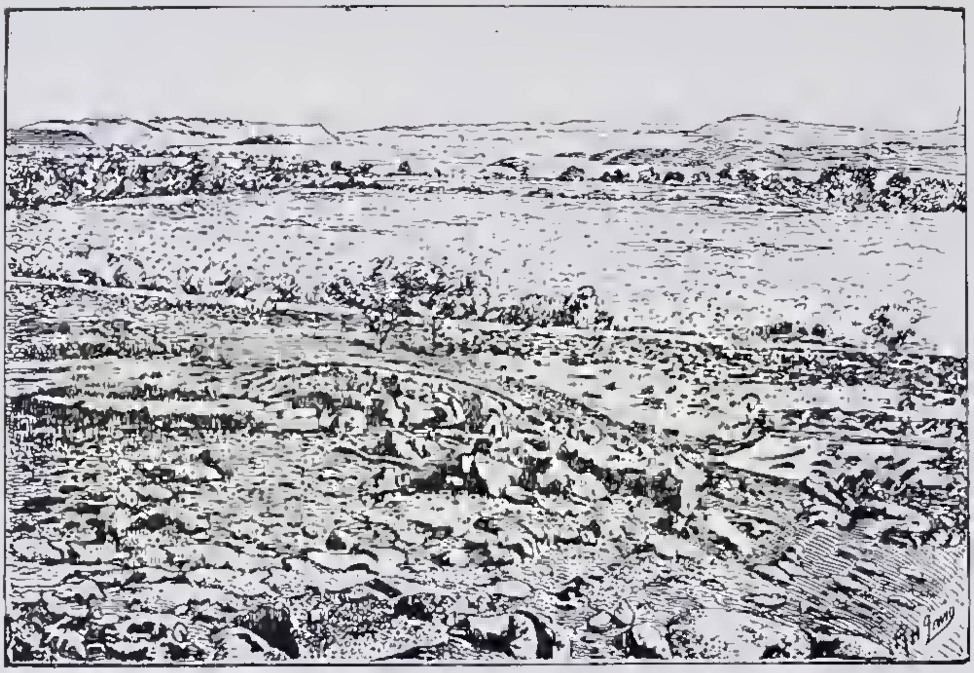

Fig. 13.
Boulder-strewn Flats, Nullagine, Pilbara Goldfield.

colleague, the late Mr. Becher, who was the first to commence the scientific study of the beds of the Nullagine Formation in the type district. Relying chiefly on the literature, a glacial origin for these was subsequently assigned by Professor David. These flattened pebbles however, I think, owe their striated character to mechanical deformation and not to ice action, a view also held by Dr. Jack, who has had considerable experience in glacial deposits, and who has also had an opportunity of examining the specimens in question.

The basal conglomerate at Nullagine is about 300 feet in thickness, though in some localities this is missing, whilst at Just-in-Time, 8 miles from Marble Bar, where it had been mined for its gold contents, the bed varied from one inch to five feet six inches in thickness.

Another good section is to be seen in the vicinity of Goonanarrina Pool on the Sherlock River where the conglomerate—a view of which is depicted in Fig 14—is seen to rest upon a platform of granitic gneiss and crystalline schists.

At Little Mount Phillips in the Barlee Tableland, the basal bed is a coarse boulder conglomerate, which is pretty well vertical.

In other localities, as at Rooney's Patch, at the head of the Oakover River (at. 23deg. S., long. 120deg. 35min. E. approx.) the basal beds of the Nullagine Formation are, as may be seen in Fig. 15, very angular, and the rock is rather a breccia than a conglomerate. This may really represent a scree or talus deposit.

Fig. 14.

Basal Conglomerate, Nullagine Formation. Sherlock River, West Pilbara Goldfield.

Fig. 15.

Weathered Conglomerate. Nullagine Formation. Rooney's Patch, Oakover River.

From the angularity of many of the pebbles in the conglomerate it may be reasonably inferred that the coast-line which furnished them was not far distant, and in all probability the present boundaries of the series approximately marks the original shore line.

What I believe to be an outlying patch of the Nullagine Formation occurs at Mt. Yagahong, near Meekatharra. Here the beds which are practically horizontal, rest upon a granite floor. The basal bed is a thin conglomerate made up of pebbles of granite, above which, as may be seen in the cliff sections are a series of dark fine-grained sedimentary rocks. (Fig 16). The beds of the King Leopold Plateau, wherever I have had an opportunity of examining them, everywhere exhibit a remarkably uniform sandstone facies, indicating but little change in sedimentation in this portion of the State, at this period.

Fig. 16.
Sedimentary Beds. Mount Yagahong, Murchison Goldfield.

Before the close of the period represented by the conglomerate and boulder beds to which reference has just been made, volcanic activity commenced in that portion of Western Australia now occupied by the Nullagine Formation. From numerous and widely separated centres of eruption, of which the remains at present exist, lavas and ashes were thrown out, submerging fairly large areas of country. So far as researches in the field have been carried, the volcanic focii, all seem to be situated along or on the northern portion of the area in proximity to what would appear to be the shore line of a gradually receeding ocean. The great extent of the lava flows and associated ejectmenta seem to imply that these centres of eruption must, during Nullagine time, have appeared as a remarkable chain of coast volcanoes, but whether they are distributed along lines of orographic movement is one of those, as yet unsolved problems of Western Australian geology.

The occurrence of sandstones, quartzites and other sediments interbedded with lava flows, etc., point to the fact that some of these volcanic eruptions took place under water, and must have been followed by intervals during which sedimentation was carried on.

In the King Leopold Plateau in the far north, these volcanic beds occur in great force, and form the highest parts of the country.

At Mount Hann, a very remarkable cliff-faced mountain situated on the highest summit of the plateau, dissected by the upper reaches of the King Edward, the Drysdale and the Prince Regent Rivers, the volcanic rocks can be well seen. (Fig. 17). The

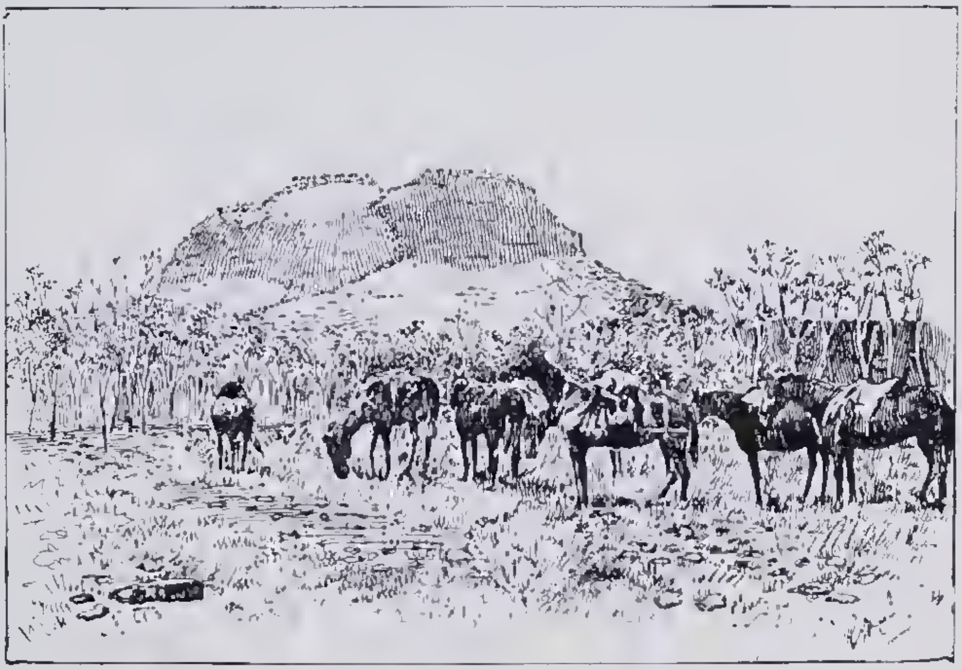

Fig. 17.
Volcanic Rocks, Mount Hann, Kimberley Division.

cliffs formed by the faces of the lavas and ashes, rise perpendicularly from 100 to 300 feet in height. Only one spot on the western face of the mountain by which an ascent could be made was found. From the summit of Mount Hann, about 300 feet in height, an excellent view of the surrounding country could be obtained, and the great extent of the volcanic rocks visible; they were seen about 5 or 6 miles west of the mountain, to rest upon quartzites, which occupied the country as far as the tidal waters of the drowned valley of the Prince Regent River.

In the vicinity of Synnot Creek in the King Leopold Plateau, is a very coarse volcanic breccia which covers a very wide area, and is associated with the lava flows; as a rule the ashy beds are

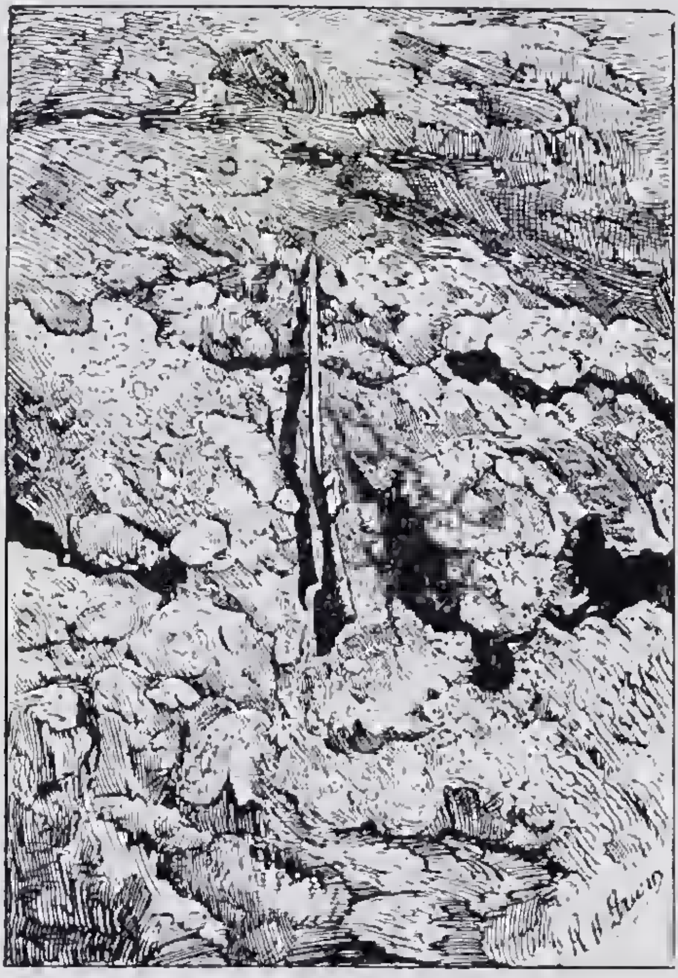

Fig. 18.
Volcanic Breccia, Synnot Creek, King Leopold Plateau, Kimberley Division.

very much finer in grain than that shown in Fig. 18. In this particular instance, it seems quite clear that the coarse agglomerate occupies the throat of one of the volcanic vents which has not yet entirely disappeared by denudation; it is still surrounded by lava flows and fine-grained ashy beds. In the heart of the Hamersley Range (or plateau) the sedimentary rocks may be seen underlying the beds of the volcanic series. (Fig. 19).

In certain localities these volcanic rocks reach a very considerable thickness, often over 500 feet.

So far as our observations have been carried, it appears that, as a rule these lavas have the composition of basalts or dolerites.

Fig. 19.
Stratified Rocks beneath the Volcanic Series, Fortescue Gorge, Hamersley Range.

though in certain places, such as Mount Ankatell they are closely allied to the augite-andesites; while at Bamboo Creek on one of the tributaries of the Coongan River, acidic lavas, quartz felsite, or rhychte, occur near the base of the Nullagine Series.

The steam-holes in many of the amygdaloidal lavas are filled with secondary minerals, partly chalcedony and partly calcite.

The wide-spread occurrence of these lavas and their associates. which are much more numerous and wide-spread in the far north, nearer to that great circle of fire which forms a festoon round Northern Australia, and the relatively few volcanic focii so far noticed, would seem to imply that fissure cruptions played an important part in the formation. This type of volcanism finds a parallel in the 200,000 square miles occupied by the Deccan Trap areas of India, and those extensive lava plains of Northern Queensland, which I have been privileged to examine.

As has already been pointed out, the Nullagine volcanic series lies very near the base of the formation, and the lavas from which it is made up vary in composition from basic to acidic. The precise cause of this differentiation. which seems to have produced what may be called a gradational series of rock types, has an important theoretical bearing, yet requires careful investigation.

An important group of carbonate rocks occupies a distinctive and well-marked stratigraphical horizon in the Nullagine Formation, and covers a very considerable area of country in the Barlee and Hamersley Ranges, and in the valleys of the Ashburton and Oakover Rivers. As developed in these districts the group normally consists of magnesian limestones, which vary somewhat not only in chemical composition but in general appearance. Several analyses of these have been made, and the limestones have been found to contain from 12 to 22 per cent. of carbonate of magnesia, from 14 to 30 per cent. of carbonate of lime and of carbon dioxide from 21 to 47 per cent., in addition to varying proportions of silica.

The limestones often have a characteristic surface not unlike an elephants hide. On account of its definite characteristics, and its mode of origin which serve to separate it from the bulk of the Nullagine beds, it has been deemed advisable to designate the group by a distinctive specific name. For this purpose I propose to adopt for this lithological and stratigraphical unit, the name, *The Carawine Dolomite Series*, from the name of that locality on the Oakover River, where the dolomite is so well developed and where the numerous beautiful cliff-sections afford splendid opportunities for investigation. (Fig. 20).

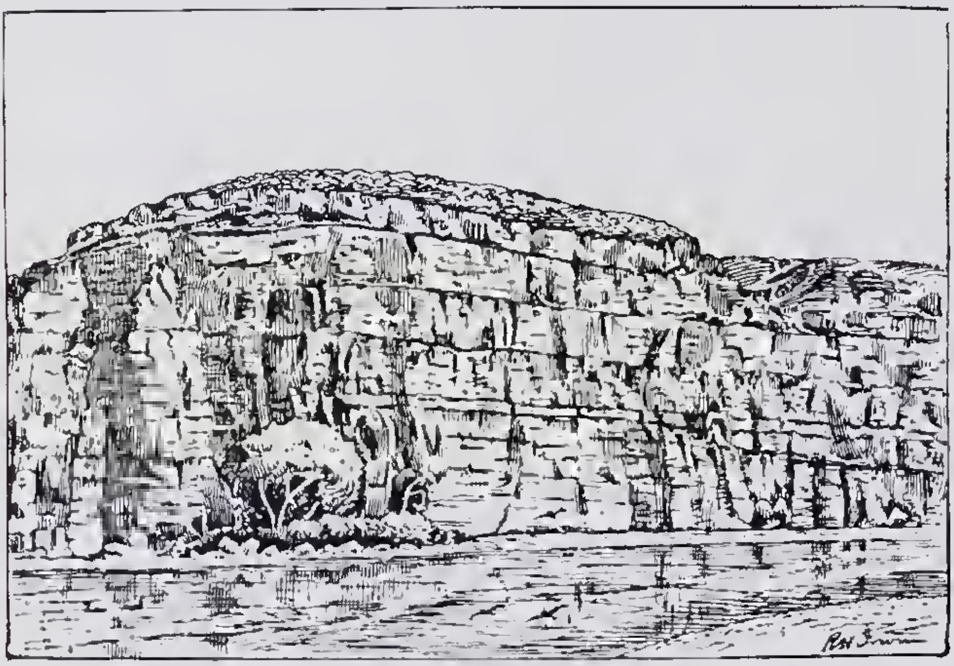

Fig. 20.
Dolomitic Limestone, Carawine Pool, Oakover River, Pilbara Goldfield.

The thickness of the limestone in the Carawine Pool* section is as measured not less than 300 feet; the base of this bed of dolomite is exposed on the eastern side of the Pool, and is seen to rest upon a volcanic rock. The limestone contains bands of chert and jasper, which have not however, up to the present yielded any recognisable fossils, though in all probability their origin may be ascribed to the accumulation of siliceous skeletons of sponges or diatoms. The limestone as exposed at Carawine covers a very wide extent of country, for it has been found to be continuous at least 20 miles to the southward. In certain localities springs of water, highly charged with carbonate of lime, issue from the cliffs

*Lands Department Litho. 108/300.

at the rate of many thousands of gallons per day. Some of the limestones at Carawine have been faulted. (Fig. 21).

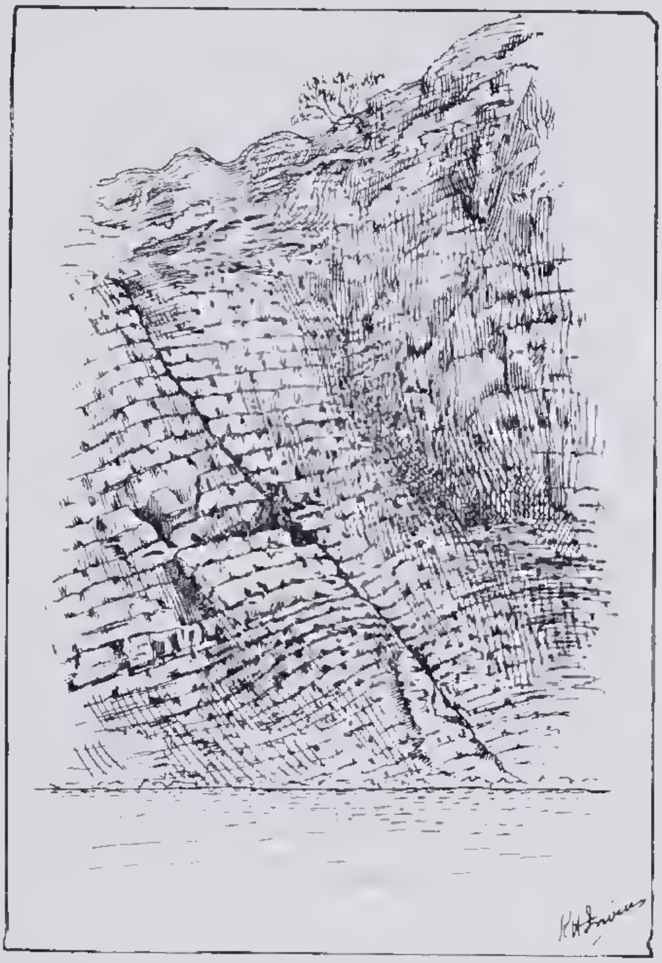

Fig. 21.
Fault in Dolomitic Limestone, near Carawine Pool, Oakover River, Pilbara Goldfield.

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At Irregully Creek, in the Ashburton River, the Carawine Dolomite Series, which in this locality consists of gently inclined flaggy limestones, rests upon a bed of conglomerate two or three feet thick, which in its turn reposes directly, and with a violent discordance on the older beds beneath. Near the mouth of Soldiers' Secret Creek, another important tributary of the Ashburton River, the limestone which is at least 350 feet thick rests directly on the upturned edges of the schists and slates, which form the matrices of the auriferous deposits. No conglomerate was found at the base of the Nullagine Formation, as developed in the tableland which forms the divide between the watershed of the Lyons and the Gascoyne.

What may possibly turn out to be the northern extension of the Carawine Dolomite Series is to be found in the Napier Range in Kimberley. (Fig. 22).

Mount Russell*, a hill on the boundary between the Murchison, Peak Hill, and East Murchison Goldfields, distant about 25 miles

* Lands Dept. Litho. 60/300.

north-west from Lake Way, and which rises to about a height of 250 feet above the general level of the surrounding country, is built up of dolomitic limestone which however, is represented by only very thin beds, nowhere exceeding three or four feet in thickness, alternating with siliceous shales or slates. (Fig. 23). The beds are almost uniformally horizontal,

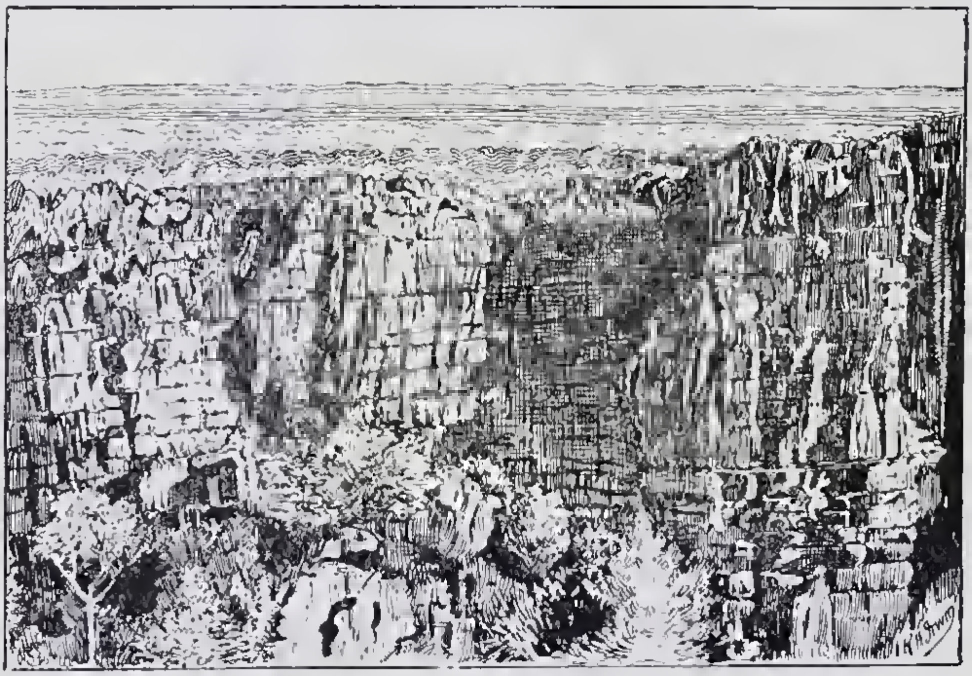


Fig. 22.
Limestone Cliffs, Napier Range, Derby, Kimberley Division.

Fig 23.
Flaggy Dolomitic Limestone and Shale, Nullagine Formation, Mount Russell, East Murchison Goldfield.

and the general succession indicates a condition such as is often found in proceeding from a shore-line to deeper areas of deposition. The limestones are clearly of marine origin, and as the siliceous beds are found to alternate with them, it may be inferred that they were also laid down in the sea, of which the southern margin is defined by the beds of Mount Yahagong, in lat. 27 deg. South, to which reference has already been made. The Nullagine Sea, therefore, extended over about fourteen degrees of latitude, north of Mt. Yahagong, near Gabanintha.

Lying conformably above the Carawine Dolomite Series is a considerable thickness of arenaceous sediments, quartzites, ferruginous sandstones, grits with subordinate sandy shales. At Mount Margaret in the Hamersley Range, these are represented by very fine-grained ferruginous flaggy sandstones with some very siliceous bands, and also some banded ironstones, the beds being practically horizontal. The ferruginous beds contain magnetite and hematite, the percentage of iron being as much as from 28 to 37 per cent. These ferruginous quartzites, jaspers or cherts, are sometimes somewhat calcareous. These banded ores bear a very remarkable resemblance to those banded ores, jaspilites, etc., which make such conspicuous features in most of the southern goldfields, and suggest a common origin for the two. An excellent example of these banded jaspers is to be seen in the Coongan River at Marble Bar, which perhaps may be regarded as typical. (Fig. 24).

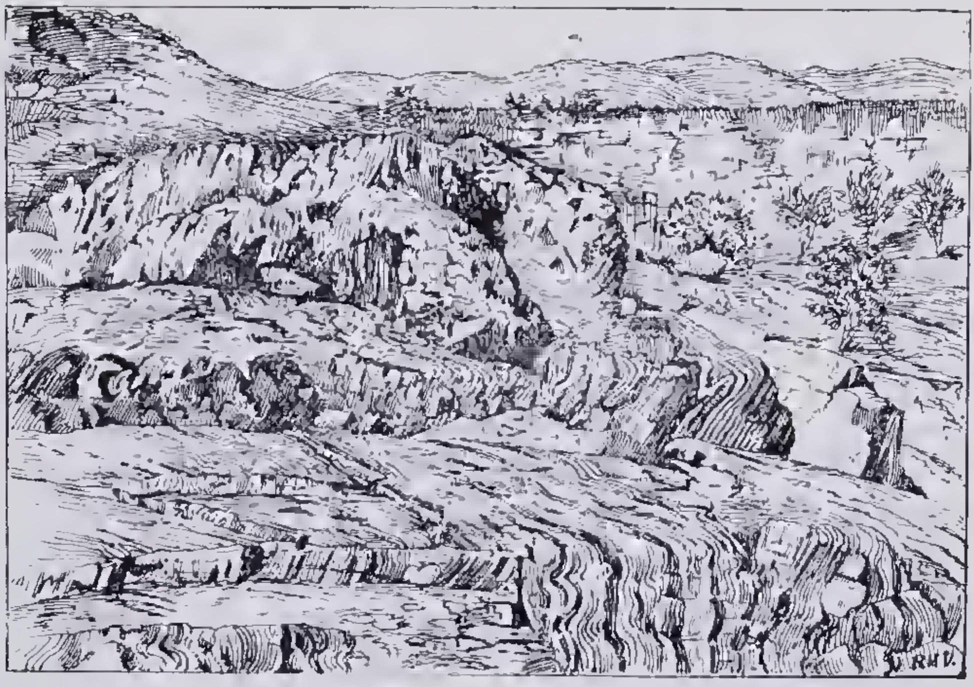


Fig. 24.
Jaspilites, The Marble Bar, Coongan River, Pilbara Goldfield.

Here the laminae forming the "Bar" dips at an angle of 50deg. to the west. The thickness of the bed is about 220 feet from wall to wall. The rock presents a brilliant appearance due to the interlamination of red, white, and dark coloured bands. The ferruginous beds of the Hamersley Range are clearly of sedimentary origin. Near Yelina Soak,* these sediments are seen to be gently folded (Fig. 25) and at Punda Spring** (Fig. 26) the ferruginous beds are very

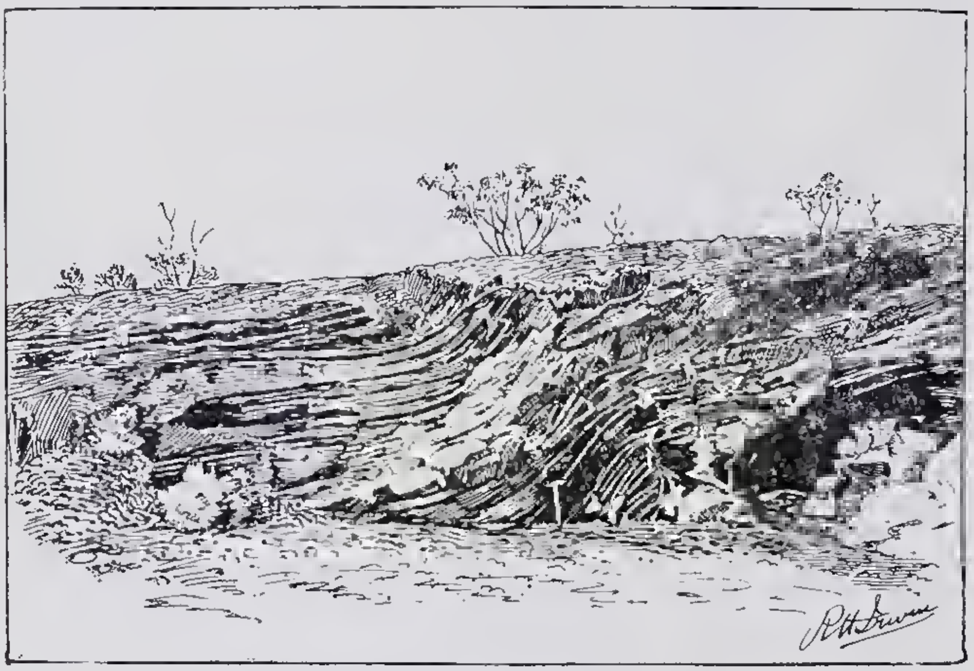


Fig. 25.
Curvatnre in Sandstone, Yelina Soak, East Murchison Goldfield.

Fig. 26.
Contorted Jaspilite, Nullagine Formation, Punda Spring.

*Lands Dept. Litho. 61/300.
**Lands Dept. Litho. 91/300.

violently contorted, reminding one very forcibly of the contorted jaspilites as seen in the goldfields to the south, an excellent example of which is to be seen at Marda (Fig. 27), near Mount Jackson in the Yilgarn Goldfield.

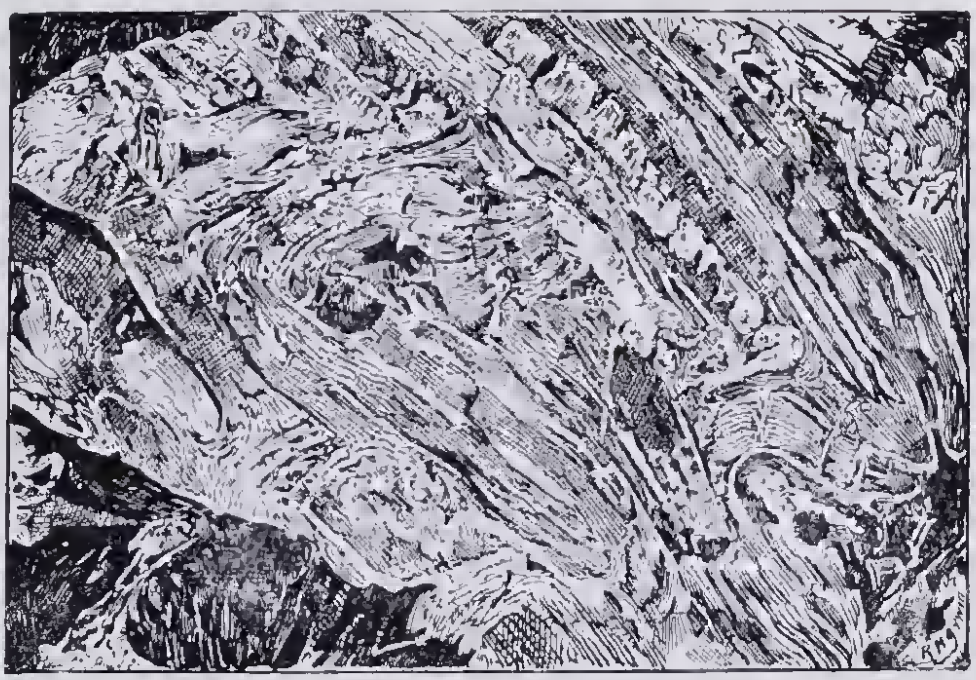


Fig. 27.

Contorted Jaspilite, Marda, Mount Jackson, Yilgarn Goldfield.

A remarkable, and very important feature in the plateau region occupied by the Nullagine Formation is the abundance of dolerite intrusions, which take the form either of nearly horizontal sills or steeply inclined dykes.

These dolerites have a remarkably uniform composition, and wherever they have been examined th rocks exhibit little or no trace of recrystallisation or other signs of metamorphism. Occasionally a glassy selvage due to rapid cooling may be noticed occuring at the contact between the dykes and the rocks it traverses. The dolerites seem to be in practically the same condition in which they originally congealed, and no great terrestrial disturbance seems, when the Nullagine Formation is viewed broadly to have effected the region since the time of their injection. The dykes are all readily distinguished by their dark-greenish colour, a rusty and in places exfoliating weathering. Some extend across country in more or less straight lines for many miles, and give rise to fairly conspicuous features standing out boldly on the back of the ridge, of which an excellent example, the Black Range (Fig. 28) is to be seen in Pilbara. The name is given from the almost black weathered rocks of which the range is made up. One of these dykes or sills may be seen near Mt. Frew* invading the sedimentary rocks along the planes of bedding. (Fig. 29).

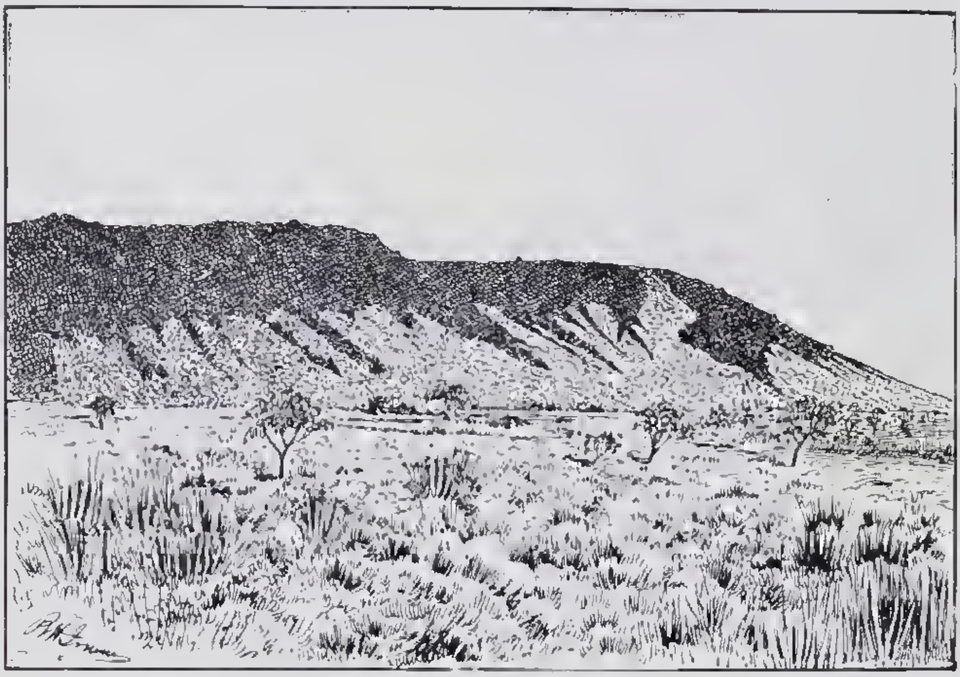


Fig. 28.
Dolerite Dyke, Black Range, Hillside, Pilbara Goldfield.

Fig 29.
Dolerite Sill in Sedimentary Rocks, Mount Frew.

*Lands Dept. Litho, 90/300.

A conspicuous hill in the watershed of Monkey Creek**, shows a beautiful example of a dolerite sill resting on indurated shales, with the cover overlying the dolerite removed by denudation. Occasionally an effect of the igneous intrusion in arching up the overlying strata may be noticed, an excellent instance of which is to be seen in Fig. 31) here the intrusion is laccolitic in character,

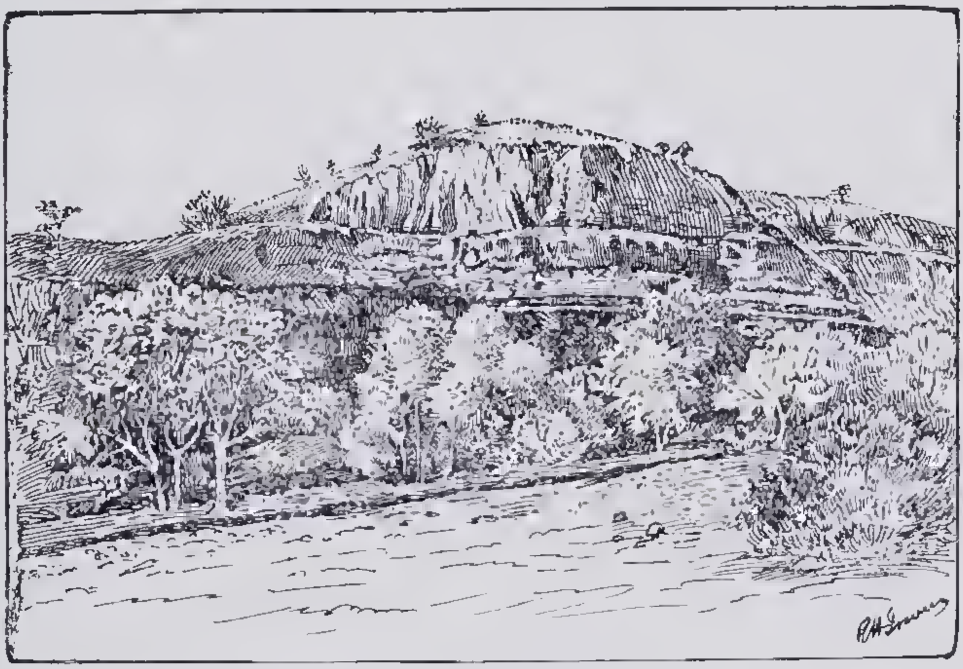


Fig. 30.
Quartz Dolerite Sill, resting on Shales, Monkey Creek.

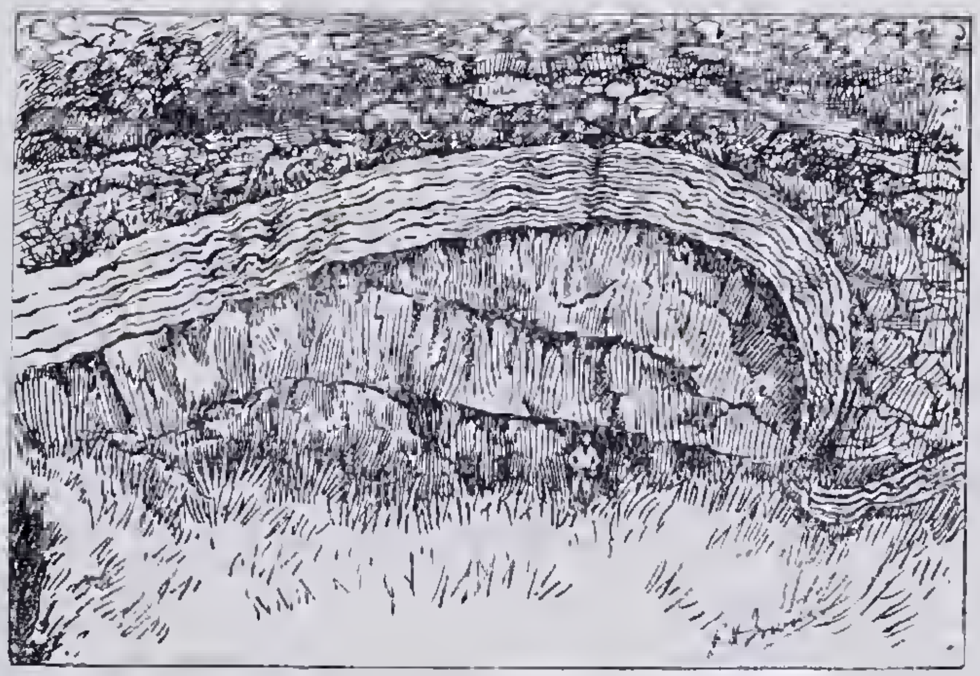


Fig. 31.
Sill in Sedimentary Rocks.

** Lands Dept. Litho. 80/300.

Near Kunningina Hill†, is to be seen a portion of what may be called a compound laccolitic form of intrusion of what is usually described as the cedar-tree type (Fig. 32) here tapering sheets of dolerite may be seen running out into the neighbouring sediments. the sedimentary rock being, as may be seen dipping away from the dolerite in all directions.

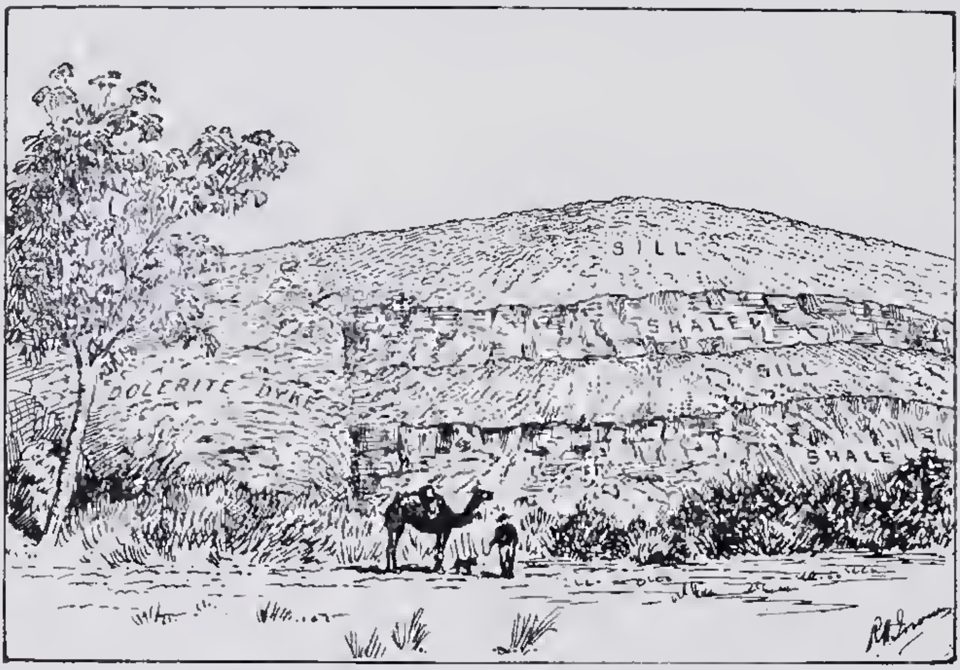


Fig. 32.
Laccolitic Intrusion, Cedar-Tree Type, Kunningina Hill.

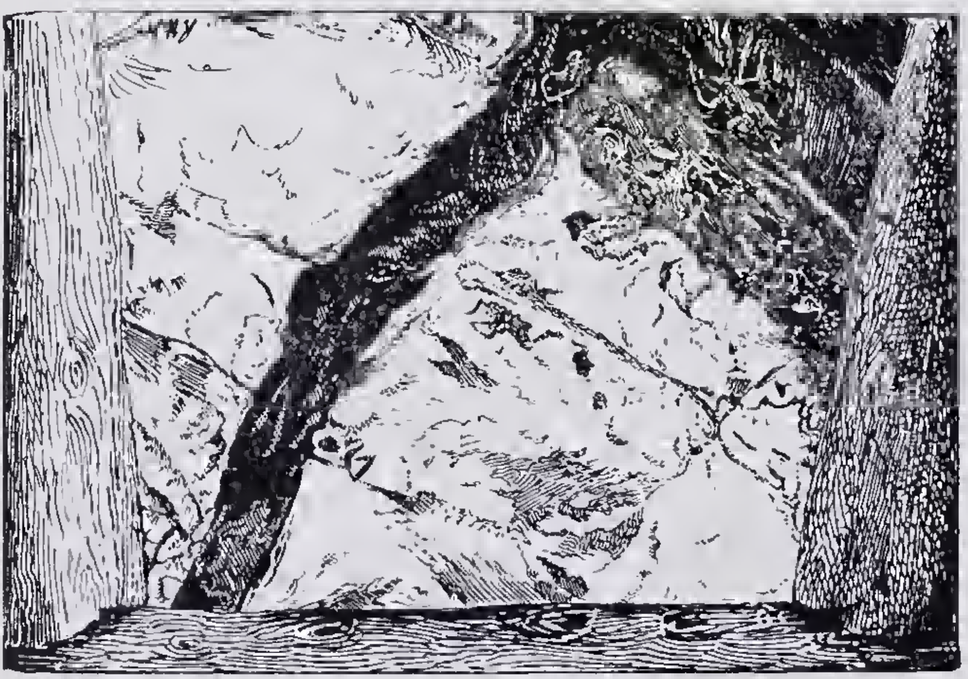


Fig. 33.
Dolerite Dyke Cutting through Reef, Oroya-Black Range Mine, East Murchison Goldfield.

† Lands Dept. Litho. 99/300.

On the northern face of the plateau in the watershed of the Maitland River in the West Pilbara Goldfield, may be seen a splendid example of one of these dolerite dykes, cutting the horizontal strata transversely, but unfortunately no opportunity of photographing it could be had.

These dolerite dykes have been noticed in mine workings, traversing the auriferous deposits. An excellent instance of which may be seen in the workings in the Oroya-Black Range Mine at Sandstane. (Fig. 33). The dykes may also be seen at other localities outside the limits occupied by the Nullagine Beds, as at the Croydon Road Crossing on the Sherlock River. (Fig. 34).

Fig. 34.

Gabbro Dyke, near Croydon Road Crossing, Sherlock River, West Pilbara Goldfield.

In addition to these dykes and sills, there are a large number of quartz reefs, containing more or less gold and copper traversing the Nullagine Formation, only however, in those special localities which have undergone more or less earth movement.

From such brief descriptions as it has been possible for me to give you during the short time at my disposal, it appears that during Nullagine Time, there must have been a huge reservoir of molten matter lying beneath the surface to the north of latitude 26, and merely awaiting a suitable opportunity of rising to the surface.

There is as yet little definite evidence as to the nature and composition of the parent magma, from which these igneous rocks were derived, nor any adequate explanation as to why the rocks were acidic in some localities and basic in others.

The geological age of these dolerite intrusions cannot, in the light of our present knowledge be fixed with any degree of certainty. As regards the problem connected with the relative age of the lavas, ashes, and the dykes and sills, there is but little direct evidence; it is possible that they may be grouped together into one series, which may be held to represent one distinct phase of the volcanic phenomena of the State.

Since their deposition the Nullagine beds have been uplifted. and are now disposed in a series of broad anticlinal folds, having taken part in orgraphic movements during a period which appears to have preceeded the formation of the Permo-Carboniferous strata. The beds were everywhere uplifted by mountain building processes accompanied by folding, faulting, and occasional plication. In the Strelley River gorge a section is to be seen which shows the sediments and associated volcanic rocks bent up into a sharp anticlinal fold, the axis of which is north-east and south-west. This fold is depicted in Fig. 35, but the fold was produced so long

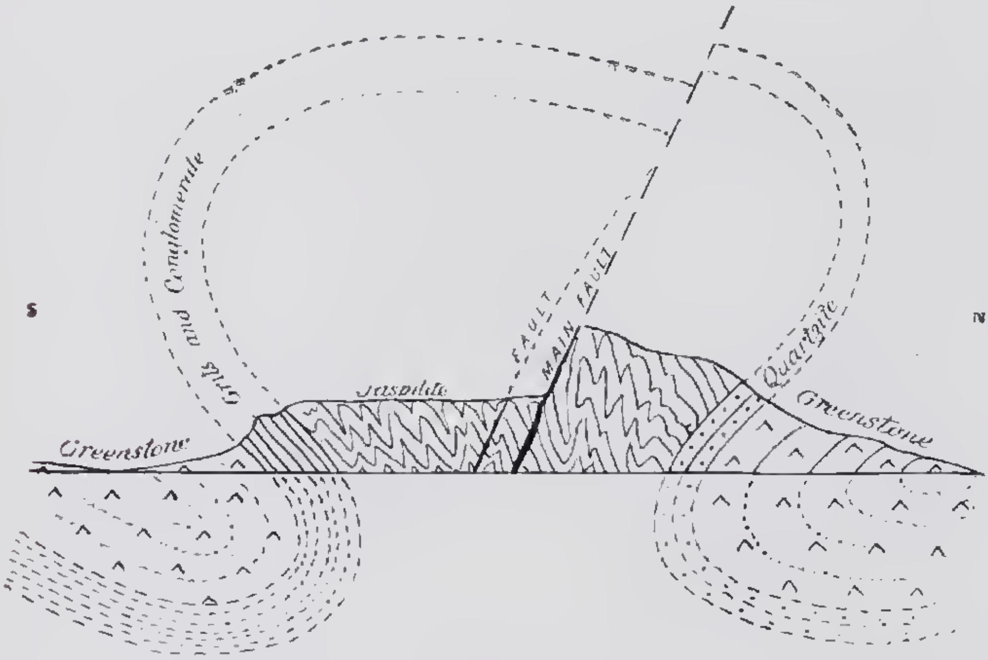


Fig. 35.

Generalised Section along the Strelley River Gorge, Kimberley Division.

ago that its crest has been worn away, and the arch snapped in two. The dotted lines represent the restoration of this arch. Another excellent example of this folding is to be seen in the denuded anticlinal at Bangemall, on the Lyons River, the two bands of quartzite which form the legs of the fold, rise as conspicuous serrated razor-backed ridges, traceable across country for many miles. (Fig. 36). This post-Nullagine movement was doubtless coincident with similar movements elsewhere in Australia, though at present these cannot be definitely correlated.

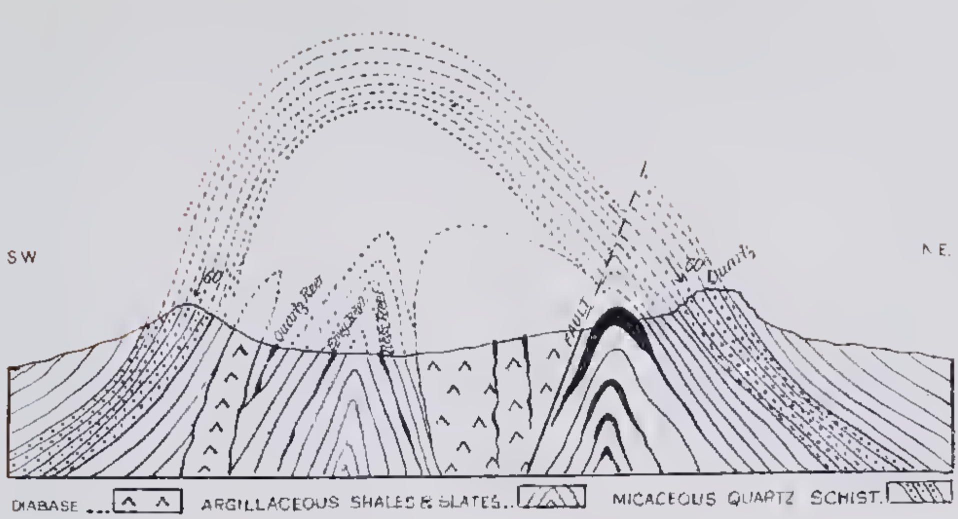


Fig. 36.
Generalised Section across the Bangemall Anticline, Gascoyne Goldfield.

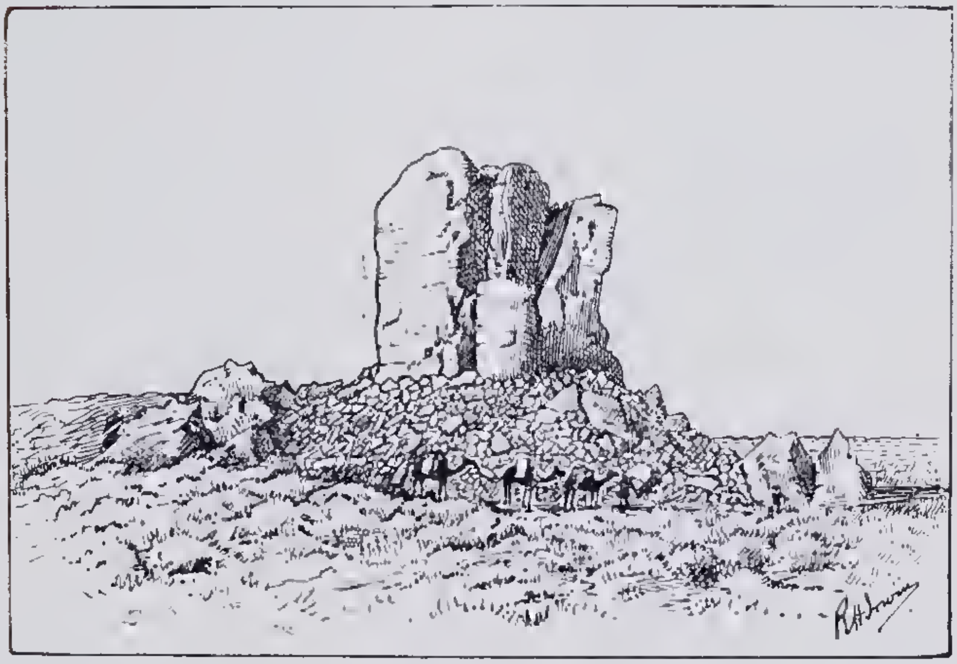


Fig. 37.
Sandstone Butte, thirty-three miles east of 692 M. Rabbit Proof Fence.

In post-Nullagine times erosion of the series was excessive, and possibly long continued. The strata were cut down until in some cases they were represented by mere isolated outliers (Fig. 37) such as may be seen thirty-three miles east of the 692 mile* post on the rabbit proof fence near the head of the Oakover River. The horizontal or gently inclined beds have been deeply incised, and narrow trenches cut into them, forming magnificent canons, but often some miles in length down which the waters find their way seawards. A view of one of these canons, carved out of the

* Lands Dept. Litho. 99/300.

quartzites of the Prince Regent River may be seen in Fig. 38). These sediments lie on a much lower geological horizon than the lava flows of Mount Hann. These canons are of great beauty, and it is much to be regretted circumstances have prevented many of them being photographed.

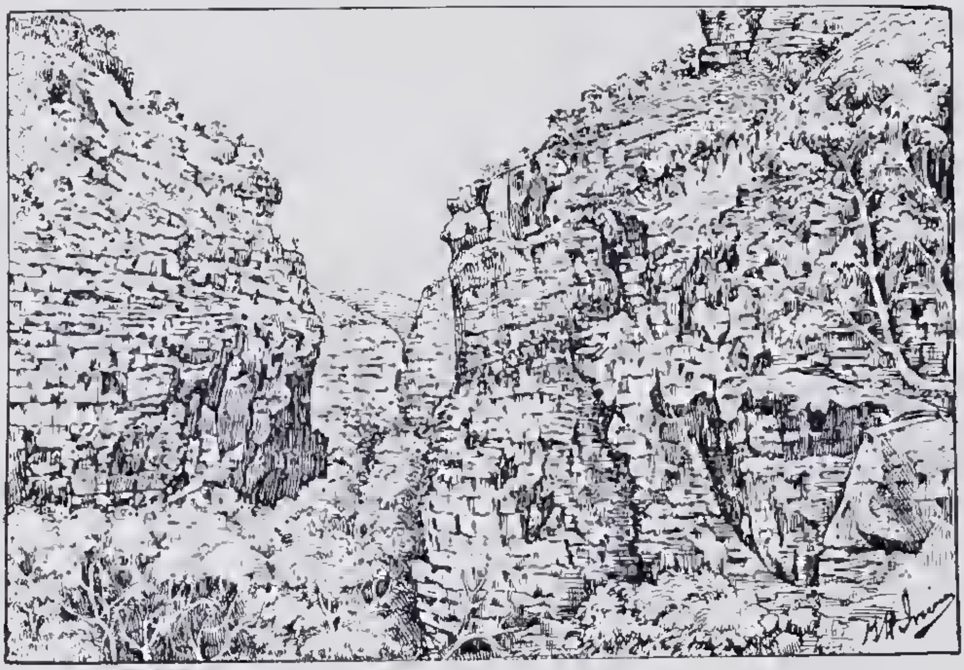


Fig. 38
Cañon, Prince Regent River, Kimberley Division.

For a very long period of time there was a danger of our geological observations being lost in a mass of detail, and the time is rapidly approaching when what may be called the histological aspect of the subject, can give place to generalisation.

The recognition of the positon of the Nullagine Formation in the geological time scale is a point of considerable importance. None of the beds, despite the fact that the dolomites are of marine origin, have as yet yielded any fossils, hence any correlation of the strata will be little else than tentative. The earliest observer, Mr. H. P. Woodward assigned a Devonian Age to the formation, though the evidence does not seem to be conclusive. The next observer, the late Mr. Becher, writes that of "the age and origin of these interesting Nullagine beds nothing definite is known." Prof. David infers that the beds are "probably of older Palaeozoic age (? Pre Cambrian.")

The only direct evidence we have bearing on the question of their age, is that acquired by my colleague, Mr. Talbot, in his recent explorations in the north. The beds of the Nullagine Formation are seen to pass unconformably beneath much newer strata in the Paterson and Broadhurst Ranges, in the watershed of the Rudall River.

These newer beds which occupy the whole of the country traversed by the ill-fated Calvert expedition, which extend as far north as the Fitzroy River Valley. Fossiliferous Mesozoic rocks have been met with in this area at a depth of about 1,400 feet in one of the bores put down in the search for artesian water at Derby. There is, therefore, no positive evidence as to the age of the Nullagines beyond the Pre-Cambrian or Archaean below, and the Mesozoic above, the latter limit being determined by the *Belemnites* in the bore-hole referred to.

Geologists are unfortunately, somewhat prone to refer every stratigraphical or lithological unit to European or other standards, and to give names to the beds of which they are supposed to be the equivalent. I am afraid that any attempt at present to harmonise the time-tables, will only end in confusion, and tend rather to hinder than to advance knowledge.

In its lithological characters, its structural relationships, and its igneous phenomena, the Nullagine Formation bears a very marked resemblance to the beds in South Africa known as the Potchefstroom or Transvaal System, of the age of which all that it is possible to say that it is Pre-Devonian. The Nullagine beds also bear a very close relationship to the Bijawar or Cuddapah Series of Peninsular India, which constitute a part of the Purana Group, which is assumed to be the equivalent of the Algonkian as the term was originally understood in American stratigraphical nomenclature.

The seat of all the Western Australian mineral wealth lies in the rocks more or less directly associated with the beds of the Nullagine Formation, and one at any rate of the unsolved problems which presents itself, is, the ore deposition associated with Pre-Nullagine time, or is it more recent than the mountain building era, during which the schistose structure was developed?

In the multiplicity of the problems, the master one is that just propounded, and the solution of it involves pretty well all others, a condition which almost instinctively brings to mind the words in the Talmud:—

"The day is short, and the work is great, it is not incumbent upon thee to complete the work, but thou must not therefore cease from it."

We are glad to see, that despite all the difficulties, geological science, which is perhaps one of the very best of grounds for training the faculty of observation, and the power of reasoning, has taken its rightful place in the highest educational institution in Western Australia. In years to come, we shall look forward to the time, when some of those trained within its walls will play a part in helping to solve some of the many problems in Western Australian geology, of some of which but a passing glimpse has just been afforded you.

"Wherever and by whatever means sound learning and useful knowledge are advanced, there to us are friends. Whoever is privileged to step beyond his fellows on the road to scientific discovery will receive our applause and if need be our help. Welcoming and joining in the labour of all, we shall keep our place amongst those who clear the roads and remove the obstacles from the path of science, and whatever be our own success in the rich fields which lie before us, however little we may now know, we shall prove that in this our day we knew at least the value of knowledge, and joined heart and hands in the endeavour to promote it."

So spoke the President of the British Association for the Advancement of Science in the year 1865, and to his words I merely add by way of an echo, "So say all of us."

My self-imposed task is over; my term of office as your President, has now come to an end, and in vacating the Chair, in favour of my successor, may I ask you to ponder over the deeper meaning conveyed in the words of one, alas! of our very few, Australian poets:—

"God said let there be light. They but fulfil
With banded aim, His first recorded will,
Who pass obedient to the prime command,
The torch of Science on from hand to hand."

PRINCIPLES OF CURRENCY.

By
Mr. F. E. Allum.

(Read 14th September, 1915.)

The word currency is used to denote that which passes from hand to hand as a medium of exchange. At the present time, coin, notes, cheques, bills of exchange, postal orders, etc., constitute our currency.

Simple exchange or barter is clumsy and inconvenient, except for those isolated occasions when one person has exactly what another wants at the same time that the second person has exactly what the first wants. This coincidence is so rare that the need for the use of some commodity as a store of value and a medium of exchange, that is to say as currency, is one of the earliest felt by traders in any community. It is only in small villages where a simple form of communism has been established that any collective life can be carried on without a currency in which to measure the value of the various services performed. In barter one of the greatest difficulties is how to deal with large objects difficult or impossible to divide. One of the first conditions to be fulfilled by the medium to be used as currency, must therefore be divisibility. Most of the currencies of the past, except that of the pastoral states, were made of materials easily divided to meet the needs of small transactions.

For currency it is desirable also to select something which is generally wanted, as an article which is in fairly constant demand will remain at about the same value at all times. Stability in the value of the material used as currency is obviously important. It is desirable also to have as currency something that can easily be carried about, easily recognised, difficult to destroy, and homogeneous in character.

It is clear that it is difficult, if not impossible, to find a commodity fulfilling all these requirements, nor are they always of equal value. The nature of the trade of the country concerned would decide which of the attributes were the most important. For a small country with simple industries, a currency that can easily be passed from hand to hand, keeps about the same in value, is easily divided, and easily recognised, would be about all that would be required. History shows that for such conditions currencies of cowrie shells, wampunpeag, rum, sugar, tobacco, or metallic coins have all proved able to meet the requirements of trade without much inconvenience. For a great commercial or industrial State, such a currency is not quite sufficient. For dealing with wealth in large sums, portability and stability of value become much more important. The medium of exchange need not be the actual standard of value, but only some token representing it. The use of such a token permits of a medium of exchange of great portability being in use, together with a standard of value of great stability. We see such a system in operation in the United States. The standard of value is a (theoretical) gold dollar, standard gold coins being made of the values of 10, 5 and 2½ dollars. The principle currency is however of paper; a most portable material. The one serious drawback to this system is the ease with which the material used for currency can be destroyed, particularly by fire.

Under modern conditions heavy and bulky material is not desirable for use as currency, although in pastoral States slow and cumbersome oxen appear to have been sufficiently portable for the needs of the community. Such a medium of exchange would obviously be useless for the thousands of small transactions of modern life. Even metal, when it becomes cheap is apt to be too bulky for convenient use. A curious instance of this occurred in Sweden. From 1644 to 1776 there was a currency of thick square plates (plätar) of pure copper of various sizes, the largest weighing as much as 17 kilogrammes (37½ lb. avoirdupois). The value in silver dalers, with the year of its issue, was stamped in the corners and in the middle of each plate. The reason for using these cumbersome blocks was a desire to benefit the Swedish copper mines. For a long time these plates formed the chief medium of exchange in Sweden, and as they were very unwieldly, merchants had to provide themselves with wheelbarrows when making payments of any considerable sum. The value in sterling of the large plate was about £1 6s. 5d., so that a payment of three pounds involved the transfer of a hundredweight of copper plates. In our own currency the penny, which is only a token representing the 240th of a pound, is inconveniently large.

The attribute of divisibility is very important for modern retail trade. Oil, corn, cowries, wampunpeag, tobacco, etc. were all superior in this respect to cattle. Many things, such as skins, which have for a long time been the principle medium of exchange among the red Indians, can be divided, but unfortunately two small pieces are not of the same value as one large piece of the size of the two put together. Moreover the more such material is cut, the less valuable it becomes. With metals, however, owing to the ease with which they can be melted together after division, this drawback does not exist to any extent, and in the case of the precious metals hardly at all. In the case of the material chosen for currency divisibility is essential, while divisibility without loss of value is highly desirable. Gold and silver possess both these attributes, and in that respect are ideally fitted for currency.

Approximate indestructibility is also desirable. Something is required that will not evaporate, decay or rust, and is not easily dissolved or burnt. Here again gold and silver appear to be the materials which best fulfil the requirements. It is not difficult to obtain these metals, or the alloys of them that are customarily used for coinage, in a state of practical homogeneity. In currencies of cattle, skins, wheat, oil, etc. this attribute is sadly lacking. It being difficult to produce a unit of any of them which is of precisely the same quality as that of any other unit.

The greater the volume of retail trade, the more necessity is there for the currency to be composed of something which can readily be recognised. In a pastoral state there is probably always plenty of time to thoroughly examine an animal which is tendered as payment in order to be sure that it comes up to the required standard. For present day conditions such a currency would be hopelessly unsuitable. Precious stones, ideal as they are as a store of value, are unsuitable for currency because of the difficulty of appraising their worth. If diamonds, so portable and indestructable, were in frequent use as currency, I fear that many of us would be in danger of finding our stores of wealth largely composed of worthless glass. In respect of easy recognition, pieces of metal seem to be best suited. Cut into certain sizes, and stamped all over with the same markings, as are our modern coins, they are easy to recognise at a glance.

It will be seen from the foregoing that nothing is able to serve all the requirements equally well, but that metals, and particularly the precious metals, approach nearest to the ideal. Alloys of copper, nickel and aluminium have also been found suitable.

At the present time we use gold

as a commodity,
as currency,
as a store of value, and
as a measure of value.

Such an arrangement has great advantages, but it is not essential, and has frequently not been the case. For instance, the measure of value might be silver, the principal currency gold, and the store of wealth diamonds. In Queen Elizabeth's time silver was the measure of value, gold was used for large payments, while the standard of value in reckoning long leases was corn.

One of the chief inconveniences of the system of reckoning in one substance and paying in another is that payments, such as rents taxes and tolls, intended to remain the same, do in fact become very different without any apparent change having taken place. If rent is payable in wheat, reckoned at so many bushels of wheat to the pound sterling, the amount would always be recorded in pounds, shillings and pence as the same, whereas in bad seasons it would really mean a heavy rent, and in good seasons a relatively low one.

In lands where hunting is the principal occupation, it is found that the measure of value and the medium of exchange is usually furs or skins, or perhaps articles of ornament. In North America both these forms of currency have existed. Strings of beads made of shells, known as wampungeag, served the Indians, both as ornaments and currency. So firmly fixed was this, that the Court of Massachusetts, in 1649, ordered it to be received in payment of debts among the settlers at a rating of forty shillings for a piece a foot long (if of black beads), and two feet (if of white beads). This form of currency being very indestructible, was used by the Indians as a store of wealth, and was hoarded just as coin is hoarded.

Another, and perhaps better known currency, is the cowry shell. These are used in West Africa, India and Siam. In India they generally pass at a rating of 5,000 to a rupee (about .01 penny each). In Fiji whales teeth have been used as currency, one red tooth being worth about twenty white teeth. Amber, engraved stones, and scarabs have all been used as currency at various times and places.

In pastoral States, cattle and sheep have usually formed the measure of value and the currency. The ancient Hebrews reckoned their wealth in flocks and herds, although they used wedges of gold for a store of value and for payments on a large scale.

Animals as currency have many conveniences, they do not require to be transported, but can convey themselves from the debtor to the creditor, they are easily counted, and they are, in a pastoral state, universally in demand, also they keep at about same value for some years. Their chief drawback is lack of divisibility.

In Greece oxen were used as currency, although at the same time gold and silver were used as a store of value and occasionally as a medium of exchange.

It is interesting to us that it is from these pastoral days, with their animal currency, that we get many of our words relating to coin and currency.

The figure of an ox was one of the first to be impressed upon metallic currency, and our word pecuniary is derived from the latin *pecus*-cattle.

The word fee again comes from the Anglo-Saxon *feoh* (cattle). While in modern German, the word *vieh* also means cattle. In Norse, Anglo-Saxon and old English, the word *skat* meant cattle, and also tax, payment or tribute. Thus we have derived the expression Scot free—free from tax or tribute.

Cattle being counted by the head, they were called *capitale,* hence the word capital, also the legal term chattel.

In agricultural states, corn has usually been the currency. In Egypt in particular this was so. In Mediterranean lands, olive oil has been used as currency. This is a convenient medium from the point of view of divisibility. It lasts a very long time, and is in constant demand. Fufilling therefore, two of the conditions necessary for a commodity when used as currency. In Central America cacao nuts have been used.

Two of the best known vegetable currencies are tobacco and sugar. In the North American plantations, now the New England States, tobacco was the currency for a very long period. In 1732 Maryland made tobacco and Indian corn legal tender for payments.

In the West Indies, payments were legal in sugar, rum, molasses, indigo and tobacco.

In Barbados the currency was at first cotton and tobacco. In 1640 sugar became the currency and was rated in sterling at 10s. per 100 lbs. By the close of the 17th century, coin had taken the place of sugar to a great extent, and by 1715, a metallic standard was formally established.

Manufactured goods have also figured as currency. Pieces of cloth known as guinea pieces have been used on the west coast of Africa; salt in Abysinnia, Sumatra and Mexico; Benzoin gum and beeswax; in Sumarta, feathers, tea, etc.

In general the development from simple barter to the modern system of metallic and paper currency has followed much the same course. Various media of exchange were used until the idea was hit upon of making a metallic token to represent the article formerly used. A piece of metal comparatively rare at the time was taken and stamped with a mark to indicate that it was worth a unit or multiple of the customary standard of value. Thus in the case of ancient Greece, payments were made in bronze coins, reckoned in terms of cattle. That is to say, the money of account was cattle, but the currency was copper. As time went on the idea of the original currency became vague, and the metallic representative itself became the standard of value, and the money of account, as well as the medium of exchange. Increased mining operations made the chosen metal more common, and more of it had to be given in exchange for other things, that is to say: prices rose. The amount of coin to be handled then became inconveniently large, and at length a rarer metal was selected to represent the higher values in a more portable form. Thus copper, then silver, and lastly gold, were pressed into use for metallic currency. Ultimately owing to great expansion of trade, even gold became too bulky for convenience, and the further device was resorted to of storing the gold in a safe place, and issuing written promises to pay gold out of that store when demanded. These documents (bank notes) greatly facilitated trade. By their aid the ownership of very large amounts of gold can easily be transferred from one person to another without the gold itself being moved. The chief drawback to the use of Bank Notes is their liability to destruction by fire, and the ease with which they enable a thief to get away with sums which he could not transport at all in the form of gold or silver. When in Europe the currency was chiefly made up of gold, silver, and notes, highway robbery was very rife. A later development of paper currency, the Bank cheque however put an end to that form of theft. The cheque form is useless until signed by someone who has money deposited at the Bank, while the devices of crossing and making the cheque payable only to the written order of the payee. have provided means by which payments of any amount can be made without handling anything more valuable than a piece of paper. Bills of Exchange, Money Orders, Postal Notes and Treasury Notes are still further developments of paper currency. When metallic currency is used the payee receives a commodity of the value of the thing he has parted with, whereas if he takes paper he has received that which of itself is of no value, and can only be used by him as a medium of further exchange provided that all parties concerned are satisfied as to the good faith and ability of the person named upon the document to meet the demand for the standard metal when it is ultimately made.

It will be seen that this last stage constitutes a sort of perfected barter. because the only things of value which are actually passed from hand to hand are the goods.

It is interesting to trace how our present system of currency: a gold standard, with gold coins and silver, bronze and paper tokens, came into being.

In Anglo-Saxon times the standard of value was the pound sterling, divided into 240 silver pence. That is to say, a pound weight of silver of the fineness used by the Easterlings (the name given by the Angles and Saxons to their ancestors on the Continent). That fineness was 11 oz. 2 dwt. of pure silver, and 18 dwt. of alloy, which can be expressed in the modern decimal system of recording fineness by the figures .925. This fineness of the silver coins of Britain has remained unchanged down to the present day, except for a period of 15 years in Tudor times, when the following debasement took place:—

Henry VIII.:	1543,	fineness	.833.
	1545	,,	.500.
	1546	,,	.333.
Edward VI:	1550	,,	.500.
	1551	,,	.250.
	1553	,,	.921.
Elizabeth:	1558 fineness restored to .925.		

The gold standard was adopted in 1816, and since that time the words "pound sterling" have been used to denote the weight of a sovereign, that is to say 123.27 grains of gold of 22 carat fineness (or .916), which pound is also divided into 240 pence. The words pound sterling therefore, as now used, have no relation to any pound of gold, nor to the old sterling fineness, but are simply the old familiar terms descriptive of the former currency which have been transferred to the new gold currency. In the course of time however, the word sterling has come to mean "the standard fineness as fixed by law," and in that sense is justly applicable to the gold sovereign.

Until 1816, silver was the legal standard of value, and the value of all other things, gold included, was reckoned in it. From Stuart times onwards, however, gold was much more used than formerly, and because of its convenience for making large payments, became of principal importance in public estimation. It thus arose, that although silver was the nominal standard, gold from its usefulness became the more important metal.

When however, the rating of gold in sterling was too low, gold coins were bought up and exported as bullion to the countries where a better price could be obtained.

The Government would then raise the rating, and back came the gold coins, but, unless the new rating very accurately corresponded with the market values of the metals, away would go the silver ones. For about two centuries difficulties due to the impossibility of keeping both the gold and silver coins in circulation at the same time were hardly ever absent. The currency at last got into this condition:—

There was a fair supply of gold coins, but the silver coins consisted almost entirely of worn, clipped and debased pieces, so bad that it would not pay anyone to sell them as metal. Reflection will show that that state of affairs was, in its principle, very similar to that of the currency we now have in use. Gold, although not nominally the sole standard, was in fact treated as such, and the silver coins, nominally standard coins of intrinsic value, had in point of fact become more or less worthless tokens passing for recognised fractions of the gold coins. The principle of the present currency: a gold standard with token subsidiary pieces, was therefore in existence, although the public did not realise the import of it. At last a man arose who saw the meaning of the situation, and the reason for the state of currency chaos which had lasted for so long. That man was Lord Liverpool. In 1805 he addressed a letter to King George III. in which he pointed out the nature of the disease and prescribed the remedy. This letter, famous to all students of currency, made it clear that it was impossible to attempt to measure commodities in two things at the same time. That there must be one standard only, and that if for the convenience of retail trade, coins of any other material proved to be wanted, then they must be made to pass for so much more than their metallic value as to prevent all temptation to melt them down, and further, that as at the time gold was held in the highest estimation by the public, and had thus been made a virtual standard, it was desirable to legally instal that metal as the standard of value, and in future to use silver for the manufacture of token pieces.

In his letter, Lord Liverpool dealt at length with evidence showing how impossible it had proved to maintain a currency in which more than one metal was required to circulate at its intrinsic value. He states that "By a decree of the Star Chamber Court, on the 7th February, 1636, seven persons convicted of culling out the most weighty pieces of coin of this realm, and melting them down and exporting the same, as well as foreign coin and bullion, to foreign parts were fined £8,100, and committed prisoners to the Fleet till they paid the fines so set upon them. It is asserted that individuals had by those practices made a profit of £7,000 to £8,000 per annum. . . . "But notwithstanding the proclamations, and the severities exercised for enforcing the execution of them, it appears, from a writer who lived in those times, that silver, either in foreign coin or bullion, was sold during the whole of this reign at 1d., 2d., 3d., etc. per ounce, above the Mint price, and he alleges that £30,000 in sixpences, shillings and half-crowns were melted annually by one single goldsmith for six years together, from 1624 to 1630."

The Secretary to the Treasury, Mr. Lowndes, in a report dated the 12th Septmber, 1695, states "That in consequence of the defective state of the silver coin, great contentions daily arose among the King's subjects, in fairs, markets, shops and other places throughout the Kingdom, to the disturbance of the public peace; that many bargains and dealings were totally prevented and laid aside, which lessened trade in general; that persons before they concluded any bargain, were necessitated to settle first the price or value of the very money that they were to receive for their goods; and that they set a price on their goods accordingly; that these practices had been one great cause of the raising the price, not only of all merchandises, but of every article necessary for the sustenance of the common people,, to their great grievance."

Lord Liverpool's conclusion was summed up in the following words, "*Coins of both metals cannot be sent into circulation at the same time without exposing the public to a traffic of one sort of coin against the other by which the traders in money would make a considerable profit to the great detriment of Your Majesty's subjects.*" . . .

He pointed out that the then existing silver coins were "subordinate and subservient to the gold coins, and in this quality only are current," and stated that in his opinion "gold coins should continue to be the principal measure of property and instrument of commerce."

Lord Liverpool's advice was followed, and in 1816 the gold standard was formally adopted, with silver and copper coins as tokens passing current for definite fractions of the new gold pound sterling. The new standard coin, the sovereign, was first coined and issued in 1817.

From that time onwards the currency troubles of the British Isles ceased, and it is hard in these days to realise the conditions of chaos which reigned in this matter only one hundred years ago.

Britain was the leader in the matter of the adoption of the single gold standard, but nearly every other nation has by this time followed. The "Latin Monetery Union" first formed in 1865 (France, Belgium, Greece, Italy and Switzerland) endeavoured to maintain the dual standard. In 1878, however, the coinage of silver standard five-franc pieces was "suspended," and a virtual adoption of the gold standard thus introduced. Other countries adopted the gold standard in the years shown below:—

1868, Spain.
1871, Germany, Norway and Japan.
1875, Holland.
1899, Russia.
1900, United States.

In 1899, the sovereign was made legal tender in India. In 1906 however, it was fixed at a rating of 15 silver rupees.

Experience therefore appears to show that the only sound principle of currency is to have one commodity as the standard of value, and to express all values in terms of that standard. All other instruments of exchange, whether of metal or paper to be subsidiary to that standard. Token coins to circulate at so much more than their metallic value that profit cannot be made by melting them into bullion.

In adopting this principle it is not necessary for the actual standard of value to be represented by a coin. In the United States there is no gold dollar, nor in Germany is there a gold mark. The gold coins represent multiples of the standard.

It is not necessary in busines to make constant use of the standard coin (as is commonly done in England and Australia) so long as a sufficient store exists for the exchange of tokens on demand.

In view of the simplicity of the principles laid down by Lord Liverpool, and of the complete success which followed their adoption, it is remarkable that about twenty years ago there should have arisen quite a powerful movement to reintroduce the old system, or something indeed, a little worse. The bi-metallists of the nineties wanted to fix the ratio between silver and gold by law. In the old chaotic system some relief could be got by adjusting the ratio of the coins to the market worth of the materials of which they were composed, but this new proposal would not even have permitted that. The movement was probably set on foot by people who were losing by the fall in the gold price of silver, such as pensioners home from India, who had their pay reckoned in silver rupees and then changed into ever decreasing sums in sovereigns, also exporters of goods to India and China, who suffered in the same way. There were others, and a larger class, who were doing very well out of the fall in the price of sliver. They naturally kept quiet. Not much was heard from the importers of Indian, Chinese and Japanese goods who found a pound spent in Asia was able to buy more and more goods every year, goods which they sold in Europe at the same prices as before. However the attempt to govern the fluctuation in the value of a commodity by Act of Parliament is about on a par with the fabled exploit of Canute and the waves, and so, after a very energetic campaign in its favour which lasted for several years, the bimetallic scheme died a natural death.

The fundamental fallacy of the bimetallists appears to be that gold and silver are not commodities in the ordinary sense of the word, but that there is something intrinsically different in them, and that it is possible to fix not only their value, but the ratio between their respective values, by Act of Parliament, although a proposal to do the same for the prices of say corn and coal or potatoes would probably be at once dismissed as absurd. Currency questions will never be clearly understood unless it is born in mind that the standard of value is only one of many commodities, chosen it is true for the qualities referred to in the beginning of this paper, but in no way different from the others in the matter of its price being fixed by the combined action of the demand for the article on the one hand, and the cost of its production on the other. The danger of investing gold and silver with mystic properties not shared by other commodities was dealt with by Locke as long ago as the year 1691, when he wrote, "An ounce of silver in pence, groats, crown pieces, stivers, or ducatoons, or in bullion, is, and always will be, of equal value to any other ounce of silver."

NOTES ON THE GEOLOGY AND PHYSIOGRAPHY OF ALBANY.

By

J. T. Jutson and E. S. Simpson, B.E., B.Sc., F.C.S.

(Read 12th October, 1915.)*

(With Five Plates and Two Text Figures.)

CONTENTS.

INTRODUCTION.

The town of Albany is situated on the northern side of Princess Royal Harbour. This harbour is an almost completely land-locked body of water about five miles long from north-west to south-east, and about two and a half miles in width, which at its eastern end connects with King George's Sound by a narrow channel. Much of the country surrounding Princess Royal Harbour is of a rugged and broken character, rising into high rounded domes and ridges of granite on the northern side, and into a prominent serrated ridge of granite and the rock known as "coastal limestone" on the southern. This latter ridge separates the waters of the harbour from those of the open ocean. (Pl. I.).

King George's Sound is a large sheet of water almost land-locked on three sides, but open on the east to the ocean. It is connected at its western end with Princess Royal Harbour, and at its north-western corner with the estuary known as Oyster

*By permission of the Director of the Geological Survey of Western Australia.

Harbour. The Sound is bounded on the north chiefly by high steep ridges of granite which plunge sharply into the sea; on the west by the low sand hills of Middleton and other beaches, and by high cliffs of granite; on the south by a precipitous line of granite, flanked by the coastal limestone; and on the east by the ocean, with Michaelmas and Breaksea Islands dividing the entrance into three channels.

Oyster Harbour has an extremely narrow entrance, but opens out to a width of about two miles. Most of it is very shallow, and at low tide, large areas of its bottom are exposed. At its entrance, the opposing sides are strikingly different, that on the west being the end of the low Middleton Beach and sand-cliffs, known as Emu Point, and that on the east being a granite mass 513 feet high, which rises rather abruptly from the water. The western shore of the harbour is either fringed with low-lying silted up ground or with cliffs composed of sedimentary rocks of little height, which bear evidence of marine abrasion. Most of the eastern shore is only a few feet above sea level with low ridges in the near background. The King and Kalgan Rivers enter at the northern end.

Fig. 39.

From the western end of Princess Royal Harbour and stretching at least as far as Torbay Inlet, there is a belt of low-lying swampy ground parallel to the coast, and occupied in places by small lakes (e.g. Grassmere or Lake Powell, adjacent to the Grassmere railway station). Into this area, which might for convenience be referred to as the "Grassmere Valley," the Seven Mile Creek and Marbellup Brook drain. To the north of Grassmere Valley the country ascends to a low extensive and somewhat dissected plain, which is formed of marine sediments.

We may summarise the chief physical features of the country as follows:—

(1) Swampy land, a few feet only above sea level.

(2) Slightly elevated plains of marine sediments, these plains in the vicinity of Albany being dissected by shallow wide open valleys.

(3) Belts of granite, dissected by streams, with isolated hills and groups of hills of the same rock attaining to various heights up to 700 feet above sea level. Within a short distance outside the area dealt with in this paper, the granite hills attain a height of close upon 2,000 feet or more.

(4) Along the coasts of Princess Royal Harbour and King George's Sound, bold rocky cliffs, which alternate with smooth sandy beaches, behind which lie shallow lakes and swamps with intermediate sand ridges.

(5) The granite and limestone ridge between the harbours mentioned and the open ocean.

GEOLOGY.

The general geology has been described by Mr. A. Gibb Maitland,† Government Geologist of Western Australia (see Bulletin 26 of the Geological Survey), and his map is here reproduced with some slight variations and additions to the geology and some other details which illustrate the physiographic changes discussed in this paper.

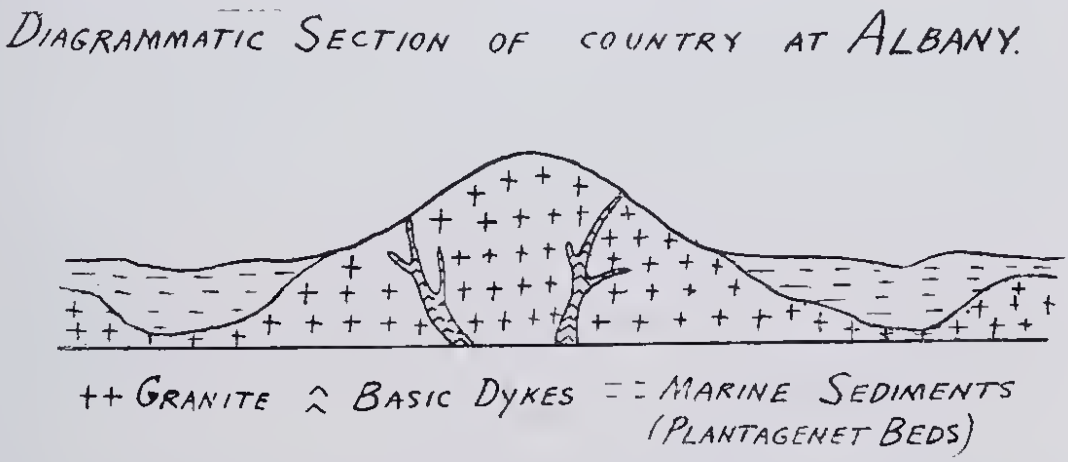


Fig. 40.

†Some earlier references are given by Mr. Maitland, but as they do not affect the main questions here discussed, we do not quote them.

FUNDAMENTAL IGNEOUS COMPLEX.

The fundamental rock is granite which has a wide distribution throughout the Albany district, its chief outcrops forming all the higher ridges and hills, except portions of the Darwin Ridge. It forms the rock of all the islands, and of most of the prominent sea cliffs, as well as constituting the main portion of the Porongorup Range, 20 miles to the north, between Albany and the sedimentary Stirling Range. In the vicinity of Albany the granite varies much in texture from fine to coarse-grained, and is frequently porphyritic. It is traversed by veins of aplite and pegmatite. The granite is essentially composed of quartz, microcline, oligoclase, hornblende and biotite. Its surface contour is most irregular, reaching 1305 feet above sea level at Mount Gardiner, and extending in places beneath the marine sediments to some depth below the ocean level. It has suffered enormous erosion prior to the deposition of the Plantagenet Beds described later, and further denudation since their formation.

Intrusive into the granite are numerous basic dykes (dolerite and basalt) which range in width from less than an inch to many yards. These dykes may be seen on many of the bare granite hills penetrating the granite with remarkable clearness, rivalling in this respect the diagrams of text books. At the brick pit about three miles to the north-west of Albany, a decomposed basic dyke cuts through not only the granite, but also the over-lying marine sediments. This evidently belongs to a later series of basic dykes than many of those intrusive into the granite, and may possibly be related to the basalts of which those at Bunbury are the type.

PLANTAGENET BEDS.

In the hollows of the granite the marine series of sediments already referred to, rest. These beds, the deposition of which has largely levelled the country, the authors propose to name the "Plantagenet Beds," in view of their wide distribution throughout the Plantagenet district. They extend at least from Torbay (to the west of Albany) as far eastward as the Phillips River, and northward to the southern side of the Stirling Range. The only localities where they have been studied in any detail are Albany, Warriup (about 35 miles north-east of Albany) and Cape Riche, though characteristic fossils have been collected at many other points. The rocks at Albany are well shown in the brick pit mentioned above. They consist of a silt at times cemented into a fine-grained sandstone, and they still retain practically their horizontal position, showing that although the land has since their formation been relatively elevated and depressed, scarcely any disturbance of the rocks has occurred. Siliceous sponges are especially abundant throughout these beds, many complete skeletons of lithistids being obtainable, whilst isolated spicules of the same and of tetractinellids form an important proportion of the whole rock. In addition, gasteropods, cephalopods, lamellibranchs, and echinoids are found, but unfortunately they are, as a rule, too poorly preserved for specific determination, though an extensive collection might enable the species of some forms to be ascertained.

Lithologically these beds are characterised by—

(1) Their uniformly fine grain.

(2) The comparatively small proportion of kaolin present.

(3) The almost total absence of calcium or magnesium carbonates.

(4) The large proportion of purely siliceous material present (quartz and opal).

(5) The fact that siliceous (opal) sponge spicules form an appreciable, at times a preponderating, part of the whole mass.

(6) The usual slight coherence of the particles to one another.

The following are analyses‡ of two coherent sandstones belonging to this series from Cape Riche:—

	White Stone.	Yellow Stone.
SiO_2 sol. in 5 % NaOH	60.22	82·58
SiO_2 insol. ,, ,, ...	23.40	
Al_2O_3	6.25	5.95
Fe_2O_3	1.95	2·34
MgO...	57	·39
CaO	·13	*nil*
H_2O above 100°	2.74	2·82
H_2O at 100°	3·50	3·49
Alkalis and loss	1·24	2·43
	100·00	100·00
Bulk specific gravity	1·33	1·44
True specific gravity	2.18	2·20

In consequence of having been laid down upon a very irregular surface of granite the thickness of the Plantagenet Beds must be variable, in some places being very thin and probably nowhere exceeding 300 feet. Their exact age is undetermined, but from the frequently unconsolidated nature of the materials, their approximately horizontal stratification, and the modern appearance of the contained fauna, the sediments cannot be very ancient. Fossils from various localities have at times been examined by Mr.

‡ By E.S.S.

Robert Etheridge, of the Australian Museum, Sydney, but on account of their poor state of preservation, he has been unable to state their age more definitely than (taking the substance of his statements for various localities in unpublished letters to the Geological Survey of Western Australia) as "either recent or young Tertiary."*

On the other hand the most definite evidence in regard to the age of the Plantagenet Series is afforded by the fossil *Aturia australis* (McCoy), a cephalopod, having in Victoria, according to McCoy††, and Chapman‡‡, a range from Oligocene to Lower Pliocene. One specimen of this was determined some years ago by R. Etheridge, Junior, in material from Cape Riche, and a second quite recently by L. Glauert in undoubted spicular silt of the Plantagenet Series from the Bremer River**, 100 miles north-east of Albany. In view of the occurrence of this fossil, and of the known extensive submergence of Southern Australia during Miocene times, the authors believe that the Plantagenet series will ultimately be determined as of Miocene age.

From a physiographic and geological point of view, it is very necessary that a detailed examination should be made of the fossils contained in these widespread deposits. The same remarks apply to other fossiliferous rocks of comparatively late age in the southern portion of this State (e.g., those at Lake Cowan) which may ultimately be correlated with the Plantagenet Series.

LATER FORMATIONS.

The rock known as the "Coastal Limestone" occurs on portions of the crest and slopes facing the ocean of the high ridge between Princess Royal Harbour and King George's Sound on the north, and the Southern Ocean on the south, to which reference has already been made. Charles Darwin, during the famous voyage of the "Beagle" landed near Bald Head and made various observations there. As the ridge referred to bears no distinctive name, we propose to term it the "Darwin Ridge," in honour of the great naturalist who first studied its structure. The coastal limestone may be observed covering and plastering over the granite, which from its numerous outcrops at all heights from sea-level to crest may be regarded as the back bone of the ridge. Mr. Maitland has described this limestone and considers it to be of aeolian origin, a conclusion reached independently by the authors, who have observed that it is composed mainly of foraminifera and fragments of calcareous algae, which have been blown into their present

*See Bulletin 26 of the Geological Survey of Western Australia, p. 60.

††Palaeotology of Victoria, Decade III., Pl. xxiv., pp. 21, 22.

‡‡ "Australasian Fossils," 1914, p. 210.

** Bremer River runs into Bremer Bay.

positions by the prevailing winds. The rock represents in their opinion, old sand dunes that have been in large part consolidated.

Owing to the variability in composition from place to place, the whole of the sands of these old dunes have not been consolidated into the hard coastal limestone, although the latter rock outcrops so widely that in mapping the country fairly definite boundaries must be given to the area in which the limestone predominates, and in this way it must be saparated from those other dunes which appear so far to have entirely escaped consolidation, or almost so.

This irregularity of conversion of the dunes into limestone is rather to be expected than to be wondered at, when the process of consolidation, namely, the solution from the sands themselves and the redeposition of carbonate of lime, and the different characters of the sands, which are partly calcareous and partly almost wholly siliceous, are considered. The process may be regarded as a more or less continuous one from the time of its commencement to the present day, and it is still going on. Concurrently with this consolidating process, the limestone is being reduced again to sand by atmospheric agencies, and these two antagonistic forces have no doubt been at work from the time when consolidation first commenced, which would probably soon follow the formation of the dunes.

There is no definite evidence as to the age of the older dunes, but judging from their distribution they were formed subsequent to the deposition, and uplift of the Plantagent marine beds.

The remaining rocks of the district belong to the recent period and comprise the sands of the present forming dunes of the coast and of the beaches and bars of the present seas, together with the fine silt (including diatomaceous earth of Grassmere and elsewhere) now filling the lakes and swamps of the low-lying portions of the district. They need not be further mentioned here.

PHYSIOGRAPHY.

RECENT DISPLACEMENTS OF THE STRAND LINE.

There is evidence in the Albany district of three comparatively recent—geologically speaking—displacements of the strand line. The first (positive) of these three is that of the submergence of the old eroded granite land surface, upon which the Plantagenet marine beds rest. As those beds now form a wide-spread plain of marine sedimentation, the ocean, on the displacement referred to, must have stretched as far north as the Stirling Range, and also to the east and west of Albany, the eastward extension covering many miles. The Plantagenet beds near Albany rise to a height of 170 to 200 feet or more above sea-level, but their maximum thickness is not known. The depth of the Plantagenet Sea has not been determined, but as the present hills and ridges of granite rise high above the existing plain of marine sedimentation---and were thus not submerged—and the organisms contained in the strata do not appear to be of very deep-water origin, the depth of the sea was probably not more than a few hundred feet. The summits of the old granite hills and ridges would thus at that time have formed a group of islands and islets, at no great distance from the coast, being in this respect a close counter-part to the present Recherche Archipelago, some distance to the east of Albany. There is also no evidence at present available to determine the height of the old land surface prior to submergence.

The second displacement was a negative one, the old sea-bed in the neighbourhood of Albany attaining a height of more than 200 feet above sea-level. This fact is indicated by the present height of the plain of marine sedimentation, which however, does not measure more than a minimum amount of displacement, as a positive movement has since taken place. Between the time of the latter and the negative displacement, the land must have occupied a much greater area than at present. Judging by the channels forming the various entrances to King George's Sound, the land probably extended at least as far east and south as these entrances, and perhaps also considerably to the south of the present ocean coast line west of Bald Head.

The third displacement was the positive movement just referred to, which resulted in the drowning of the lower end of the old King-Kalgan River, and the formation of Oyster and Princess Royal Harbours and King George's Sound (the latter two possibly however, forming at first portion of a strait extending to the present Torbay Inlet). These points will be later discussed and the evidence stated to show that on this displacement, the sea covered somewhat more land than at present. To the north of Albany the depth of the sea caused by this movement might only have been a comparatively few feet (as the partially drowned valleys of the present King and Kalgan Rivers have not very deep water), but if the old land extended eastward from Limestone Head, in the latter locality, assuming no change in depth has since taken place, it would be more than 150 feet, as the sea there is now a greater depth than this. It is quite possible that the 30 fathom line was about the boundary of the old land.

There may have been a later negative movement, but the writers are not aware of any definite evidence as to this, although it has been noticed in many parts of the Australian coast. If however, it is taking place, it will hasten the reclamation of the land.

THE DROWNED VALLEYS AND PLAINS.

That the land has been comparatively recently submerged (the third displacement above described) is at once suggested by the huge rounded masses of granite that rise boldly from the sea; by the irregular nature of much of the coast line; by the various sea channels; and by the full appearance of the rivers.

Amongst the granite outcrops are the islands known as Breaksea, Michaelmas, Mistaken and Seal. These are either at the entrance to or within King George's Sound. On the mainland, the high and steep hills known as Mounts Melville, Clarence and Adelaide, rise sharply from the sea, and the same remark applies to the granite mass opposite Emu Point at the mouth of Oyster Harbour. Limestone Head at the southern entrance to King George's Sound also shows a bold outline. It evidently consists of granite, coated with coastal limestone.

The irregular nature of much of the coast line is shown by the large harbours frequently referred to in this paper, as well as by the smaller indentations to the east and to the west.

The various sea channels include the channel between Eclipse Island and the mainland, the three entrances to King George's Sound, and the entrances to Princess Royal and Oyster Harbours. The former harbour (Princess Royal) originally apparently had three entrances, but the two southern ones have disappeared, owing to causes which are subsequently stated.

The peculiar full appearance so indicative of drowned valleys is very well shown in the lower portions of both the King and the Kalgan Rivers, the valleys of these streams in such portions containing far more water than they would if they acted merely as drainage channels for the ordinary rain waters falling within their respective basins. (Pl. II., Figs. 1 and 2).

These facts are therefore taken to be conclusive evidence of the recent drowning of the lower portions of the valleys and of the plains on which the rivers formerly meandered. Thus the King and Kalgan Rivers were, prior to this drowning, united below their present mouths into one stream, which made its way over the land now covered by the waters of Oyster Harbour and King George's Sound, and apparently passed through the notch that now forms the south channel of the Sound. By this submergence the rivers were betrunked and the three large harbours (Oyster, Princess Royal, and King George's Sound) were brought into existence, with probably however, at first an extension of the sea through to Torbay Inlet, with the long east and west Darwin Ridge as an island. Since drowning, various changes have taken place which have reduced the sea area, as will be shown in a later section.

It may be noted that three channels form the entrances to King George's Sound, and three channels (having the same east and west direction as, but narrower than those of the Sound)*, apparently formerly existed as the entrances to Princess Royal Harbour.** So far as the Sound channels are concerned, we have suggested above that the old united King-Kalgan River probably passed through the south channel, and thus the latter becomes intelligible, but the origin of the Princess Royal channels is not clear, as no present stream can be suggested as having occupied any one of those channels prior to submergence.

Both on the mainland and island coasts of the harbours, cliffs appear to have been little cut by the sea, thus apparently emphasising the comparatively recent drowning of the land: but in this connexion, it must be remembered that the mode of weathering of the granite into rounded masses by exfoliation, would tend to keep the cliffs relatively low by the constant slipping into the sea of the large onion-like flakes of rocks above the sea-cut cliffs, thereby reducing the height of the latter.

On the ocean coast between Bald Head and Torbay Inlet, the cliffs are high and steep, and the coast line, despite certain promontories of granite, is on the whole very regular and unindented, suggesting strongly that marine abrasion has been at work for a considerable peirod of time. The nature and structure of the rocks must however, as regards this point, be taken into consideration. As already indicated, the surface rocks of the Darwin Ridge are the coastal limestones, plastering and covering over, as consolidated sand dunes, the old granite. The action of the wind in building up sand dunes along a coast almost invariably smooths the outline of that coast, and hence it may be concluded that the present form of the coast in question is due to this cause. This land must however, in the absence of direct evidence to the contrary, be regarded as having taken part in the depression which caused the drowning of the valleys and plains, and consequently the coast line must have extended farther south. This raises the question as to when the sands which now form the limestone were built up. If we regard them (and therefore the resulting limestone) as of later occurrence than the drowning of the valleys, that is a sufficient explanation of the present contour of the coast; but the limestone, as limestone, although it is still forming as shown above, certainly appears for the most part to be older than the loose sands which form the various bars about the large harbours, and which represent the deposits since the last known submergence. The formation in large part of the limestone may therefore probably be regarded as prior to such submergence, although the point cannot at present

*In addition to the agreement in number and direction between the two sets of channels, the most southerly of the three is in each case, the widest.

**The causes of the disappearance of two of these channels are later stated.

be definitely proved. On this hypothesis, the coast has probably sustained considerable marine abrasion, which largely accounts for its present even outline, such abrasion being assisted by the great strength of the waves on this outer exposed coast, and the absence of any protecting sand bars.

BUILDING OF SAND BARS AND THE GROWTH OF THE LAND SINCE THE LATEST SUBMERGENCE.

That sand bars have been extensively built in various places, is evident on a very casual examination, and likewise that, largely owing to such building, the sea has been silted up into land, with the formation of temporary lagoons and lakes, and the tying of islands to the mainland and to one another.

An excellent example of a long sand bar is the well-known Middleton Beach, at the north-western end of King George's Sound. This beach is about three miles long, and stretches north-easterly from Mt. Adelaide to Emu Point. The sea was originally about a mile farther west, stretching south-westwards from Bayonet Head to Strawberry Hill, and thence south-eastwards to Mt. Adelaide; but the intermediate area, owing to the exceptional facilities provided by the sand bar, has now almost all silted up, although still swampy and possessing one main sheet of water, Lake Seppings. The building of the Middleton bar has reduced the mouth of Oyster Harbour to its present narrow dimensions, and by such reduction, the silting up of the bay just mentioned has been much facilitated. It is the formation of this bar that has caused the Middleton Beach to be such an excellent bathing spot.

Other sand bars—behind which are swamps and lagoons—have been recently built to the east of Albany.

An illustration of the building of the particular form of sand bar known as a "tombolo," which results in the tying of islands, is shown in the narrow peninsula running north from Frenchman Bay to the entrance of Princess Royal Harbour. This strip of land consists of two low sandy areas, connecting two higher belts of granite with the main mass of the latter to the south. On the King George's Sound side, the sandy portions are bounded by low cliffs of sand, whilst on the Princess Royal Harbour side the sand slopes gently to the sea. The difference is due partly to the rougher sea of the outer harbour compared with that of the inner, the former tending to build the sand into banks, and partly to the action of the wind in blowing the sand over into the smoother water of the inner harbour. The granite hills of the peninsula are apparently old islands now tied to one another and to the southern mainland by the sand bars just mentioned. The result has been to reduce the number of entrances to the Princess Royal Harbour from three to one, and to give greater play to that bay for silting up. The acceleration of the latter will be understood when it is noted that the present entrance is but a little over a quarter of a mile wide, while the more southerly of the two old channels was over a mile in width.

If, as seems probable, the sea on the latest submergence stretched as a strait from King George's Sound to Torbay Inlet with Darwin Ridge as an island, such strait (which might for convenience be referred to as the "Grassmere Strait") has since been largely silted up, and has now become the Grassmere Valley, with the lakes, such as Grassmere or Lake Powell and others, as temporary phases in the growth of the land. The conversion of water into dry land has been considerably assisted in this area by the formation in the beds of fresh water lakes of thick deposits of diatom frustules. By this means Grassmere has been plainly reduced to one half its earlier extent, what was formerly the southern half of the lake being now occupied by a dry bed of diatomaceous earth at least six feet thick.

None of the three channels forming the entrance to King George's Sound has yet been converted into dry land, but the Admiralty charts show that there is a shallowing of the channel (the North Channel) between the mainland and Michaelmas Island, which if continued will result in the tying of the island to the mainland.

The mouths of Oyster and Princess Royal Harbours still remain open. In the former case, the flow of water from the King and Kalgan Rivers, together with the tide, may be responsible for this, but in the latter case, although the tide probably has some influence, dredging has to be continuously practised to keep an open waterway of the necessary depth.

One of the general results of the building of the sand bars is to facilitate silting and consequently to rapidly increase the area of land reclaimed from the sea, the materials forming the new land being the detritus brought down by the rivers and creeks and the sands carried by tides, currents or winds into the silting area. As this silting up progresses, and assuming no deformation, Oyster Harbour, amongst other changes, will disappear, and its place will be taken by low swampy land, through which the King and Kalgan Rivers will meander, but as one river, the two having become engrafted by the reclamation of the land.

Another result is the smoothing of the coast line which lies to the east of Albany, where immediately following the latest submergence, the coast was more broken and irregular than the present one.

By the process of natural reclamation here outlined, swampy land is formed, which on being drained, is well suited to the growth of various agricultural products.

GENERAL ROCK WEATHERING.

Some brief remarks may be made on this point. The principal hard rocks of the district are the granite and the coastal limestone. They present a clear contrast, the former being carved into rounded forms, and the latter into serrated ridges and sharp points.

The effect of the spheroidal weathering of the granite on a great scale as tending to keep the marine-cut cliffs low, has been noticed above. Another point is that these spheroidal coats slip at times from higher to lower levels on the land, and so form landslips of which abundant evidence exists at Albany. These landslips cause a danger that must be safeguarded against as residences encroach on to the higher portion of Mt. Clarence. The vegetation is of course removed with the rock mass on a landslip, leaving a bare and frequently steep surface. Rain falling upon this surface, washes away the soil and debris as fast as formed, and thus many of the granite slopes are destitute of plant life. A striking instance of this feature is the bald, smooth mass of granite forming the southern end of Mt. Melville.

The general weathering of the granite is also influenced by the numerous basic dykes of two distinct types, by the pegmatite veins, and by the very marked variations in texture and composition of the granite itself.

The sharp and serrated mode of weathering of the coastal limestone has been already referred to. On the ocean side between Skull Head and Cave Point, the limestone has a high dip toward the sea. This assists the slipping of the rocks from the cliff face, when the latter is undermined by marine abrasion.

In connection with the weathering of the coastal limestone, reference may here be made to the fine examples of casts of roots, stems, and branches of shrubs and trees in carbonate of lime dissolved out of the limestone, vide Plate III., Figs. 1 and 2. Apart from its own intrinsic interest, this phenomenon will always possess a great historic value to Australian natural history students, by reason of Charles Darwin having very fully described it. To that admirable account nothing need be here added.

OTHER FEATURES.

The Albany district is rich in physiographic interest. Beside the phenomena described in this paper, there are possible wave-cut terraces, various plains of erosion (indicated by the granite masses at various levels) and residuals on such plains. The writers have however, not sufficient evidence to justify at present any account of these interesting occurrences.

SUMMARY.

The Albany district possesses a much indented coast line with precipitous cliffs of granite and less frequently of limestone, both on the islands and mainland, alternating with smooth sandy beaches. The land features are diversified, the various forms comprising prominent hills and ridges, a low somewhat dissected plateau of marine sediments, a high coastal ridge of granite partly covered with the coastal limestone, and low swampy ground at the heads of the harbours and behind the recent sand bars. The picturesque King and Kalgan Rivers are the two main streams of the area, the other streams being small and comparatively insignificant.

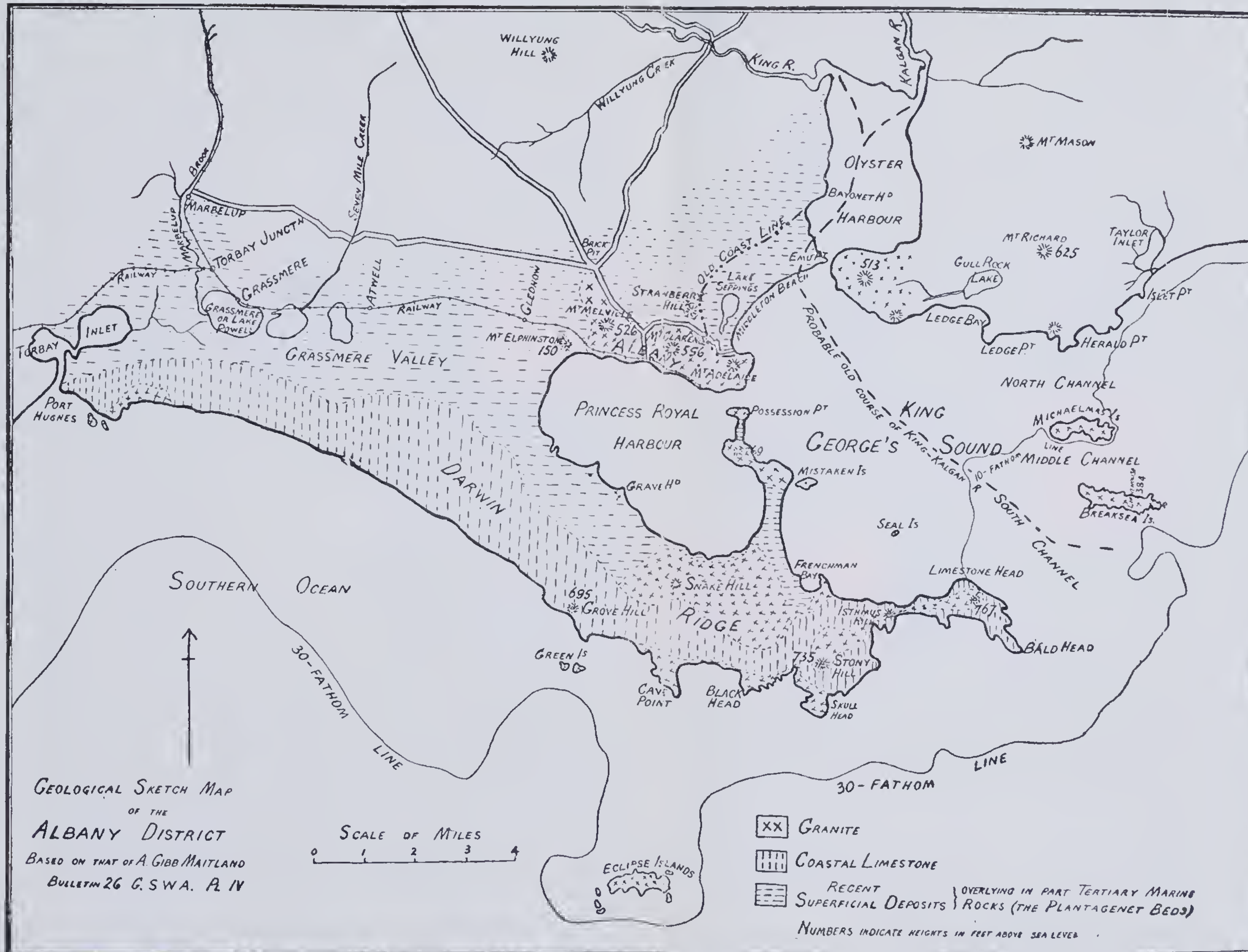
A study of the geology reveals granite as the fundamental rock intersected by pegmatite veins and dolerite and basaltic dykes. In the eroded hollows of the granite lie an extensive series of marine beds known as the Plantagenet beds (which are probably of Miocene age); and along the ocean coast, old sand dunes which originally spread over the old granite ridge there have been largely consolidated to form the coastal limestone. The most recent deposits include the superficial fluviatile and lacustrine silts, sands and infusorial earths, together with the sands of the various sand bars and of the present-forming dunes.

At least three geologically recent displacements of the strand line have taken place, the earliest of these being the submergence following which the Plantagenet marine beds were deposited. The second resulted in the uplift of the land upon which the King and Kalgan Rivers and other streams carved out their channels. The third movement drowned the lower ends of the valleys and the adjacent land. As a result of this movement the sea may have extended as a strait from King George's Sound to Torbay Inlet.

Since the last definitely known (positive) movement, land has been naturally reclaimed from the sea by silting up, the latter being hastened by the formation of lines of sand bars. The most prominent of these bars is that which has produced Middleton Beach. By such silting and building of bars, some old islands have been tied to the mainland

The granite weathers into prominent rounded masses, and the coastal limestone into serrated ridges. Landslips occur on the granite hills.

The writers are indebted to their colleague, Mr. H. P. Woodward for various information relating to the Albany district.


Willyung Hill
Willyung Creek
King R.
Kalgan R.
Mt Mason
Oyster
Bayonet Hd
Harbour
Mt Richard 625
Taylor Inlet
Gull Rock Lake
513
Ledge Bay
Ledge Pt
Herald Pt
Islet Pt
Brook
Marbelup
Torbay Junctn
Seven Mile Creek
Railway
Grassmere
Grassmere or Lake Powell
Atwell
Gledhow
Brick Pit
Old Coast Line
Emu Pt
Lake Seppings
Strawberry Hill
Middleton Beach
Mt Melville 526
Mt Clarence 556
Albany
Mt Adelaide
Mt Elphinstone 150
Torbay
Inlet
Grassmere Valley
Port Hughes
Probable old course of King-Kalgan R
King George's Sound
North Channel
Michaelmas Is
Middle Channel
10-Fathom Line
South Channel
Breaksea Is.
Princess Royal Harbour
Possession Pt
Grave Hd
Mistaken Is
Seal Is
Frenchman Bay
Limestone Head
767
Bald Head
Isthmus Hill
Darwin
Snake Hill
695
Grove Hill
Ridge
735
Stony Hill
Skull Head
Green Is
Cave Point
Black Head
Southern Ocean
30-Fathom Line
Geological Sketch Map of the Albany District
Based on that of A. Gibb Maitland Bulletin 26 G.S.W.A. Pl. IV
Scale of Miles
0 1 2 3 4
Eclipse Islands
Granite
Coastal Limestone
Recent Superficial Deposits
overlying in part Tertiary Marine Rocks (the Plantagenet Beds)
Numbers indicate heights in feet above sea level

NATIONAL MUSEUM MELBOURNE

Photo E.S.S. Fig. 1.

Kalgan River, showing effect of recent partial submergence of the valley of a small stream.

Photo E.S.S. Fig. 2.

King River, showing effect of recent partial submergence of the valley of a small stream.

NATIONAL MUSEUM MELBOURNE

Photo J.T.J. Fig. 1.

Weathering of coastal limestone with calcified roots, Sand Patch, south of Princess Royal Harbour.

Photo J.T.J. Fig. 2.

Calcified roots in sand dune, exposed by wind erosion. Sand Patch, south of Princess Royal Harbour.

NATIONAL MUSEUM MELBOURNE

Photo E.S.S. Fig. 1.

Green Island (granite), and granite foundatians to coastal limestone cliffs, Cave Point.

Photo E.S.S. Fig. 2.

Oyster Harbour. A drowned plain, showing granite outcrop on eastern side and end of sand bar on western side.

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Photo E.S.S. Fig. 1.
Steep coastal limestone cliffs on ocean, South of Grassmere.

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THE SIGNIFICANCE OF SOME PHYSIOGRAPHICAL CHARACTERISTICS OF WESTERN AUSTRALIA.

By

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(Read 9th May, and 13th June, 1916).

With a Map, Plate VI.

In travelling through the Central and Eastern Goldfields regions of this State, a geological observer cannot fail to become impressed with the constant recurrence throughout them of a quite limited number of physiographical types of land-sculpture, which are repeated over huge areas in endless variations of size and shape, but with constant and remarkable identity of the essential similarities which constitute a type. It is obvious from this identity that like causes have been operating in like manner over very widespread regions to produce like effects, and it follows from this that a proper interpretation of the physiographical evidence is likely to give important results in explaining the more recent geological history of the State. Until lately, the subject of the physiography of Western Australia had been dealt with only very briefly by writers on its geology, and usually only casually in connection with descriptions of particular localities, without any attempt, as a rule, to put forward any general account of the geomorphology of the State as a whole. In 1914, however, this absence of systematic description was greatly remedied by the publication of Geological Survey Bulletin No. 61, which the author, Mr. J. T. Jutson, very modestly calls "An Outline of the Physiographical Geology (Physiography) of Western Australia," but which well merits a more ambitious title which would be suggestive of the wealth of information therein contained. In his Part V, Chapter 1, he gives a synopsis of the opinions of previous writers on the origin and age of what he terms the Great Plateau of Western Australia, and in Part I. (p. 20), he records his own view of the matter as follows:—

"As regards the origin of the Great Plateau, the areas of exterior drainage are regarded by the writer as uplifted peneplains, but concerning that portion of the Great Plateau situated in the interior, he is somewhat uncertain whether to classify it as an uplifted peneplain, or an uplifted plain of arid erosion, but, as shown later, inclines to the idea of a vast peneplain, since uplifted to its present height." Among the opinions of previous writers cited by Mr. Jutson, it may be useful in the present connection to recall that F. T. Gregory (1861) believed "that since Tertiary time the country has been both elevated and depressed, more than once perhaps, but bodily and equably and without tilting," that E. T. Hardman (1884) states that in the ranges in the South-Western portion of the Kimberley district, "the plateau-like outline is extremely well-marked, indicating an old plain of marine denudation subsequently carved out into hills and valleys by the action of sub-aerial denudation"; that Prof. Ralph Tate (1893) pointed out that Australia in Cretaceous time was a vast archipelago, and that the antiquity of Australia as a whole is only post-Cretaceous; that Prof. J. W. Gregory (1907) held that since middle Palaeozoic times no great earth-folds have disturbed the structure of the Australian mass, and all the later movements on the continent appear to have been the vertical sinkings of wide earth blocks; that Prof. T. W. E. David in 1911 refers to the vast peneplains of Western Australia as being raised 1000 to 2000 feet above sea-level; and that Mr. Jutson himself in 1912 described the Darling plateau as a truly uplifted peneplain, and the date of the uplift as pre ~~post~~-Pleistocene. It has been very generally recognised, therefore, that there has been much up and down movement of the State as a whole, though opinions differ a good deal as to the extent to which the movements of subsidence actually resulted in submergence of the land beneath the sea. Prof. Gregory, for example, appears to hold that the greater part of Western Australia "consists of an Archaean block or coign, which has never been below the level of the sea, although time after time the sea has washed its borders."

Since Mr. Jutson's book was issued there has been a further paper by Prof. Gregory, published in "The Geographical Journal" for June, 1914, on "The Lake System of Westralia," in which a map is given showing the country divided into a number of very flat drainage basins, gradually rising to high country over 2000 feet above the sea in the interior. His summation of the position is:—"The dry lakes of Westralia are therefore depressions in a river system which was probably Miocene in origin; these rivers have been broken up by their inability to keep their channels clear from encroaching sand dunes during the post-Miocene desiccation, which may be explained by a reduction of internal rainfall coincident with the uplift of the country for about 1000 feet." Elsewhere in the paper he refers to the suggestion of the present writer that the salt lakes might be the remains of a marine invasion, and regards it as possible, as proved by the marine limestones at Norseman, but considers it improbable owing to the varying levels of the lakes and the absence of marine fossils north of Norseman. The writer is not at all impressed with these reasons for regarding a widespread marine invasion as improbable, as the varying levels of the lakes would be a perfectly natural and obvious consequence of the gradual emergence from the sea of a submerged peneplain, and the absence of fossils is very inconclusive because, as it happens, fossils are equally absent over the country to the south of Norseman also. So far as is yet known this single locality contains all the recent marine fossil evidence available, yet while it is admitted that the presence of marine shells at a height of about 900 feet above sea levels, is proof that the land was submerged under the sea to that depth, their absence at higher levels is apparently to be held to prove that they were laid down at the limit of the submergence. The only fair deduction from the facts is that the destruction of fossil evidence of the presence of the sea has been extraordinarily complete, and we appear to have been fortunate in having the Norseman beds preserved at all to prove that there was a marine invasion.

During many journeys through the Goldfields districts the writer has become more and more impressed with the belief that there is much physiographical evidence to show that the main features of the surface relief in the goldfields areas owe their final shape principally to marine action, and that subsequent subaerial erosion has been able to do very little more than slightly modify the shape of the country as it was left by the receding waters. Also that this evidence of marine action may be found up to at least the 2000 feet level. It has been pointed out by the Government Geologist, Mr. Maitland, in his latest sketch of the geology of the State, written for the Australian visit of the British Association in 1914 (Geological Survey Bulletin No. 64), that "By far the greater portion of the State is in reality a very extensive plateau, averaging about 1,400 feet in height, though isolated portions reach altitudes approaching 4000 feet." Mr. Jutson gives a map in Bulletin 61, showing the elevations of the portion of the State south of the tropic of Capricorn, which shows a very small portion over 2000 feet in height, and a considerable area between 1500 and 2000 feet, but the great bulk of the region under 1500 feet. If, therefore the sea reached to the present 2000 feet level, all the land above water south of the tropics would be parts of the Stirling Ranges in the south, and a large island and several smaller ones in the northern part of the Murchison, East Murchison and Mt. Margaret Goldfields. It is the object of this paper to discuss the physiographical evidence and show how it sustains and corroborates the marine theory.

There is usually a very great similarity in the scenery of our Eastern and Central Goldfields. Everywhere we find great plains, often extraordinarily evenly level over large areas, with low rounded hills or groups of hills rising from them with very gentle slopes. A steep slope is rather an exception, though many such are to be found without difficulty. Rather frequently, when the rock composing the hills is a hard one capable of resisting erosion, as in the case of the well-known "jasper-bars," it stands out in rough well-marked ridges, which follow the lines of strike of the hard rock. Where the hills are composed of dense and little-jointed intrusive rocks they usually take large rounded outlines, forming distinct and often somewhat prominent hills, but those formed of the more schistose and jointed rocks commonly show less relief and much less curved contours. The hills formed by granite are of very distinctive appearance, being usually bare, bald surfaces of hard rock, protruding from the surrounding plains. These bare surfaces are commonly more or less pitted with shallow small solution basins in which water collects during rains. The granite protuberances very often strongly remind one of rocks and islands standing up out of a sea, and along the south coast east of Albany, we may see exactly the same type of protruding granite rocks in the numerous islands which there are seen standing quite similarly out of the actual sea. The similarity of scenic type is so exact as strongly to suggest identity of the sculpturing agencies.

Where the rising ground occupies a considerable area it frequently happens that smaller plains are found on the hills at various levels, so that an observer, in passing through a hilly region, frequently travels most of the way over very flat surfaces, with little elevated country in sight, although on the whole the surface is a good deal higher than the surrounding main plains, and from a distance appears to form a distinct "range." The "Black Range" for example on being approached from the west side is seen for many miles away as a distinct high ridge, but plain after plain is crossed in getting to it without having almost any perceptible rising of the road, until one finds oneself travelling —still on flats—over the top of the high country. This characteristic of the larger masses of high land is so usual as to be fairly regardable as normal. Another good example is seen on the road from Meekatharra to Peak Hill. The Robinson Range, on which Peak Hill stands, is seen from the plains to the south of it as a high blue range, but one rises so gradually on to it, over plains wth very gentle slopes connecting them, that the top of the ridge is reached without having encountered any very perceptible acclivity. And the top when reached is itself more or less a number of small plains separated by low-lying ridges of higher ground, and with Peak Hill and another similar conical point of hard quartzitic rock standing up like pyramids from the plains. Peak Hill itself, it may be mentioned, is a very small affair, little more than a large natural cairn formed by the outcrop of a belt of hard quartzite and the *talus* therefrom. On the flat at its foot, in the open cut workings of the Peak Hill mine, the surface of the ground is seen to consist of a ferruginous conglomerate of stones and coarse gravel, many of the stones of which are well rounded, showing them to have been worn smooth by attrition in moving water. This is not at all a unique occurrence, for there is quite distinct "deep lead" ground at Nunngarra on the Black Range, which shows water worn gravels in places, and distinctly water worn boulders are visible on the "Big Patch" at Quinns, high up on Nowthanna Hill. At Quinn's also there is a distinct well-rounded brown iron ore conglomerate, apparently not concretionary, near the saddle on the road to Burnakura over the hill, which seems to be a cemented gravel and not a pisolitic deposit. Both at Peak Hill and at Quinn's, however, there is a possibility that these water rolled stones *may* belong to formerly existing basal beds of the Nullagine series, the bulk of which have been entirely removed by erosion, except for these relics, so too much reliance cannot be placed on them alone as evidence of these high plains having been recently subject to the action of moving water. The writer has noticed on many occasions nevertheless, that rounded and subrounded stones—not demonstrably waterworn as a rule however—appear to be much more common on the higher slopes of ridges standing well up out of the plains than in the latter and along the lower skirts of the hills. A good example is seen on the road from Leonora to Lawlers, a few miles south of Diorite King, where the road crosses over a hill of some height. Here rounded stones and boulders—which may however be merely weatherworn and not waterworn—are fairly common on the higher slopes of the hill, but wanting as one gets down on to the plains on each side. Mention may also be made of a very distinct bank of well rounded coarse conglomerate near Wiluna, well up on the ridge near the State Battery, which is unequivocally a coarse gravel deposit. Professor Gregory has alluded to the writer's mention of this gravel bank, but the description given by him seems to apply to a quite different locality and shows that he could not have seen the same section as was referred to. Wiluna, however, is very close to the southern edge of the Nullagine beds, and there is just a possibility that this gravel bank also may be a relic of these, though it is not very likely.

A point on which some stress must be laid is that the plains are found at all elevations up to about the level of Peak Hill (1900 feet). They usually merge one into another with a generally very gentle southerly or westerly slope forming the very flat basins to which Professor Gregory has drawn attention, gradually dipping towards the coast. The average gradient is extremely flat; for example the difference in level between Lake Way (2030 feet) and Lake Lefroy (1050 feet) is 980 feet, but they are about 320 miles apart, giving an average grade between them of only 1 in 1724. This extreme flatness of the grade of the main central drainage basin has to be borne in mind in considering how it may have been brought about, as it is not easy to get a convincing explanation of it by reference solely to subaerial erosion.

The low relative height and usually very thoroughly rounded shapes of the hills in the Central and Eastern Goldfields districts indicate a very advanced stage of erosion of what doubtless were once much higher and more important hills. Very little more and the hills would be cut down entirely to one great peneplain. This form of level surface characteristically results from long-continued sub-aerial erosion, and its occurrence is therefore to some extent *prima facie* evidence that the land has been for a very long time subjected to the subaerial agencies which would bring about such features. It may fairly be submitted, however, that if a land surface in such or approaching such a mature stage of planation were to subside below sea-level to such an extent as to bring the sea over the greater part of it, and were again to be elevated well above the sea level, the effects of the original merely subaerial planation would be greatly accentuated by marine erosion during the periods in which the surface was in process of being submerged and raised again.

While the low hummocky type of hills surrounded by plains is characteristic of the lower ground, there is a very marked change in the type of land sculpture when we get into some of the higher country. One of the best examples is seen in the Frazer Range to the west of Peak Hill. Here we suddenly find ourselves in the presence of a hill-sculpture of a type quite unlike the hills previously described. Instead of low rounded hills there are rough ragged peaks with their sides deeply furrowed into hard sharp-edged outstanding ridges and deep rough ravines, and giving jagged pointed outlines from all aspects. The type is that of an outstanding rock-mass deeply dissected by storm-water erosion. But at the foot of it, at the Mount Fraser mine, the approach is over wonderfully level plains running against the hills exactly as one sees sea-beaches form against a rugged hilly shore. A short distance out on the plain a well has been sunk to a depth of about 140 feet, passing through alluvial material containing much small gravel, fairly rounded, of river type, showing that the flat has a buried valley in it. The existing flat carries one of the numerous branches of the Murchison River, seen as a running stream only after heavy rains. Between the well and the Mount Fraser mine the track passes over one of the most striking geological curiosities it has been the writer's fortune to observe. The bedrock is a hard prismatically jointed greenstone, the surface of which is often quite bare of soil for yards at a time. In one or two places noticed, the bare rock surface was seen to be cut to a quite even plane, forming a smooth floor to which the joints gave the appearance of a mosaic pavement, the prismatic columns being there rarely as much as an inch across. It is difficult to believe that wind could have planed such a hard rock to an even surface, though the occurrence is quite comprehensible if regarded as formed by beach erosion. At this place also the resemblance of the edge of the plain to a beach is most marked; it is quite level and runs in and out among the rocky spurs meeting it in the most regular manner at one level, forming inlets, bays, and every feature seen on a beach. It must be said, however, that no beach gravels were seen at this point.

At the Horseshoe some 17 miles northward from Peak Hill there are extensive deposits of gravel, not nearly so thoroughly waterworn as is usual on a sea beach, however, along the foot of the Horseshoe mountain, which are well seen where they have been worked for alluvial gold. These gravels maintain approximately the same level for some distance along the flank of the range, and lie at a much steeper angle of slope than is maintained into the plain alongside, which soon becomes practically level. They appear to be a talus from the slopes of the hill, roughly sorted along a horizontal line by the action of water, but not subjected to very violent or long continued abrasion. All the way from Peak Hill to the Horseshoe, the beach-like contact of the plains with the hills is very well-marked. At the "Breakaways," about 12 miles from Peak Hill, the road leaves the plain over which it has been travelling and turns as if about to run up on the higher ground apparently, but is soon found to continue on a strip of the plain running between an island of higher ground and the mainland. The higher ground is cut to steep escarpments ("breakaways"), which usually have but little talus at the foot of them, and curve off at the foot of the cliffs in quite characteristically beach fashion. The level of the plain is perfectly preserved all round the foot of the cliffs, very sinuous though its outline is, and round the islands. The conclusion seemed quite irresistible that here we had a beach cut by a body of water occupying what is now the plain.

Reverting, however, to the hills at Mt. Fraser above the beach line, it is to be noted that we no longer get the hummocky rounded outlines so usual in the hills at lower levels, but a quite distinct type, that resulting from well advanced erosion still in the most active stage. The Horseshoe Range and the high peaky country towards Mt. Egerton show the same type persisting in the highest ground, with the lower hills, as at the Mt. Egerton goldfield, worn down to flattened stumps which may very possibly owe their final shape to having been completely submerged. The Nullagine beds are here again, however, visible in the near vicinity, and it is quite possible that the erosion which cut down the old rocks to such flattened stumps was pre-Nullagine in point of time, and that they been merely uncovered again by subsequent erosive action.*

The same very sharp contrast between the types of sculpture of the hills in the lower and higher country is seen very markedly in the Pilbara goldfield. The high mountainous country between

* A later visit to the Upper Gascoyne District has led me to think that the rocks at Mt. Egerton, taken to be pre-Nullagine, may belong to the Nullagine series.—A.M.

Marble Bar and Lalla Rookh stands out like a rugged island from the smoothly-worn plains surrounding it, and the edges of the plains lying against the high land all round maintain a strong general likeness to beaches. The hills themselves are peaked, furrowed, and jagged, the peaks often being capped with nearly horizontal strata of the Nullagine beds, showing the mass to be a deeply dissected old plateau. The Wodgina range also stands out from the plains as a similar rough high hill, deeply furrowed. The high rough range at Warrawoona presents quite a similar contrast to the plain country on each side of it, the latter being in the last stages of peneplanation, while in the ridges storm-water erosion is still very active.

In the south of the State, the Stirling and Eyre Ranges show the same feature, rising in rugged rocky peaks from surrounding country in an advanced stage of planation, quite similarly as the rocky islets on the south coast rise out of the surrounding sea. It is clear that there must be some physiographieal explanation of the marked difference in the character of the rugged peaks as compared with the well-rounded hummocky country and plains round about them. Petrological differences have no doubt had a great deal to do with the question, the outstanding island-like heights of Wodgina, Lalla Rookh, and Warrawoona being mostly composed of very old metamorphic and igneous schistose rocks, while the surrounding plains are mostly granite, and the Stirling and Eyre Ranges are likewise composed of old sedimentary rocks surrounded by granite. In both the Pilbara and Stirling regions however, the rocks which form the high hills are themselves often cut down round the skirts of these hills quite equally with the granite, and are thus found extending some distance into the surrounding plains, as is also the case at the Robinson Range. It would seem most probable therefore that though these high lands stand out principally through their resistance to weathering in the first instance being greater than that of the granites round them, they have suffered erosion round their bases to the same approximate level as the granite round about them owing to the action of an erosive force acting on both without discrimination. The only such force competent to produce the effect as we now find it seems to the writer to be marine erosion, and it is therefore believed that these island-like hills were really islands with the waves acting round them to reduce the lower country to one approximate level.

The topography of the country crossed over in travelling from Port Hedland to Marble Bar is very instructive. After crossing a small strip of superficial limestone right at the coast, the road runs almost level for miles over sandy plains, which gradually are found to have a coating of soil—usually very shallow—upon a planed-down surface of granite bed-rock. After a time occasional low ridges of granite and small hills of granite are encountered, but the plain is seen to run round these and to go on inland continuously. It is slowly rising all the time, but at a grade imperceptible in travelling. In 89 miles from Port Hedland to Coongan, the rise is 406 feet, or an average grade of only 1 in 1157, or 4½ feet per mile. As we go inland the isolated ridges and small peaks of granite become larger and more common, but the plain runs continuously round them as before, until it strikes against the sides of the main island-like mass of hills lying between Marble Bar and Lalla Rookh. Many of the more prominent granite hills rise quite steeply from the plain, often with a talus of large rocks at their base, exactly resembling granite islands off the coast. From a high hill the general appearance of the plain being a sea and the hills islands rising from it is most striking. The plain sweeps away to the north of the main island, well to the east of the Coongan River, and through the Doolena Gorge an easy way opens into the hills and enables us to reach Marble Bar (railway level 603 feet). To the south of the island the plain sweeps round continuously, broken by projecting ridges running out from the main mass of hills, by separate islands like the Wodgina Range, and by high black doleritic ridges, to Corunna Downs, and well on towards Nullagine. Here it must be fully 700 feet above sea level, probably more, but it is practically continuous right from the sea beach up to this level. For the most part the bed rock appears to be quite close to the surface, though doubtless there are many places where the superficial material is of considerable depth—usually, however, much less than 100 feet, as is shown by the numerous wells—and we therefore see that the whole of this huge peneplain may be taken as cut fairly evenly from the solid granite rock. It is very noticeable also that where the rock is bare at surface, and in the outstanding islands and ridges, the granite generally is very little weathered, but on the contrary is fresh and hard. In this it resembles the wave-swept granites on the coast, and numerous granite bosses on the eastern goldfields, but this condition is difficult to reconcile with any theory of purely subaerial erosion, whether by rain and river action, or by wind erosion—both of which require softening of the rock by weathering before there is much perceptible removal of material. The features are exactly those which would result if the country were to subside gradually until the sea reached the vicinity of Nullagine, and then rose again to its present level. The plain is practically continuous from the foot of the high land inland to well out to sea from the coast, the sea bottom continuing to shelve seawards in continuation of the plain. At Nicoll Bay near Roebourne, there is an inland extension of the beach which is said to be only very rarely covered by the sea, and which shows as a bare mud flat of great extent sloping very gently seaward. At its inland margin there are some small sandhills and then the mud flat continues inland on much the same grade. The sandhills at the head of the bay, and the small marginal cliffs where the beach sets in against the higher land surrounding it towards the sea entrance, mark a stage of rest in the gradual retreat of the sea water, and are absolutely similar to like sand hills and breakaways on the margin of many of the inland lake basins.

But why, it will be asked, should we appeal to marine planation, when the peneplain might possibly be explainable as due to ordinary fluviatile planation. There are several considerable rivers traversing the plain, e.g., the Shaw, the Coongan, the De Grey, the Turner, the Sherlock, and the Yule. These all flow down across the plain, and at times after heavy rains they carry large flows of water, and become wide powerful rivers, of great erosive capacity. Such rivers are well-known to be potent agents in reducing the lower parts of their valleys to wide flood-plains, through which they meander with frequently changing courses, here cutting down into the bedrock, and there levelling up hollows by filling them with sediments. No doubt there is a certain amount of this action in the case of the rivers referred to, but in going through the district it did not appear to the writer that there was much evidence of its having been either extensive or long continued, certainly not to the extent of being the main agency in reducing the country to its present state of even planation. On the contrary most of the rivers appeared to be cutting down their beds, having generally fairly straight courses without meanders, and high banks on each side of wide beds capable of carrying the floods without overflowing on to the plains. Where the Shaw River was crossed near the "Gorge" there seemed some appearance that the bed of the river was excavated out of alluvial material altogether, giving some support to the flood-plain theory, but this might be equally well explained on the marine planation theory by supposing that the Shaw River debouching out of the mountainous country on to the edge of the shallow sea would form a considerable "fan" or "delta" of gravel, through which it would cut its way downwards as elevation of the land led later on to retirement of the coast-line. So far as the writer's observation of these rivers has extended, it would appear to be an allowable generalisation to make that they are all, from Pilbara southwards to the Murchison, engaged in cutting their beds more deeply into the plains which they traverse, and not in building flood plains. Confining the instances to such as have been personally visited, this would apply to the rivers just now mentioned, and to the Jones River, the Harding River at Roebourne, the upper feeders of the Ashburton and Gascoyne Rivers crossed on the route from Peak Hill to Nullagine, the branch of the Gascoyne River seen between Peak Hill and Mt. Egerton, and the upper feeders of the Murchison River, seen on the south side of the Robinson Range. Further south, in the goldfields districts, the streams are not usually traceable for great distance as recognisable watercourses, but at Poison Creek and Jones's Creek on the Leonora to Lawlers road, there are other good examples of streams cutting down into their beds rather than flooding and building up plains. Where the Lawlers road crosses Poison Creek, there is a distinct appearance of stratification in the ferruginous grits seen in the sides of the creek bed, and something of the sort has also been noticed in the bed of the Gascoyne (S. Branch), near Mt. Egerton, and in that of the river on the track from Ruby Well to Wiluna. At this stage, however, we may leave the question of the formation of the superficial material composing the plains to be taken up later on when some other evidence bearing upon it has been described and examined. The point of most importance just at present is that the existing rivers are cutting down into the plains and not building them up. Nevertheless, it is not over-looked or forgotten that comparatively slight movements of elevation and subsidence of the land as a whole may alter the grade of rivers from time to time, so that at one time they tend to fill their valleys with alluvial flood-plains and at another to cut down through these deposits on to the bed-rock again. It is therefore freely conceded that by itself no great significance should be attached to the fact that the existing rivers are cutting into the plains which they traverse, nor can their present phase of action be taken to prove that they have not themselves formed these plains in the first instance. It is when taken in connection with a number of other considerations that their evidence should be regarded as corroborating the marine planation theory rather than that of river erosion

Before leaving the subject of the existing rivers, however, mention should be made of a feature of several of them which may be of much significance in assisting us to trace the historical development of the present topography, namely, the numerous "gaps" which are so noticeable in the N.W. districts. Many of these are described in chapters 1 and 2 of part VI. of Mr. Jutson's bulletin, previously referred to, closely resembling one another in the general feature that rivers are found breaking through ranges of hills quite unexpectedly, without any very visible reason why they should have been able to find an outlet through the high country instead of going round it, following the present low ground. If the country on the up-river side of the hills were generally high, we might understand that it has been formerly higher than the hilly country traversed, and that the rivers have cut their way down through the hills simultaneously with a general lowering of the upper parts of their basins to a level much below that at which the hills were originally attacked. But the most curious point about the gaps which the writer has seen, is that they leave a plain on one side of a ridge of hills, plunge through the ridge, and come out on another plain on the other side, and that if the ridge is followed along its length the plain on the up-river side is found to be practically continuous with that on the down-river side, round the ends of the ridges. The Shaw River has three "gaps" of this sort, two where it runs across a pair of high hard ridges of gabbro, and a very long one where it goes right through the heart of the high hilly country lying between Marble Bar and Lalla Rookh. Again, close to Marble Bar the Coongan River is found cutting its way through the hills quite similarly, emerging on the plain country through the picturesque Doolena Gorge as a wide flat-bedded channel walled by precipitous rocky sides. It is difficult to find a consistent theory of the erosion of these gaps and gorges, occurring as they do on what would appear to be naturally the lines of greatest rather than of least resistance, and of the prevalence of such gaps as a recurring characteristic in many different streams, by reference to sub-aerial erosion alone, but a good deal of the difficulty disappears if we regard the surrounding plains as having been occupied by the sea, and the hills and ridges as islands standing out of it. Doubtless the higher land would be cut deeply into by valleys formed by storm-erosion before the subsidence took place which converted them into islands, but once they were submerged to any considerable extent, so as to allow the sea to convert the higher peaks into groups of islets, the breaching action of the water, aided by currents round and between the islands, would be quite competent to account for much cutting down of channels between islands. As the succeeding elevatory movement progressed and the islands arose more and more out of the sea, it seems probable that some of the main channels cut by the water between islands would tend to be cut deeper as being the most direct outlets to large areas of water, partly imprisoned on the inland side of the ridges, and that these flows would determine the form of the basins left when the sea had entirely retreated. The stormwater outfall would naturally follow the course shaped by the retiring sea waters.

A very beautiful example of a gap in which there is no river, is seen on the road from Peak Hill to Nullagine, about 25 to 30 miles out from Peak Hill. For this distance the track lies over very level plains, cut into here and there by a "creek," which is one of the heads of the south branch of the Gascoyne River, and the shallow sections exposed in the watercourses show the soil to be underlaid by layers of ferruginous compacted sand and small pebbles. In one place numerous thin flakes of hard whitish limestone were picked up, showing the presence of beds of the Nullagine series. Several clay pans were seen, in which fresh water would accumulate during rains. While passing over these plains the road is heading towards a blue range of hills, visible for many miles, and as one gets closer and closer to this range, it seems impossible that it can be crossed except by climbing over it. But suddenly a wide pass opens right through it, and the plain continues as a flat wide strip of level ground, plentifully covered on surface by subangular stones, between steep slopes on either side. Soon the road emerges again from the range on its north side, and continues for miles over more plains without having risen at all perceptibly to the eye in crossing the range. Doubtless exact measurements would show a good deal of variation in level, as the range appears to be a watershed between two drainage basins. Further north the plain runs along the foot of several hills, here mostly formed from the Nullagine beds, and everywhere the contact between the plain and the toes of the hills preserves its beach-like characteristics. There seemed to the writer to be no possible explanation of the extraordinary uniformity of level of the plain, and unbroken persistence of the beach type of the edges of it, other than that it took its final shape from being covered by a sheet of water. It did not seem possible to reconcile such extreme regularity of planation with any known action of wind, or wind and rain combined, as erosive agents. There must be a small rise and fall in the plain country, however, for the road over it, though showing no grades very perceptible in travelling, gradually passes from the watershed of the Gascoyne River on to that of the Ashburton. The stock route wells along this track are mostly sunk, apparently in deep soil, with sands and clayey little coherent strata beneath, of probably quite recent age, but some of them seem to go into the Nullagine beds.

At the Ilgarere copper field we find great stretches of plain country, sparsely covered with "mulga," and often quite bare over considerable areas. These plains resemble those usual further south in the Eastern Goldfields, in being mostly covered on surface with a plentiful sprinkling of iron oxide and cherty gravel usually somewhat rounded, but possibly owing the rounded shapes more to concretionary growth in the case of the ironstone gravel and surface wear and weathering in that of the other stones than to water attrition. This feature will be considered later on. On the west side of one of these plains we come to some hilly country, composed of slates and basalt of the Nullagine series, and fairly deeply cut into by a number of distinct "gullies," evidently eroded by running water within the most recent times. One branch gully came up into the plain and could be seen to be partly cut out of it and to lie below its level. These watercourses were parts of the headwaters of the Ashburton River, and in them ordinary river erosion is evidently proceeding rapidly now whenever storms supply the necessary water to cause the streams to fill. The watercourses are evidently younger than the plains, and cutting back into them. This shows that the formation of the plains must date back some considerable distance in point of time, and that there has been a change of conditions which has allowed of the starting of a cycle of river erosion, still in quite an early stage.

PLAINS—"BREAKAWAYS"—AND SALT LAKES.

In the East Murchison and Mt. Margaret Goldfields and southwards from them to the south coast, we find ourselves in a region of small rainfall in which running streams are rare, and cases of appreciable river erosion almost entirely absent until the coastal strip is reached. The most prominent physiographical characteristic of this part of the country is extreme peneplanation, there being no really high hills, such as there are being of the worn-down hummocky type, and the greatest part of the area is occupied by extensive plains and salt lakes. As previously mentioned the plains generally merge into one another—though often we have the main parts of each at considerably different levels—and dip on the whole very gently southward. One of the best examples of this sort of country may be seen between Meekatharra and Cue. There are two principal lakes in this region, Lake Annean and Lake Austin, with several smaller ones like the lake near Quinn's. The lakes occupy the lowest parts of very flat basins, and have very ill-defined margins in most places, the bare mud flats along their edges becoming covered gradually with a growth of vegetation, which is scanty at first, but soon gets more luxuriant as one passes outwards from the salt-pans. But one may go on for miles out from the lakes without encountering any rise in the plain country perceptible to the eye, the grades being so flat as to be almost unnoticeable without precise levelling. From Lake Annean one may go over plains eastward, by going round the higher land at Quinn's and Burnakura, and reach Quinn's Lake, and from there go south-westerly, all over plain country, to Lake Austin. Coming south from Lake Annean one may also follow plain country all the way to Lake Austin, although the railway goes over higher ground at Tuckanarra and Stake Well. Lake Annean however, is quite 80 feet higher than Lake Austin.* The lakes are seen to be merely the lowest depressions in one large plain which has a slight dip southward. On following this plain outwards, we find that it very commonly is fringed with lines of cliffs, often 50 to 100 feet high, usually cut from weathered granite much lateritised on the surface. These cliffs (escarpments) are known on the fields as "Breakaways," probably from some idea that the ground has broken and fallen along them. They show no sign, however, of being fault-scarps, being very irregular in outline as a rule, with often outlying "stacks" separated from the mainland and having scarps all round them. The cliffs are full of small caves and rock-shelters worn out of the laterite and the soft kaolinised granite lying beneath it, and often there are fallen blocks of the laterite at the foot of the cliffs. Very usually the slope of the plain curves up very perceptibly to the toe of the cliffs, but the general horizontality of the edge of the plains along the bottom of the cliffs is very marked. The shapes and outlines presented along the contact of the plains with the cliffs are quite similar to those seen along the cliff-lined shore of a sea or lake, and after close examination of many of them with rival theories of wind and water formation in mind, the con-

*Cue Station 1485, Day Dawn Station 1398, Nannine Station 1475 Austin Station 1364, Nallan 1389, feet (Railway heights).

clusion has always seemed to the writer quite unavoidable that these scarps have been formed by the breaching action of a considerable body of water occupying the area now represented by the plains. Quite similar "Breakaways" are seen in parts of the shores of Lake Lefroy and Lake Cowan at the present time, and the scenery along almost any of these "breakaways" continually recalls that seen along any sea or lake shore which is fringed with water-worn cliffs. When we see the features characteristic of cliffs caused by sea or lake erosion, reproduced along the shores of salt lakes like Lakes Cowan and Lefroy, which are almost certainly raised up portions of an old sea inlet, extending deep inland from the south coast, and find them again further north round the plains of which other salt lakes and salt pans are the lowest depressions, the conclusion seems irresistible that the mulga-clad plain of the north is merely a somewhat later stage of the salt lake basin further south, and that the surrounding "breakaways" represent the cliffs formed when these plains were occupied by large bodies of water.

When speaking of the "breakaways" of the Murchison, East Murchison, and Mt. Margaret goldfields, which are the part of the country in which the finest examples of this feature are to be found, it is necessary to notice one very striking characteristic of many of them, which requires to be explained by any physiographical theory which attempts to account for the present relief of the country. Most of the best marked "breakaways" are flat-topped, and a little examination shows that the flat-tops are remains of an old plateau which has been very extensive. The Flat-topped Hill at Cue for example which is now an isolated "stack" or "butte" has evidently been part of the adjacent flat-topped hills nearer the town, which like it, are capped with a lateritic covering derived from the kaolinised granite forming their lower portions. At intervals all round the Cue plain this plateau is seen, especially a few miles to the east of Gabanintha on the road to Wiluna, and on the south side of the plain, where the cliffs are so prominent as to have found special mention on the maps. Other good examples are seen on the road from Cue to "The Pinnacles." The present plain appears to have been excavated to a depth of probably as much as 100 to 200 feet out of a much older plain of which only flat topped portions protected by a hard lateritic covering have survived. Quite similar cliffs with lateritic flat tops to them are seen again some miles north of Mertondale, high enough to receive special mention on the map, and others near Wilson's patch, on the high ground on the road from Lawlers to Lake Darlot before dropping down to the level of the lake plain, at Hell's Gates some eight miles east of Maninga Marley on the road from there to Lawlers, and a particularly good example at Walkinjerie, a little west of the road from Sandstone to Birrigrin. The Walkinjerie hill, as it appears from the plain, is a narrow plateau of weathered granite, lateritised on the top surface, almost perfectly flat on the top, and surrounded by plains probably quite 70 to 80 feet lower than the plateau. The cliffs or "breakaways" forming the edges of the plateau are mostly very precipitous, and not easy to ascend except in a few places. They show all the characteristics of beach cliffs particularly well. On the west edge of the plateau about 12 feet down from the top in a sort of shelf in the scarp is the Walkinjerie rock-hole, well-known to travellers on the Birrigrin road as carrying a good supply of water. The rock-hole catches the drainage from a fairly large surface of the flat top of the butte, but its occurrence where it is found, on the face of a precipice, is very unexpected and not very easy to explain.

There are several possible explanations of this older plateau. It seems most probably quite considerably older than the present plains, and it may well represent part of a peneplanated surface formed before the subsidence took place which submerged the land and allowed a shallow sea to carve the present features. It is even rather likely that this surface was to some extent a reappearance of an immensely older one, on which the beds of the Nullagine series had been deposited, for traces of these are found not very far to the north of this region, and the big mass of them in Mt. Yagahong shows that they must have been a thick and extensive series. It is obvious that before the Nullagine beds were laid down the underlying old rocks must have been planed down and submerged, and when subsequent erosion removed the covering beds again it seems possible that much of the old planated surface might be uncovered without being itself much more deeply eroded than when previously a land surface. For the purposes of the present paper it is sufficient to regard this older plateau as part of an older land surface probably antecedent to the last submergence which mainly determined the existing relief. It may represent an older marine plain, possibly dating back to the subsidence which led to the formation of the Eucla limestones.

Further south there are frequent occasional traces of an older surface in outliers of laterite and lateritic conglomerate found every here and there lying on the old rocks in such a manner as to show them to be merely relics of a much more extensive formation. One such isolated block—a small one—of ironstone conglomerate near Mt. Monger, was found to have been nearly undermined by alluvial gold diggers, the basal layer of the conglomerate containing a little gold. The lateritic beds at Coolgardie railway station and the Coolgardie Hospital are a good example of this old superficial formation. Whether the auriferous sandstones and grits of Kintore are of this age or much older, is at present quite an open question; they also are a relic of an older superficial formation, mostly obliterated during the final carving out of the existing relief.

"DEEP LEADS."

In writings on the subject of our plain country it has been somewhat usual to have a good deal of insistence placed upon the point that in them the bedrock is generally very close up to the surface so that there is only a very small depth of soil covering it. There is no doubt that such a condition is of very common occurrence, there being many places where the planed surface of the bedrock is practically bare. This is well seen in several places along the shores of Lakes Cowan and Lefroy, in the case of which it can hardly be attempted to be questioned that the levelling or planing agent has been water. Yet it is known from the few borings which have been made in these lakes, that the detrital material in one case at least, is 377 feet deep below the present surface of the lake bed, and so little has been done to test the depths of the basins that it is entirely premature to assume that they must always be shallow. It must be regarded as still quite an open question whether these lakes ought not to be regarded as filled up valleys of quite considerable depth rather than shallow eroded rock basins. There is quite a large quantity of evidence now accumulated on the subject of the "alluvial deep leads" not uncommonly found on our goldfields, which goes to show that under the plains there often are numerous valleys of considerable depth in the bedrock. Some examples may be cited:—The "Lady Mary" lead near Norseman is a buried watercourse running into the Lake Dundas basin. Where the lead was first found the ground was shallow, but as it was followed towards the lake the prospecting shafts became successively deeper, up to at least 70 or 80 feet, the grade of the old watercourse falling more steeply towards the lake than that of the present surface does. If both grades continue as at present, the valley of the old watercourse must lie well over 100 feet below the level of the present bed of Lake Dundas.

The "Princess Royal" lead is a quite similar buried watercourse, running under the residence areas at Princess Royal and out towards Lake Cowan. The shafts down to the auriferous "wash" were shallow at the southern end, but the lead became deeper and deeper as it went towards the lake, and the last shafts were about 90 feet deep. It was in the workings from one of these shafts that the sponge spicule deposits described by Dr. Hinde were discovered, which he has taken to be of deep sea origin. The bottom of this lead below Lake Cowan is probably quite 100 feet below the present bottom of the lake.

At Kalgoorlie there are several well-marked "deep leads" formed by a system of buried watercourses running from the Maritana Hill westerly and southerly under the flats on which are the towns of Kalgoorlie and Boulder. Near the hills the "leads" are shallow, but they attain depths of 90 to 100 feet below the flats. The surface slopes very gradually and gently to Hannan's Lake, but the grade of these older watercourses, where they were worked, is considerably steeper than that of the surface, and if it continues they must lie well over 100 feet below the present bed of the lake. Their course however, has not been traced down to the lake, and the bedrock appears to be close to surface wherever holes have been sunk in the edge of the latter. It does not follow, if the lake beds are filled up old valleys, that the present lakes must necessarily be over the deepest parts of these old valleys, and it is quite possible that the latter may lie under other portions of the flats surrounding the lakes.

Another quite similar deep lead has been traced from the east side of the Boulder Hill at Trafalgar, down into ground up to 118 feet deep in the flat east of the hill.

At Bulong the "Oversight" lead is traced by shafts from shallow ground, 10 to 15 feet deep, down under the flats surrounding Lake Yindarlgooda, the deepest shafts being there somewhere about 140 feet deep. Here the "lead" opened out into a wide flat-lying layer of gravel, too poor in gold to be worth following. The bottom of the "lead" is well below the present level of the lake, and the grade of the old watercourse is much steeper than the slope of the present surface towards the lake. As at Hannan's Lake, the bedrock at the present lake is said to be visible practically at surface, so the deep ground—if not cut off by faulting—must lie under some of the surrounding flats.

At Kanowna the "deep leads" have been very famous for their large yield of gold. They form a whole series of buried watercourses, Wilson's Gully, the Cemetery Lead, the White Lead, the Fitzroy lead, and the Q.E.D. lead all uniting to form the North lead. At its deepest known point the lead is well over 100 feet below the present surface. On the eastern side of the hill on which is the Robinson mine, there is yet another well-marked lead, the "Moonlight Lead," of which another branch was discovered not long ago. This runs down to about 80 feet below the surface at the point where further sinking on it was abandoned. These leads lie under flats which join to the northwards and have several small salt lakes upon them.

At Paddington a deep lead begins in shallow ground near the Broad Arrow dam, and has been followed past Paddington to Smithfield, where the ground is about 100 feet deep. Here the old watercourse seems to widen and flatten, giving abundance of gravel with very little gold, and work could not be continued. The flats under which this lead runs are an extension of the Black Flag Lake basin.

Near Mt. Pleasant, between Broad Arrow and Black Flag, a lead started shallow on the high ground and soon became too deep under the flats to be readily followed. Borings have proved it to be 125 feet deep, and there seems much likelihood that it is a branch of a larger lead running southward under the Black Flag Lake, and more than 100 feet below its present bed.

At Siberia, a deep lead is found at a depth of 95 to 100 feet under what is now a hill. Some mining work done on this showed it to be a buried watercourse.

At Kurnalpi, the celebrated alluvial workings were on the slopes of a hill on the edge of a lake, and the ground became rapidly deeper approaching the lake.

At Nunngarra, on the Black Range, some work was done on two leads, one at least of which was traced to a depth of 40 feet. They disappear under flats through which they have not been followed.

At Lake Darlot, a quite similar lead was lately followed from shallow beginnings on the hills near the St. George mine down into ground about 70 feet deep, under the flats surrounding Lake Darlot, but has not been traced actually under the lake. Evidence that the ground deepens rapidly towards the lake is also seen in some of the workings in the flats at the west side of the field.

The above are all cases into which the writer has made personal examination, and to him there seems no doubt possible that the leads are old watercourses in which there was a certain amount of concentration of alluvial gold by ordinary river sorting action. The beds usually contain rounded and subrounded pebbles clearly due to attrition in running water. The most typical gravels are those in the Paddington and Oversight leads. There is generally much clay and sand with the gravel or immediately over it, and above the lowest part of the filling it is very usual to have thick beds of unctuous clay or "pug" of which the Kanowna "pug" is the most marked and well-known occurrence. In the Oversight lead a layer of hard dolomitic cemented material lies in places over the "wash" in the deep ground. Above the clayey and sandy layers nearly all the leads have a thick layer of oxide of iron, often showing concretionary and botryoidal structures, but not in my opinion properly to be regarded as true laterite. There is a general scarcity of included superficial matter, and much of the iron oxide is so pure as to suggest that its origin was as a precipitated iron oxide rather than an efflorescent laterite. The normal succession of iron oxide upon fine sedimentary cays in these buried valleys suggests slow filling under lacustrine and subsequently marshy conditions, in which first fine silts and afterwards iron oxide precipitates were accumulated. The capping of leads by masses of somewhat spongiform oxide of iron is so very characteristic in this State that the finding of a line of this sort of iron oxide, which is easily distinguished from laterites and gossans, may almost be regarded as a probable indication of deep ground, with possible gold, beneath it. In all the leads which have been examined by the writer, the deep leads appear to have been filled up and buried during a period long antecedent to the actions which have given the existing surface its present shape.

Opposite the Kanowna railway station on the head of the "town lead," we find a very hard silicious fine conglomerate lying over the wash layer in the lead. A somewhat similar hard cherty quartzite caps a small hill not far from the road to the racecourse, and under this cap there is loose quartz gravel made up of pebbles of the thoroughly rounded marine type. Where this occurrence fits into the geological history of the locality is at present a matter of speculation so far as the writer is concerned; it is however, evidence of lacustrine or marine conditions in that area in no very distant geological period. The little gravel hill is quite isolated, and is the only one of the sort seen by the writer anywhere in the district, and it is certainly much older than the last stage of surface sculpture. It may be perhaps connected with the "cement" (fine grained conglomerate) beds of Kintore, but is evidently a relic of an older superficial formation which has otherwise almost entirely disappeared.

The Deep leads, however, are not by any means the only proof that there is often an older land surface buried under the existing plains, and which is often at such variable depths below the latter as to show that it was not so uniformly level as the present plain surfaces. This is quite often seen in mining shafts and in stopes which come up close to surface, it being not at all uncommon to find much variation in the depths at which the bedrock is found beneath the surface. This deep "surface" or "made ground" as the miners commonly call it, often gives considerable trouble in tracing the outcrops of reefs into the flats, as it has to be sunk through to find the outcrops. Depths of "surface" up to 20 feet are not uncommon. Much greater depths of it are often found in sinking wells, many of which go down 30 to 100 or more feet before the bedrock is reached. Unfortunately it is hard to get exact data on this matter, as the well-sinkers rarely make any distinction between soft weathered portions of the bedrock and the detrital deposits which cover it. There are a great many cases known where wells of quite considerable depth are sunk almost from surface in soft weathered rock, which is merely the bedrock softened and kaolinised by weathering, and areas of such rock appear to be as useful in acting as reservoirs of under-surface water as deposits of superficial detritus. The records of ground passed through in well-sinking, therefore, are rarely at all dependable as showing whether the sinking is in detrital material or in weathered bedrock. A good deal of attention has been given by the writer when travelling about the fields to examining the dumps thrown out from the wells, and in making inquiries from men with knowledge of them to ascertain the depths at which the true bedrock has been encountered, and there are a large number of instances where the sinking has been in detrital material to considerable depths. Comparatively few, but still a few, cases have been noticed where waterworn gravels have been thrown out among the stuff sunk through. One very good instance is a well on the road from Rothsay to Field's Find, about half-way between the two so far as memory serves, where the dump of the well showed a good deal of well worn shingly gravel. This well is sunk in the plain surrounding Lake Monger and merging into the bed of the latter by the characteristic imperceptible gradations previously referred to.

From a good deal of scattered evidence of this sort, the writer has formed the conclusion that the surface of the bedrock below the existing plains is generally somewhat variable in its relief, and that if the covering of detrital material could be imagined as removed, it would appear as a surface of gently undulating hills and hollows, such as might be expected of the surface of a peneplain reduced to approximate base level by subaerial agencies, and traversed by numerous watercourses of slight grade and consequent small depth of erosion of their valleys. But these surfaces have since been submerged under the system of large lakes of which the existing salt lakes are only the shrunken remnants, and their inequalities of relief have been filled up with lacustrine or marine drifts and sediments, and so reduced to the extremely complete state of planation in which they are now found. While it is probably quite true that the main peneplanation of the bedrock as we now find it was due to sub-aerial erosion, it seems to me therefore that the final touches giving the landscape its existing peculiar characteristics, were given by submergence of the peneplain under considerable bodies of water.

MATERIAL OF PLAINS.

The materials composing the plains have always appeared to me very much more consistent with deposition as marine or lacustrine sediments than as wind-borne material. Nothing is more characteristic of the goldfields plains than the way in which they are covered over immense areas with a coating of stones at surface. Very many of these stones are oxide of iron pebbles often showing concretionary structure and which may well have been formed almost in situ as pisolitic growths. We know that many of our typical laterite cappings both on the granite hills of the Darling Range, and on the sedimentary drifts of the coastal formation, appear to be formed first as small pisolitic concretions in the surface soil which are added to in course of time as solutions carrying iron are drawn toward the surface by capillarity and the iron fixed by evaporation and further oxidation. In the same way it is quite possible that many of the iron oxide pebbles on the goldfields plains may have been formed very much where we now find them, and it may be pointed out that this explanation of their presence would apply whether the superficial covering was formed from either wind-borne or water deposited sediments. If the superficial soil is to be regarded as wind-borne this explanation of the ironstone pebbles is almost the only one possible, for it is clear that these heavy pebbles could not have been wind-borne to any appreciable extent. As a matter of personal opinion the writer does not attach much faith to this explanation of the formation of the iron oxide pebbles, as most of them seem to him not to be concretions *in situ*, but rather more or less worn concretionary laterite pebbles which have been moved from their place of origin and involved in sedimentary drift. They are often much mixed with pebbles of jasper, chert, and other hard and weather-resistant rocks, and fragments of white quartz. In places where the bedrock is close to the surface, it is not at all uncommon to see the surface so thickly strewn with quartz fragments as to be white in colour over quite extensive areas. Usually such quartz is not perceptibly water-worn, the fragments being sharp-angular or no more rounded than is usual with fragments of even hard rocks which have been exposed to weather on the surface of the ground, but every now and then it is by no means uncommon to find fairly well rounded pebbles of these hard rocks. It is not at all unusual to find that when trenches have been cut through areas where much fragmentary quartz is visible that the bedrock is not so close to surface as one might have thought, but is covered by several feet of superficial soil, all containing a good deal of the fragmentary quartz. It is difficult to understand how wind borne material could have through it heavy lumps of material mounting upwards from the bedrock, but the explanation is simple if we regard the drifts as sedimentary, as water has very considerable lateral transporting power. The stony layer is usually much more noticeable right at surface than on sinking a little way downwards, often appearing as if angular gravel had been thickly spread purposely over brown soil. This is doubtless due to superficial concentration of the heavier stones included in the soil. The advocates of the theory of the soil being wind-borne material, if they can succeed in explaining satisfactorily why heavy angular fragments of stone should be distributed through the superficial material, can easily explain the concentration of a superficial layer by appealing to the removal of the light soil by wind and rain, as no doubt these agencies are quite capable of so explaining the occurrence. At the present moment, we know that wind *does* blow away some dust from the surface, and that rains wash away soil as mud, leaving any heavier material in the soil accumulating as a layer of superficial gravel. The only difficulty is to see, if the stuff was wind and rain borne in the first place, how it came to be so full of stones which could be so concentrated on surface. The theory of aqueous deposition finds no difficulty in explaining the occurrence of the stones in the drift—quite similar muds with stones in them may be seen along the shores of Lake Cowan any day one cares to look along the trenches dug for the Norseman Causeway—but suggests as an explanation of the superficial layers of stones a certain amount of concentration of the heavier material by water removal of fine silt as well as by the subsequent accentuation of the same action by rain and wind after the lake waters have gone and the beaches have become dry land.

The "made ground"—to use the miners' term—quite often shows alternations of more sandy and more clayey material as would be expected from deposits in water, and in no case has the writer come across any considerable mass of such ground which he could regard as even probably derived from accumulations of wind-borne dust and sand. The physical character of the superficial soils overlying the bed rock seems to him to be quite against the theory of wind deposition.

SAND HILLS AND SAND PLAINS.

In this statement, however, sand-hills and superficial sand-drifts must be excepted, but these also when examined present notable features which are of much consequence in arriving at a theory of their formation. It may seem the "most unkindest cut of all" to the supporters of the wind-erosion theory to claim their sand hills in support of that of water planation, but it is in the position and behaviour of the sandy areas that the writer has found what appear to him to be powerful arguments in favour of the theory of lacustrine or marine planation as against that of wind-erosion. Sand-hills and sand-patches are found very commonly all over the country at all levels, but it is very noticeable that the biggest and best formed sand-hills, except those close to the coast, are usually, so far as the writer's own experience goes, on high land surrounding the lake plains. One of the most extensive sandy areas encountered on the goldfields, is crossed on the road from Gabanintha to Wiluna, a short distance east of the rabbit-proof fence. Here the ridge between the Lake Annean to Lake Austin lake plain and that surrounding Lake Way and Lake Violet rises to a considerable height above these plains, and the sand is very heavy to traverse. It is formed often into well-marked sand dunes of typical shapes, now covered with spinifex and small scrub, and rarely shows signs of having been in motion as drifting dunes for a very long time. The dunes are practically fixed by the vegetation, and wind appears to have but little effect on them. The sand-ridges are found southward to Birrigrin and Barrambie, being very difficult to traverse between these two centres, and the rabbit-proof fence from Barrambie to Gum Creek passes through them for many miles. Everywhere they are on the high ridge on the edges of the lake plains, and are practically fixed in position by a coating of vegetation.

The Barr Smith Range, passed over on the old road between Kathleen Valley and Cork-tree well, on the way to Wiluna, is another very characteristic sand-plain, with only very small dunes, now well fixed by vegetation. It is high ground on a ridge between two extensive brown-soil plains. This tract of sandy country is found westwards nearly to Birrigrin and Black Range. Another similar stretch of sand hills, very bad for travelling through, separates the plains near the Mt. Sir Samuel mining area from those of New England and Lake Darlot, there being a high sandy ridge between them from the New England country nearly all the way south to Wilson's Patch. The sand hills are particularly well seen where the road from Mt. Sir Samuel to New England crosses the high ground, but here, too, the dunes have every appearance of having been long fixed in their existing positions, being well covered with scrub.

Another well-known line of sandy country lies between Menzies and Davyhurst, on the north and south ridge between the Goongarrie Lake plain and that of Siberia Lake. Here too, the dunes seem to have been long fixed by vegetation.

Between the Jaurdie Hills and Coolgardie there is a sand-patch several miles in width on the highest ground between brown soil flats on either side of it, and several similar patches are seen along the railway line between Northam and Kalgoorlie. Near Tammin it is very noticeable that the sand-patches are usually, if not always, on the ridges between the fertile lower-lying plains.

Going down the rabbit-proof fence from Burracoppin to Ravensthorpe, a great deal of very sandy country is traversed, but even there the prevalence of the sand on the higher ground is very marked.

Another extensive sand-plain is crossed on the road from Yalgoo to Rothsay, on the high ground between the Yalgoo plain and that of Lake Monger. Here no dunes were seen however, the sand plains being remarkably flat.

Yet another good example of sand plains on high ground is seen in travelling from Northampton to the old Geraldine mines on the Murchison River. The road rises up off the fertile plains and undulating country to the north of Northampton on to a sand-plain on a high ridge separating the valley of the Bowes River from that of the Murchison. This plain shows few and only very small dunes where seen by the writer, and forms a distinct sandy plateau considerably higher than the brown-soil country on either side of it.

Now how are we to account for this extraordinary predilection of the sand deposits for the higher ground? It is not the experience of wind-action elsewhere, where its effects on sand can be watched in progress, as in the case of the coastal dunes, that the plains should be swept free of sand and this accumulated on the highest ground round them. It is true that there are very frequently sandy areas in the plains, so that they are not clear of sand by any means, but the freedom of great areas of them from sand is very remarkable if their erosion has been due in any marked degree to the cutting action of wind-driven sand. Where we see drifting sand dunes, as on the south coast, it does not seem to matter much whether the ground is high or low; the dunes march forward before the prevailing winds over high and low ground without discrimination. There is no visible tendency to build up on one spot more than another, except right along the beaches, where the loose sand thrown up from the sea is first stopped by the defence of vegetation. Sand-hills build up most characteristically along this frontier, between the fresh supplies of sand ever thrown on the beach by the waves and the barrier opposed to its inward drift by the fixing action of vegetation. Among the inland lakes excellent examples of sandhills round the margins of the lakes are quite commonly seen, for example on the south side of the Siberia lake on the road from Davyhurst to Siberia, and on the shores of Lake Koorkoordine on the road from Southern Cross to Koolyanobbin. And just as we often find marginal sand dunes round the existing salt lakes, so the main belts of sandy country correspond with the position in which we might expect sand dunes to have been formed round the older and larger lake-beds, which now form the brown soil plains. They are still in position where they were formed when the lakes were filled with water, and are therefore on the high country separating the lake basins.

While on this subject it is instructive to notice the very different type of surface prevailing in the sand dune country from that on the brown-soil plains. Where the surface has been moved obviously by wind it is uneven, and in small hills and hollows resembling waves, which in cases rise to the magnitude of dunes where the bodies of sand are larger. We at once get the typical wind-shaped surface, exemplifying the well-known fact that material accumulated by wind lies in waves and drifts and not in level deposits. But how then can we ascribe the levelness of the plains to wind action? Wind is not a cutter of level surfaces, but of uneven ones.

It is readily admitted that windstorms of much violence are not uncommon on our fields, and on any fine day in summer it is quite usual to be able to see several whirlwind clouds of dust dancing over the landscape at one time. But so far as the writer's observation has gone, it is very uncommon, if not unknown, to see any signs of the ground being worn away perceptibly by dust storms. If they were a strongly-operating cause of removal of the surface soil we should expect to see quite commonly, trees with the top portions of their roots laid bare by the wind, and standing well out of the soil, but the general appearance of the trees is usually quite distinctly the contrary of this, the soil often appearing rather to have accumulated round the stems than to have uncovered the roots. A good deal of attention has been given to observing this point, and the writer is quite satisfied that the vegetation on the plains usually shows no sign of any appreciable wearing down of the surface soil by wind erosion.

TRAVERTINE DEPOSITS.

Turning to another feature of many of the lake plains, it does not appear to have attracted much notice hitherto that deposits of impure limestone are not uncommon in many of them. Usually it has the appearance of travertine, and where it has been described it seems often to have been somewhat hastily assumed to be formed by emanations of lime-bearing solutions from weathering of underlying basic rocks. This may quite well be true in some cases, and the association of the closely allied magnesite deposits with basic rocks seems fairly well established in some of the occurrences of this mineral in this State, though there seem to be others in which no such association has yet been made out. Some of the largest travertine deposits seen by the writer, however, do not appear to be on basic rocks at all, so far as can be seen. On the south side of Lake Annean on the road to Cue, there is a large amount of this travertine, apparently on granite bedrock, and another extengive occurrence is seen near Nallan, at a favourite picnic ground to the north of Cue, where the railway authorities have established a ballast pit from which the travertine is extracted for ballasting the railway. Another large patch of similar limestone is passed over to the south-east of Quinn's, on the road to Erroll's, in an area where the visible bedrock is mostly granite. Other occurrences are near Lake Miranda and Lake Way, a short distance out from the margin of the present salt-pans. Several other little patches of similar limestone have been found useful on the goldfields for burning for lime for cyaniding and building operations, although the mineral is usually too impure to give good quicklime. A short distance out from Southern Cross on the road to Marvel Loch, there is a large amount of concretionary limestone, in spherical nodules from the size of peas up to that of cricket-balls, which was burned for lime in the earlier days of the Southern Cross Goldfield. These are on a dioritic bedrock, but where the deposit occurs this rock crops out at surface in what appears to the eye to be a remarkably unweathered condition giving little support to the explanation that the carbonate of lime is derived from it. The position of the lime deposit is only a few feet above the plain of Lake Polaris, and on the margin of it. The travertine deposits at the south end of the Causeway at Norseman are quite similar to most of those just mentioned—except for the spheroidal concretionary one at Southern Cross, which appears to be different from the rest—and are found in patches for some distance up on the Norseman hill, and at first there was no reason to think that they were anything else then superficial travertines derived from the greenstone bedrock. But the discovery by Mr. W. D. Campbell, of several species of marine fossils in these limestones, here much opalised, has thrown quite a new light upon them. In this case there can be no doubt that the calcareous travertine represents the much weathered condition of a former bed of shells and shelly detritus, and bearing this in mind together with the marginal position on lakes of most of the other travertine areas, it is not a great assumption to make to suppose that they also were shell banks. Very little attention appears to have been given by any observer to the calcareous deposits, probably owing to exigences of travel and acceptance of the prevalent idea that they were merely travertines from basic rocks, but it seems to the writer that there is a very strong case made out for thinking that they are most probably of marine origin, and that they also will be found to be fossiliferous when well searched. They will probably prove to yield the decisive evidence as to the truth or otherwise of the theory of a recent marine invasion of our goldfields areas.

The spongy to pulverulent, yet often also concretionary and nodular character of these travertines, and the frequent occurrence with them of opalised matter, may easily be the result of subarid weathering of banks of shell sand. The thin coating of superficial limestone along the shore at Port Hedland is of very similar character, and to a passing glance shows little or no sign of being formed from organic detritus, yet with marine life swarming between tide-levels on the shore close by, it can hardly be doubted that the limestones are derived from similar organic remains. Much of the bedded limestone near Hopetoun, similarly, which is often pretty distinctly stratified, has also a similar travertine-like character. In the railway cuttings between Cottesloe Beach and North Fremantle we see excellent sections showing a great amount of re-arrangement of the calcareous material by solution and reprecipitation along lines on which passage of water through the mass has been possible, and there seems no good chemical reason to doubt that the transformation of shell sands into travertine-like deposits could easily result from superficial weathering under the conditions of small precipitation and rapid evaporation prevalent on our fields. The fall of rain upon the porous material, and the subsequent withdrawal of the water from the soil by capillary attraction to surface and evaporation, supply quite the ideal conditions for rapid and extreme alteration of superficial calcareous beds. It is suggested that this rapid weathering of calcareous matter may be a very sufficient reason for the absence from the lake basins of any of the signs of marine life which would be expected on the theory of their having been submerged under the sea.

SALINITY OF WATERS.

The next question to which study of the lake areas leads us is that of the degree and nature of the salinity of the natural waters found in the goldfields. This is a matter on which much light is likely to be thrown by the greatly hoped for publication at an early date by the Geological Survey of W.A. of all the numerous analyses of the waters of the States, which have been made for various purposes. From examination of a large number of these analyses the present writer is strongly of opinion that they point to derivation of their saline contents from a marine source rather than directly from integral constituents of the bedrock. It is obvious that strata laid down as sediments under sea water must contain a proportion of sea-salts in them when they are again elevated to become dry land, and even the old crystalline rocks, when their upper surfaces have been under the sea may well be assumed to have a large amount of salt water forced into them through all possible joints and fissures in them, which would mostly be retained when they were again elevated above sea level. Such interstitial salt would then have to be regarded as of marine origin, and quite foreign to the solid constituents of the rocks in which it is entangled, and would be capable of being washed out of them. It would thus be different in origin from salts set free by the weathering and chemical changes affecting the original materials of the rock itself. The commonly accepted theory that Western Australia presents a very old land-surface which has never been submerged for ages, however, demands that the saline accumulations must be regarded as principally derived from the integral minerals composing the bedrock. But so far as analyses have gone, there is very little chlorine in the crystalline rocks, and it is very difficult to believe that the enormous quantities of salt present in the salt pans and the surface soil and shallow underground waters of this State can have been formed merely by prolonged concentration of the minute amounts of chlorides as yet demonstrated to be existent as a primal constituent of the crystalline rocks. It is often stated that the areas occupied by the greenstones yield ground water much more highly saline than that of the granite districts, and also that the soda-granite country is salter than that composed of orthoclase or microcline granite. The writer is very dubious as to these statements being acceptable as correct generalisations, as there are several granite regions towards the south coast where the ground waters are extremely salt, and other greenstone districts, especially in the Murchison, East Murchison, and Mt. Margaret fields, where fresh water is found just as commonly as in the granite. In the absence of analytical proof that the greenstones average considerably higher than the granites in percentage of chlorine in their crystalline constituents, the writer is inclined to ascribe any local differences in salinity which may be noticed rather to the much more jointed and often schistose structure of the greenstones as compared with the granites, and their consequent greater liability to inclose interstitial salt water whose salt is not necessarily derived from the enclosing rock. A somewhat curious instance is seen at the Govrnment dam at Cordingup Creek at Ravensthorpe, where some 25,000,000 gallons of fresh water are impounded from rains falling on a granite catchment. Near the back of the dam one of the diorite dykes very common in this district crosses the Cordingup Creek, and at this point it was found that there was an exudation of salt water in small quantities, but sufficient gradually to affect the fresh water, and to require special measures to be taken to cut off the salt water feeder. It is incredible that this salt should be leached out of either the solid crystalline granite or the equally dense crystalline diorite, both of which are practically unweathered at this point, but there is nothing strange in there being salt water in the fissures along the margins of the dyke. Except for a short time during rains almost all the natural waters of the Ravensthorpe district are very salt, whether the bedrock is granite or diorite, and salt water must therefore be expected to accumulate in all joints, breaks, and other fissures of the rock.

By tracing the conditions of salinity of the country from the south coast northwards, the writer thinks that we shall be able to see an explanation of most of the phenomena exhibited, and to conclude that they are in keeping with the theory of marine submergence, though inexplicable on that of sub-aerial peneplanation. All along the south coast from Albany eastward to Esperance, the country is very salt, most of the streams—even running ones—being quite undrinkable even by cattle during the drier parts of the year. When flooded by rains they may be fairly fresh for a little while, but they soon become salt again, and even in rains the spectacle may be witnessed of a rushing turbid torrent of salt water. The Palinup River, Salt River, Jacup River, Hamersley River, and Phillips River may generally be seen running a little, where crossed in travelling from Albany to Ravensthorpe, but are very salt. On the granite rocks near the head of the Hamersley River, there is a camping place where a little fresh water may generally be obtained, but where the writer found that nearly all the water trickling over bare granite was quite salt. Yet it is not the granite which is yielding the salt, for rock holes in the granite are found in which the water remains perfectly fresh for weeks. The celebrated "Night Well" on the Salt River was in granite in the valley of the river and only a few feet above its bed, and above it and below it in the bed of the river there were salt water pools when the writer visited it in 1902. The fresh water was in a crevice in the granite and so had every opportunity to dissolve salt from it if the granite were the source of the salt, but the water was quite fresh. So also tanks blasted out of the granite, and with a bare granite catchment, in other parts of the southern district, retain their water perfectly fresh. The hard granite evidently is not the source of the salt, but all the overlying soil and the sand plains appear to be full of salt. It is clear that every time the streams run they must carry away a large amount of salt to the sea, and it is an indication of the enormous amount of salt available, and also of the comparatively short time during which the leaching action can have been going on, that there is still so much yet to be removed.

Going further north, the country still remains salt, irrespective of whether granite or greenstone is the bedrock, but there is no difficulty in getting fresh water during rains for storage in dams. The surface layers of the ground have been washed fairly free from salt by the rains, and in favourable places fresh water "soaks" may be found, especially where fresh water pouring off bare granite rocks has accumulated under superficial drift round their bases. It has been able in course of time to wash out and press back the salt water. Wells in such places however, are very often found to turn salt very rapidly when used, the drainage into the well evidently soon drawing back the salt water which had been displaced by fresh. It is also very often found that one must be very careful about deepening such wells, as the fresh water zone is often quickly passed through and salt water found below it. A curious instance of fresh water in salt country was found when boring for water at the Jaurdie Hills not far from Coolgardie. A small valley comes out of the hills, down which at times of heavy rain there is a fairly strong flow of water which soon is absorbed when it reaches the plain. Borings found that the alluvial drift in the flat at the mouth of this little valley was some 60-70 feet deep, if my memory is correct, and three of these bores got salt water. A fourth, put down within the triangle formed by the first three, obtained fairly fresh water, but when a well was sunk the water soon became salt. The explanation doubtless is that the alluvial drift was salt in the main, but that the fresh water from the hills had established a line of flow for itself through the drift, along which the salt had been washed out. The fresh water bore happened to hit this channel and got fresh water, but the demands of a well soon brought in the salt water from the surrounding salt country. Another fresh water well at Coolgardie in its early days was a bonanza for a short time to its owner, but it soon also became salt.

Continuing northwards, fresh water wells and soaks become much more frequent and more permanent, and the salinity of other wells is generally much less than in the southern districts. North of Kookynie, fresh water wells become quite common, though the lowest lying ground is apt to be very salt, and salt lakes are still common. Rising into still higher country the wells are on the whole fairly fresh, and many of them excellent water, though there is often great variation in the salinity of wells quite near one another. Is it not pretty clear that height above sea level is the principal factor in the problem, and that the country which stands highest has had the best chance of having the salt removed from it by rains and the gradual down grade flow of the ground waters? Also if the theory of submergence under the sea by subsidence and subsequent emergence by elevation be correct, the higher country has been longer exposed to the washing action of the rains, and has been more thoroughly leached of salt than the parts which were later in emerging. The sub-aerial theory might explain the accumulation of the salt in the lowest parts of the plains where the water gathers, but it does not explain why the South Coast region which has twice or thrice as great a rainfall as the country further north should be the saltest portion of the State.

The salt waters found in our salt areas vary greatly in total percentage of saline constituents per unit of water, and also a good deal in the relative amount of the various salts present, but it is very notable that the salts present are principally those also found in sea water, and are such as might result from the leaching of sea salt from superficial sediments. In this process certain reactions are liable to take place between the salts and the constituents of the soil which may have the effect of rendering some portions of the former insoluble, with interchange of other soluble salts not originally in the sea water in place of them. The calcium sulphate in sea water, for example, might readily react with sodium carbonate formed by the weathering of sodium-bearing silicates in the soil, to form the much less soluble carbonate of lime and sodium sulphate. Many such reactions must be expected which might soon alter the quantitative proportion between the various salts from that normal in sea water. Taken on the whole, the salts in our salt lakes and wells may truly be said to be of a marine facies, sodium chloride being always predominant, and constantly associated with much of sulphates of lime and chlorides and sulphates of magnesia. In some cases the magnesia salts are more plentiful than usual, and the composition of the saline constituents of the water then approaches that of the "bitterns" formed when part of the sodium chloride of sea water has been crystallised out of it. Whether such removal of sodium chloride be the reason of the relative excess of magnesium salts or not, it may be noted that very similar variations in the proportions of sodium and magnesium salts are common in brines pumped from saline strata in salt producing districts. In these, too, a like differential removal of certain of the salts must have taken place as the marine origin of these salt beds is undisputed, and the proportions of the salts present must therefore have been originally those normal in sea water.

The insufficiency of the theory that the salt in the ocean is derived from mere evaporative concentration of the salts brought down by rivers has frequently been remarked upon. Julius Roth, for example, found that the proportions of the salts of river and sea water were:—

	Carbonates.	Sulphates.	Chlorides.
	%	%	%
River water	80	13	7
Sea water	0.2	10	89

The learned authors of the article on "Ocean and Oceanography" in the Encyclopedia Britannica, who quote Roth's figures, also remark: "The salts of salt lakes which have been formed in the areas of internal drainage in the hearts of the continents by the evaporation of river water are entirely different in composition from those of the sea, as the existence of the numerous natron and bitter lakes shows." The water of Lake Van, for example, contains 5.3976 grams of sodium carbonate per 1000 grams of water, to 8.0500 grams of sodium chloride. The principal soluble salts formed by the chemical action of the weather on the compound silicates which form the bulk of the crystalline rocks are carbonates or bicarbonates of the alkalies and alkaline earths, and as a natural consequence these salts must be expected to predominate in the surface waters leaching through masses of weathering rock. Unless chlorine be present as a constituent of the rocks, no considerable amount of sodium chloride can be formed from such weathering, and unless, therefore, our crystalline rocks can be shown to carry a quite perceptible amount of chlorine in them on the average, there is no reason to look to them as the source of the salt so plentiful in the ground water. So far as chemical analyses have been published chlorine has very rarely been noted as a constituent of our crystalline rocks at all, and the petrological descriptions do not indicate any unusual abundance of chlorine-bearing minerals.

In this connection it may be of interest to refer to the tables of analyses of natural waters in Australia given in the Report of Proceedings of the Interstate Conference on Artesian Waters, 1912. Appendix B. gives 54 analyses of bore waters in New South Wales, characterised by the carbonates of sodium, potassium, calcium, and magnesium being in almost all cases greatly in excess of the sodium chloride present. In Appendix H. there are several hundred analyses of New South Wales artesian and subartesian waters, and the great majority of these also show alkaline carbonates in large excess over sodium chloride, although a few are mainly saline waters. In Appendix M., Tables 11 and 111 give 65 analyses of waters from Western Australia, but in these sodium chloride is almost always in large excess over all other salts present, and carbonates are of quite subordinate importance. The reversal of the relative proportions of chlorides and carbonates in the ground water at once suggests some essential difference between the conditions of the two provinces of New South Wales and Western Australia. Appendix T. shows 48 analyses of bore and well waters from the Mallee country of Victoria, with a great preponderance of sodium chloride over all other constituents. In Appendix Y. there are 34 analyses from South Australia, of waters from the Great Australian Basin; in 28 of these sodium chloride is the most abundant salt present, but in 6 cases sodium carbonate predominates, and in 11 the sodium carbonate is next to sodium chloride in abundance. In the table of analyses of Queensland waters, the relative proportions of the various salts have not always been determined, but it may be seen that in a large number of cases the sodium carbonate is the salt most plentifully present, while in others sodium chloride predominates. It seems rather probable that a careful correlation of all these different analyses according to locality and composition taken in conjunction with the geological structure at each bore might give useful results in assisting to arrive at some conclusion why certain regions have developed alkaline rather than saline ground waters. For the purposes of the present paper the main point to be emphasised in these analyses is the great salinity of the Western Australian ground waters as compared with those of Eastern Australia. It is submitted that the most feasible explanation of the occurrence of such abnormal quantities of common salt is that it is derived from sea water within a space of time so recent, geologically speaking, that it has been insufficient to allow of the salt being either carried back to the sea or concentrated entirely in the low-lying salt lakes. All the rain that falls on the surface tends to carry the salt into one or other of these final receptacles, and the fact that this action has not yet succeeded in removing the salt from the soil to anything approaching the extent that must follow from long continued leaching by rain, may be taken as supporting the view that the present condition is of comparatively recent occurrence. This argument, however, is weakened by the fact that the capacity for evaporation of water in this State very greatly exceeds the precipitation, so that it is possible and in many cases probable that very little if any of the rain falling on a district goes to increase the body of ground water and to help to drive it forward on its slow but constant course seaward. A great deal of it simply sinks into the earth for a time, but is brought up again by capillarity and vegetation and evaporated. It is therefore quite possible that the salinity of the soil of such a district might remain practically constant for an indefinite period. The most that can be regarded as certain is that the salt would tend to become more and more collected in the lowest lying portions of each district, and that in course of time the slow seaward movement of the ground water must tend to restoration of the salt to the ocean. That this result has been attained in the higher central regions of the State more thoroughly than in the southern coastal ones has been already pointed out.

The dogma that the central portion of this State has been a land-surface from time immemorial, which has been re-iterated so often as to have become generally accepted belief, seems to the present writer to be founded on no sure basis of facts and to be entirely opposed to the physiographical evidence above narrated, which all goes to show that the very shape of the landscape as we now see it has been mainly impressed upon it by the action of bodies of salt water. It is difficult to discover why such a theory should be held, for there is a good deal of evidence that the sea has extended over the greater part of the State not only once, but repeatedly since the very ancient rocks forming our goldfields were first exposed as a land surface. These oldest rocks, taking all the Pre-Cambrian ones together, are uncovered at surface at the present day in the Central and Eastern Goldfields, but in the greater part of the northern half of the State they are overlain by the much younger Nullagine formation, and there appears to be at least a strong possibility that this reappears in the Stirling and Eyre Ranges in the South. There is quite a considerable degree of probability that the whole of the State has been covered by the Nullagine formation, lying upon a previously planed-down surface of the Pre-Cambrian rocks. Subsequent erosions have removed the Nullagine rocks over huge areas. After the formation, upheaval, and land-erosion of the Nullagine beds there has again been depression of large parts of the area of the State below sea level when the Carboniferous formation was laid down, which must have extended over a very large portion of the State, as we still find large areas of it in districts so far apart as the Kimberley, Gascoyne, and Collie mineral fields. The elevation to which these beds extend suggests that when they were laid down there was much probability that a great deal of the rest of the State was also submerged. Then still later there must have been submergence of large portions of the State when the Mesozoic rocks were laid down which we find from Gin Gin northwards to beyond Geraldton, up to considerable elevations, and the limestones of the Eucla plateau, found up to heights of about 1000 feet above sea level, point to a probably rather later period of subsidence and marine sedimentation over an immense tract of country. When the sea came inland to the northern edge of the Eucla limestone area it may well have flooded a great part of the Eastern goldfields which are now below the 1000 feet level, and a comparatively slight further subsidence would have carried it over practically the whole of the Central and Eastern Goldfields if the relative levels of the various districts remained the same then as at present. The Government Geologist has also described limestones, probably of Tertiary age, occurring at a high level near the head of the Oakover River in the Pilbara Goldfield, which would indicate a subsidence in Tertiary times sufficient to bring the sea a long way inland at that point.

It is seen therefore, that there is positive evidence of successive invasions of the sea well into what is now the interior of Western Australia, up to the Cretaceous and probably the Eocene, or even later periods, and there is no reason to suppose that the limits as we now find them of the formations then laid down were the extreme limits to which the sea waters extended. It is much more likely on the contrary that the sea extended over a great deal more country, in which no traces of its presence have been preserved.

Subsequent to the laying down of the Cretaceo-Tertiary limestones there have been further oscillations upward and downward of the land forming this State, with formation of the Tertiary to recent coastal limestones and sandstones. There is much doubt as to the thickness of these sediments, as some of the bores into them which appear to have gone to depths of 1000 to 3000 feet without getting through them are regarded by the Geological Survey as being in Mesozoic strata in their lower portions. The elevation to which they reach is also not at all certainly ascertained. On the Ravensthorpe Range near Kundip, there are patches of probably rather recent conglomerate at quite 800 feet above sea level, and if some of the recent sedimentary deposits at Collie, overlying the coal measures, near Kirupp, and at Greenbushes are taken to belong to the coastal formation (Tertiary to recent) they would indicate marine or lagoon deposition at a horizon now elevated 700 to 900 feet above the sea level. Here again it is improbable that the few relics still surviving of these beds would indicate the extreme height up to which the waters of the sea may have invaded the country, and it might quite well be that the subsidence of the land was great enough to flood the plains of the goldfields. It is submitted that as there is proof up to an elevation of 900 feet of subsidences sufficient to cause formation of probably marine sedimentary deposits there is no great assumption involved in supposing that they went on to a still greater extent so as to be sufficient to cause the sea to invade the interior at levels considerably above that elevation, and enough to impress upon the surface those features of marine planation which we now find to be characteristic of the goldfields landscapes. The subsequent elevation of the land would then lead to the formation of numerous salt lakes in the depressions of the generally flat surface, whether such depressions were due merely to inequalities in the level of the sea bottom or to slight deformation basins forming in the bedrock itself in the course of its elevatory movement. Some such unequal movements of portions of the upheaved block would be only what might be expected during a continental movement of elevation. Signs of such uneven motion are not wanting. A small fault, for example, has been found in the Siberia deep lead, throwing down the old gutter some six or eight feet, and at Coolgardie there is a very interesting patch of deep ground, about 400 feet deep, of probably Tertiary or Post-Tertiary age, which seems inexplicable unless it is a small sunken field or "grave" where a wedge-shaped piece of ground has been faulted downwards. It is not unlikely that such faults in the superficial sedimentary deposits are quite common, and they may be the explanation of the apparent sudden cutting off at times of the "deep leads." If there has been much faulting of this sort, however, there has been time since it occurred for all resulting inequalities of the surface to be planed smooth, leaving no trace of the faults at surface. The sunken field at Coolgardie for instance looks just the same at surface as any of the shallow flats in its vicinity.

It seems probable that the movements of elevation and subsidence of this country have been mainly epeirogenic rather than orogenic ever since Palaeozoic times. The Nullagine series of beds are usually characterised by gentle undulatory bending without severe folding; the Carboniferous beds mostly lie at low angles of dip without much appearance of bending, and the strata of Mesozoic and Tertiary age seem usually only very slightly tilted from their original bedding. Since the time when the Nullagine beds were subjected to a certain amount of orogenic crumpling there appears to be very little if any evidence that any of the subsequently formed strata have been compressed into undulatory folds to any appreciable extent. At Collie the tilting of the beds of the coal measures seems principally due to faulting rather than crumpling. In epeirogenic movements of elevation, faulting in parts of the moving landmass must be expected as a natural consequence of the readjustments of position of material incidental to the movement. An elevation or subsidence of an area of land of continental dimensions like the Western Australian Plateau would also require us to assume the existence of powerful faults forming the boundaries of the moving block, and it may be noted that the probable existence of some such faults has already been deduced from entirely different considerations, along both the southern and western coasts of this State. There is too little evidence to enable one to say yet whether there is any indication of the last elevatory movement being merely an even vertical one or whether one or other side of the block has been upheaved more than the others. It seems possible that the physiographical evidence may yet be so systematised as to lead to some positive conclusions being drawn on this point. A little tilting of one side or another of the moving block of ground obviously might have very important effects in modifying or even reversing the directions of slope of various parts of the surface, and so altering the flow of surface waters.

The most positive indications of marine conditions in the interior of our State are those already mentioned as having been found in the Norseman district near Lake Cowan. Here there are two occurrences of remains of undoubtedly marine organisms, one a thick bed composed almost entirely of sponge spicules, described by Dr. Hinde, in the Princes Royal Deep Lead, and the other a bed of marine shells in limestone, found by Mr. Campbell near the Norseman Causeway. The shellbed is described as being 35 feet above the level of Lake Cowan, and containing opalised casts of several species of late Tertiary or recent marine shells belonging to the genera, *Turritella, Pecten, Cardium,* and *Magellania.* The sponge spicules occur as a deposit in the upper part of the alluvial material filling the Princess Royal "Deep Lead," forming a bed said to be over 35 feet in thickness. Dr. Hinde's conclusion after examining the spicules was that the deposit was formed in the open ocean at some distance from a coast-line and probably in considerable depth of water, and he thinks them likely to be post-cretaceous in point of age.

The "deep leads" all over the State are old valleys which have been filled up before the present lakes were formed, and the Princess Royal sponge spicule deposits would go to indicate that they became filled up during a subsidence which brought the sea so far inland that the present site of Norseman was in deep water well out from the coast. This might perhaps have been during the time of the Cretaceo-Tertiary subsidence, which resulted in the laying down of the Eucla limestones, and if this date could be established for the case of the Princess Royal Deep Lead, it would probably apply generally to all the other deep leads of the State which are quite similarly buried under lake flats. It would not necessarily follow, however, that marine sediments should be expected to be found in all of these, as the first effect of a movement of subsidence would be to start the filling up with drift of all the valleys near the coast long before they became submerged under sea waters. The material found filling them as a matter of fact appears generally to be of sub-aerial origin and not marine. The Princess Royal valley appears to have remained open however, and to have become deeply submerged, giving the opportunity for collection in it of the deep-sea deposit of sponge remains. The more littoral shell-beds might have been formed at almost any period during this movement of submergence and subsequent emergence of the land, but probably at either an earlier or later stage than the spicule beds, and if the species prove to be altogether more recent than the Eucla limestone period, as appears to be the opinion formed at present, it would be probable that they belong to a Post-Tertiary repetition of the process of submergence and subsequent elevation much later than the Cretaceo-Tertiary one in which the Eucla limestones were formed. From their position they look like littoral deposits of an arm of the sea, occupying the site of Lake Cowan to, a depth at least 35 feet above its present level, and seem most likely to belong to the last period of the connection of the lake with the sea before the continuance of the elevatory movement cut the former off from the latter, and raised it up some 900 feet. The presumption would then be that the deep leads generally are mostly likely of an age between the times of the Cretaceo-Tertiary subsidence and elevation which gave us the Eucla limestones and a subsequent similar Post-Tertiary down and up movement which gave the more recent Norseman beds. The leads would represent stream channels in the land surface existing between the two periods of subsidence.

The marine deposits at Lake Cowan show positively that elevation from probably a considerable depth below sea level up to about 900* feet above it, has taken place at that point, and if Lake Cowan be admitted to be the residuum of a cut off arm of the sea. it is only reasonable to extend the same explanation to Lake Lefroy, Hannan's Lake, Lake Yindarlgooda, and Lake Lepage, which are connected with one another by plains into which the margins of the lakes merge imperceptibly. Hannan's Lake however, is at about the 1060 feet level. The plain country is traceable on to the north almost continuously, though studded with frequent island-like groups of hills, to connect with Lakes Ballard, Barlee, Raeside, Carey, etc., right up to Lake Way, the elevation of which is about 2030 feet according to Professor Gregory. The physiographical features of the country round Lake Cowan are quite similar to those of the whole lake tract right up to Lake Way, and if physiographical evidence is of any value, the shaping of the land surface has been due to like agencies all the way. At Lake Cowan we have direct evidence that the lake was once an arm of the sea, and the conclusion seems irresistible that the marine invasion extended inland along the lake country to beyond Lake Way. Such an extension would bring it over all the Central and Eastern Goldfields, unless the relative levels of the different parts of the country have been altered unequally, of which no evidence has been brought forward as yet, though there is no inherent improbability that such may have been the case, and indeed there is a good deal of probability that it would be so.

According to this theory the present shape of the land surface of the goldfields up to at least the 2000 feet level would mainly be that impressed upon it during the re-emergence of the land and retreat of the sea, probably in Post-Tertiary times, and in the writer's opinion the whole of the characteristic features now visible agree consistently with those which would be necessary consequences of such a history.

It will be interesting to find how this theory will stand the test of the biological line of argument, for if it be correct there would undoubtedly be consequences affecting the distribution of both plant and animal life. The theory would require that in Post-Tertiary times this State has been at times more or less of an Archipelago in a shallow sea, which would result almost inevitably in some amount of differential variation of both the fauna and flora cut off on the islands. The result to be expected would be that we should have somewhat marked faunal and floral provinces, difficult to account for if the land surface had been continuous for a very long space of time. This interesting subject is beyond the scope of the present paper, and is left to be dealt with by writers more conversant than the present author with the botany and zoology of the State.

*Norseman Railway Station, 927 feet above the sea level.

H.J. Pether, Government Lithographer, Perth, W.A.

NATIONAL MUSEUM MELBOURNE

LIST OF ORTHOPTEROUS INSECTS RECORDED FROM WESTERN AUSTRALIA.

By

W. B. Alexander, M.A., Keeper of Biology, W.A. Museum.

(Read 13th June, 1916.)

This list contains references to the literature on the group available in Perth, including also species in the collection of the Western Australian Museum, not previously recorded from the State.

* Indicates one or more specimens in the collection of the W.A. Museum.
** Indicates type in the W.A. Museum.

S.W. refers to all that portion of Western Australia south of 25 degees S. lat.

N.W. to that portion of Western Australia between 19 degrees and 25 degrees S. lat.

K. to the Kimberley division, the portion of Western Australia north of 19 degrees S. lat.

The distribution outside the State as far as ascertained is added in brackets.

S.A.—South Australia, Vict.—Victoria, Tas.—Tasmania, N.S.W.—New South Wales, Q.—Queensland, N.T.—Northern Territory, C.A.—Central Australia, N.G.—New Guinea, N.Z.—New Zealand.

DERMAPTERA (Earwigs).

General Literature:—de Bormans, Tierreich, Lief. II., Forficulidae (1900); Kirby, Synonymic Catalogue of Orthoptera, vol. I. (1904); Burr, Fauna Sudwest-Australiens, Bd. II., Lief. 5, Dermaptera (1908); Burr, Genera Insectorum, Fasc. 122, Dermaptera (1911).

Fam. Pygidicranidae (Burr, l.c. 1911).

*Pyge shortridgei, Burr—S.W. (Ann. Mag. Nat. Hist. (8) XIII. 1914).

Fam. Labiduridae (Burr, l.c. 1911).

*Gonolabis michaelseni, Burr—S.W. (l.c. 1908).

*G. woodwardi, Burr—S.W. (l.c. 1908).

*G. brunneri, Dohrn—S.W. (S.A., Tas.), (de Bormans, 1900).

*Anisolabis occidentalis, Kirby—S.W. (de Bormans, l.c. 1900).

*Labidura truncata, Kirby—S.W. (Australa) (de Bormans, l.c. 1900).

ORTHOPTERA CURSORIA (Cockroaches).

General Literature.—Tepper, the Blattariae of Australia and Polynesia, Trans. R. Soc. S.A., XVII. (1893) and XVIII. (1894); Tepper, Notes on Victorian and other Blattariae, ibid XIX. (1895); Kirby, Synonymic Catalogue of Orthoptera, Vol. I. (1904); Shelford, Genera Insectorum, Fasc. 55, Blattidae (introduction) (1907); Shelford, Fauna Sudwest-Australiens, Bd. II., Lief. 9, Blattidae (1909); Shaw, Australian Blattidae, Vict. Naturalist, Vol. XXXI. (1914).

Fam. Blattidae.

Subfam. Phyllodromiinae (Shelford, Genera Insectorum, Fasc. 73, Phyllodromiinae (1908).

Ellipsidion decoratum, Tepp.—S.W. (S.A.) (l.c. 1893).

*E. australe, Sauss—S.W. (Australia).

*E. aurantium, Sauss.—S.W. (Australia) (Tepper, l.c. 1894).

*Phyllodromia germanica, Linn.—N.W., K. (Cosmopolitan) (Tepper, l.c. 1893).

P. (?) liturata, Tepp.—S.W. (Vict.) (l.c. 1895).

*Allacta spuria, Brunn.—N.W. (Fiji) (Tepper, l.c. 1893).

*A. similis, Sauss.—S.W. (Australia) (Tepper, l.c. 1894).

Ceratinoptera ensifera, Shelf.—S.W. (l.c. 1909).

*Temnopteryx platysoma, Walk.—S.W. (Shelford, l.c. 1909).

T. discalis, Walk.—W.A. (Tepper, l.c. 1893).

Paratemnopteryx australis, Sauss.—W.A. (S.A., Vict.) (Tepper, l.c. 1894).

*Escala circumducta, Walk.—S.W. (S.A., Vict.) (Shaw, l.c. 1914).

*Loboptera (?) duodecimsignata, Tepp.—S.W. (S.A.) (l.c. 1893).

Subfam. Epilamprinae (Shelford, Genera Insectorum, Fasc. 101, Epilamprinae, 1909).

Calolampra fraserensis, Tepp.—S.W. (S.A.) (l.c. 1893).

C. aspera, Tepp.—S.W. (S.A.) (l.c. 1893).

C. marginalis, Walk.—S.W. (Tepper, l.c. 1893).

Subfam Blattinae (Shelford, Genera Insectorum, Fasc. 109, Blattinae, 1910).

*Polyzosteria cuprea, Sauss.—S.W. (S.A.).

*P. obscuroviridis, Tepp.—S.W. (S.A.) (l.c. 1893).

*P. pubescens, Tepp.—S.W. (l.c. 1893).

**P. arenicola, Montague—N.W.

*Euzosteria subverrucosa, White—S.W. (Tepper, l.c. 1893).

E. nobilis, Brunn—S.W. (S.A.) (Tepper, l.c. 1893).

E. patula, Walk.—N.W. (N.T.) (Tepper, l.c. 1893).

*E. mitchellii, Angas—S.W. (S.A., Vict., N.S.W.) (Tepper, l.c. 1893).

Platyzosteria analis, Sauss.—W.A. (Vict., N.S.W., India).

*P. armata, Tepp.—S.W. (l.c. 1893).

P. atrata, Erichs.—W.A. (Vict., Tas., N.S.W.) (Tepper, l.c. 1893).

*P. invisa, Walk.—S.W. (N.S.W.) (Tepper, l.c. 1893).

P. consobrina, Sauss.—S.W.

P. ruficeps, Shelf.—S.W. (l.c. 1909).

P. rufipes, Shelf.—W.A.

P. curiosa, Shelf.—S.W. (l.c. 1909).

P. obscura, Tepp.—S.W. (S.A.) (l.c. 1893, Shelford l.c. 1909).

*P. scabriuscula, Tepp.—S.W. (S.A.) (l.c. 1893).

P. conjuncta, Shelf.—S.W. (l.c. 1909).

*P. morosa, Shelf.—S.W. (S.A.) (l.c. 1909).

*P. inclusa, Walk.—S.W. (Tepper, l.c. 1893).

P. albomarginata, Brunn.—S.W. (N.S.W.) (Tepper, l.c. 1893).

P. obscuripes, Tepp.—S.W. (S.A.) (l.c. 1893).

P. variegata, Shelf.—S.W. (l.c. 1909).

*P. semivitta, Walk.—S.W. (S.A.) (Tepper, l.c. 1893).

*P. coolgardiensis, Tepp.—S.W. (l.c. 1895).

P. hartmeyeri, Shelf.—S.W. (l.c. 1909).

Cutilia heydeniana, Sauss.—S.W. (Tepper, l.c. 1894).

Zonioploca medilinea, Tepp.—S.W. (S.A., Vict.) (l.c. 1893).

*Z. pallida, Shelf.—S.W. (l.c. 1909).

*Z. alutacea, Stal—S.W. (S.A.) (Tepper, l.c. 1893 as Platyzosteria ardrossanensis).

*Z. flavocincta, Shaw.—S.W. (S.A., Vict.) (l.c. 1914).

*Anamesia polyzona, Walk.—S.W., N.W. (Tepper, l.c. 1893).

A. frenchii, Tepp.—N.W. (Q.) (l.c. 1893).

A. lindsayi, Tepp.—S.W. (l.c. 1893).

A. punctata, Tepp.—S.W. (S.A.) (l.c. 1893).

Desmozosteria michaelseni, Shelf.—S.W. (l.c. 1909).

D. rufescens, Shelf.—N.W. (l.c. 1909).

*Periplaneta americana, Linn.—S.W., N.W. (Cosmopolitan) (Tepper, l.c. 1893).

Archiblatta (?) parva, Shelf.—N.W. (Ann. Mag. Nat. Hist. (8) I., 1908).

Subfam. Panchlorinae.

*Oniscosoma granicollis, Sauss.—S.W. (Vict.).

Subfam. Oxyhaloinae.

Ectoneura margarita, Tepp.—S.W. (Vict.) (l.c. 1895).

Subfam. Perisphaeriinae.

Pseudoglomeris fallax, Walk.—S.W. (Tepper, l.c. 1893).

ORTHOPTERA GRESSORIA.

Fam. Mantidae.

General Literature:—Kirby, Synonymic, Catalogue of Orthoptera, Vol. I. (1904).

Subfam. Perlamantinae. (Giglio-Tos, Genera Insectorum, Fasc. 144, Perlamantinae, 1913).

*Paraoxypilus tasmaniensis, Sauss.—S.W. (Australia and Tas.).

*Gyromantis kraussii, Sauss.—S.W. (Australia).

*Phthersigena conspersa, Stal.—N.W. (Q.).

*Cliomantis cornuta, Gigl.-Tos.—S.W. (Q.).

Subfam. Eremiaphilinae.

*Orthodera ministralis, Fabr.—S.W. (Australia).

O. marginata, Sauss.—S.W.

Subfam. Mantinae.

*Archimantis brunneriana, Sauss.—N.W. (N. Australia).

*A. sobrina, Sauss.—S.W.

*Tenodera australasiae, Leach.—K. (Australia, Tas., N.Z., N.G., Moluccas).

*Fischeria quinquelobata, Tepp.—S.W. (S.A., N.S.W.) (Trans. R.S.S.A. XXIX., p. 238, 1905).

Fam. Phasmidae.

General Literature:—Gray, Entomology of Australia, I., Monograph of the Genus Phasma (1833); Rainbow, Rec. Austral. Mus. III., Catalogue of the Described Phasmidae of Australia (1897); Kirby, Synonymic Catalogue of Orthoptera, Vol. I. (1904).

Subfam. Bacillinae.

Hyrtachus eutrachelia, Westw.—S.W.

**H. hermitensis, Montague.—N.W. (P.Z.S. 1914 (II.), p. 648, MS. name?).

Arphax brunneus, Gray—S.W. (l.c. 1833).

Acanthoderus spinosus, Gray—S.W. (Trans. Ent. Soc. I., p. 45, 1836).

Subfam Acrophyllinae.

*Podacanthus viridiroseus, Gray (?)—S.W. (Q.).

*Tropidoderus rhodomus, McCoy—S.W. (Vict.) (Prodr. Zool Vict., pl. 70).

Vasilissa walkeri, Kirby—K.

Anophelepis telesphorus, Westw.—S.W.

Acanthomima rhiphcus, Westw.—S.W.

*Clemacantha regale, Rainb.—K. (Q., N.S.W.) (l.c. 1897).

*Cyphocrania (?) cornuta, Tepp.—S.W. (S.A.) (Trans. R.S.S.A. XXIX., p. 240, 1905).

ORTHOPTERA SALTATORIA.

Fam. Acridiidae (Locustidinae).

General Literature:—Froggatt, Agric. Gaz. of N.S.W., Locusts and Grasshoppers, Part I., Vol. XIV., p. 1102 (1903), Part 2, Vol. XV., p. 240 (1904); Kirby, Synonymic Catalogue of Orthoptera, Locustidae, Vol. III. (1910).

Subfam. Acrydiinae (Tettiginae) (Hancock, Genera Insectorum, Fasc. 48, Tetriginae, 1906).

*Acrydium sp.—S.W.

Subfam. Truxalinae.

*Acrida conica, Fabr.—S.W., N.W. (Australia) (Frogg. l.c. 1904 as Tryxalis rafflesii).

*Psednura viatica, Erichs.—S.W. (Australia, Tas.) (Burr, Genera Insectorum, Fasc. 15, Eumastacinae, p. 22, 1903).

*Stenobothrus propinquus, Walk.—S.W. (Australia) (Frogg. l.c. 1903).

*Chortoicetes pusilla, Walk.—S.W. (Australia) (Frogg. l.c. 1903).

*C. terminifera, Walk.—S.W. (Australia) (Frogg. l.c. 1903).

Subfam. Locustinae.

*Gastrimargus musicus, Fabr.—S.W. (Australia) (Frogg. l.c. 1903 as Locusta danica).

Urnissa erythrocnemis, Stal.—S.W. (Australia).

Subfam Pyrgomorphinae (Bolivar, Genera Insectorum, Fasc.

Subfam Pyrgomorphinae (Bolivar, Genera Insectorum, Fasc. 90, Pyrgomorphinae, 1909).

Monistria pustulifera, Walk.—W.A. (N. Australia).

Subfam. Cyrtacanthacrinae.

*Coryphistes cyanopterus, Charp.—S.W., N.W. (Australia) (Frogg. l.c. 1904).

*C. cyanopteroides, Tepp.—S.W. (S.A.) (Trans. R.S.S.A. XVIII., p. 164, 1904).

*C. nigroconspersus, Tepp.—S.W. (S.A.) (l.c. p. 166, 1904).

*Goniaea australasiae, Leach.—S.W. (S.A., Vict., Tas. N.S.W.) (Frogg. l.c. 1904).

*G. flava, Tepp.—S.W., N.W. (C.A.) (Horn Expn. Vol. II., p. 368, 1896).

*Stropis maculosa, Stal.—S.W., N.W. (Australia) (Frogg. l.c. 1904).

*S. brunnea, White.—S.W. (Grey's Journ. Expn. Australia, Vol. II., p. 470, 1841).

*Cirphula pyrrhocnemis, Stal.—S.W. (Australia) (Frogg. l.c. 1903).

*C. carbonaria, Serv.—S.W. (Australia).

Apotropis subpustulata, Walk.—W.A.

*Trigonizella hesperina, Tepp.—S.W., N.W. (S.A.) (MS.. name in S.A. Museum).

Exarna lutescens, Walk.—S.W.

E. australis, Walk.—S.W. (N.S.W.) (Frogg. l.c. 1904).

*Cyrtacanthacris maculicollis, Walk.—N.W. (Australia) (Frogg. l.c. 1903).

*C. guttulosa, Walk.—N.W. (Australia).

*Ecphantus quadrilobus, Stal.—S.W. (N. Australia, Q., N.S.W.) (Frogg. l.c. 1904).

Fam. Phasgonuridae (Locustidae).

General Literature:—Froggatt, Agric. Gaz. of N.S.W., Locusts and Grasshoppers, Part 2, Vol. XV., p. 240 (1904), Part 3, Vol. XVI., p. 477 (1905); Kirby, Synonymic Catalogue of Orthoptera, Vol. II. (1906); Caudell, Genera Insectorum, Fasc. 120, Locustidae —introduction (1913).

Subfam. Gryllacrinae. (Tepper, Gryllacridae and Stenopelmatidae of Australia, Trans. R.S.S.A. XV., p. 137, 1892).

*Gryllacris magnifica, Brunn.—S.W., N.W. (S.A., N.S.W.) (Tepp. l.c. 1892).

*G. atrogeniculata, Tepp.—S.W. (S.A.) (l.c. 1892).

*G. marmoriceps, Tepp.—S.W. (S.A.) (l.c. 1892).

*G. nigrifrons, Tepp.—S.W. (S.A.) (l.c. 1892).

*G. paulula, Tepp.—S.W. (S.A.) (l.c. 1892).

*Paragryllacris marginalis, Walk.—K. (S.A.) (Tepper, l.c. 1892 as P. infuscata).

P. minuscula, Walk.—S.W.

Neanias lepidus, Walk.—W.A.

Eremus camerani, Griff.—W.A.

Apotrechus guttifrons, Walk.—S.W.

Ametrosomus helmsi, Tepp.—S.W. (S.A.) (l.c. 1892).

Subfam. Decticinae. (Caudell, Genera Insectorum, Fasc. 72, Decticinae, 1908).

Chlorobalius (?) australis, Walk.—S.W.

Requena verticalis, Walk.—S.W.

Subfam. Saginae.

*Terpandrus horridus, Burm.—S.W. (S.A., Vict., N.S.W.) (McCoy, Prodr. Zool. Vict., pl. 109, 1885, and Frogg, l.c. 1904, as Locusta vigentissima).

Hemisaga denticulata, White.—S.W. (Australia) (Grey's Journ. Expn. Australia, Vol. II., 1841).

H. lutea, Walk.—S.W. (Australia).

Subfam. Tympanophorinae. (Caudell, Genera Insectorum, Fasc. 138, Tympanophorinae, 1913).

*Tympanophora pellucida, White.—S.W. (Grey's Journ. Expn. Australia, Vol. II., 1841).

Subfam. Copiphorinae (Conocephalinae), (Karny, Genera Insectorum, Fasc. 139, Copiphorinae, 1913).

*Mygalopsis pauperculus, Walk.—S.W.

Subfam. Agraeciinae. (Karny, Genera Insectorum, Fasc. 141, Agraeciinae, 1913).

Psacadonotus seriatus, Redt.—W.A.

P. irregularis, Redt.—W.A.

Subfam. Phasmodinae (*Prochilinae*). (Caudell, Genera Insectorum, Fasc. 138, Phasmodinae, 1913).

*Phasmodes ranatriformis, Westw.—S.W.

Subfam. Phaneropterinae (Tepper, Phaneropteridae of Australia, Trans. R.S.S.A. Vol. XV., p. 77, 1892).

Ephippithytoidea sparsa, Tepp.—K. (l.c. 1892).

*Alectoria superba, Brunn.—S.W. (S.A., N.S.W., Q.) (Frogg. l.c. 1904).

*Caedicia longipennis, Brunn.—K. (Q., N.S.W.) (Tepp. l.c. 1892).

*C. longipennioides, Tepp.—S.W. (S.A., N.S.W.) (l.c. 1892).

C. extenuata, Walk.—S.W.

C. inermis, Brunn.—W.A. (N.A.).

Torbia elderi, Tepp.—S.W. (l.c. 1892).

Symmachis glaucescens, Walk.—S.W. (Australia) (Tepp. l.c. 1892).

Tinzeda fraserensis, Tepp.—S.W.

*Elephantodeta pinguis, Walk.—S.W. (S.A.).

Fam. Achetidae (Gryllidae).

General Literature:—Froggatt, Locusts and Grasshoppers, Agric. Gaz. N.S.W. Vol. XVI., p. 477, 1905).

Subfam. Curtillinae (*Gryllotalpinae*).

*Curtilla coarctata, Walk.—N.W. (N.T., S.A., N.S.W.) (Frogg. l.c. 1905).

*Cylindracheta kochii, Sauss.—S.W. (S.A.).

Subfam. Gryllinae.

Nemobius bivittatus, Walk.—S.W.

*Gryllus commodus, Walk.—S.W. (Australia, N.Z., N. Caledonia) (Frogg. l.c. 1905 as Gryllus servillei).

Gryllodes sigillatus, Walk.—S.W. (Australia, Hawaii, Mexico, S. America, W. Indies, Mauritius, India).

G. flavispina, Sauss.—W.A.

Subfam. Myrmecophilinae.

*Myrmecophila australis, Tepp.—S.W. (S.A.) (Trans. R.S.S.A. Vol. XX., p. 149, 1896).

Subfam. Enropterinae.

Eurepa marginipennis, White.—S.W. (Grey's Journ. Expn. Australia, Vol. II., p. 467, 1841).

*E .longicauda, Sauss.—S.W., N.W.

The foregoing list contains the names of 151 species. Of these 86 are represented in the W.A. Museum collection. In addition the collection contains examples of 60 unidentified species, the majority of which are certainly not included in the list, though they may have been described from "Australia" with no further particulars.

DESCRIPTION OF A NEW SPECIES OF FISH OF THE GENUS EVOXYMETOPON, POEY.

By

W. B. Alexander, M.A., Keeper of Biology in the Western Australian Museum.

(Read June 13, 1916).

With One Figure. Plate VII.

At 4 a.m. on the morning of February 5, 1916, Mr. W. J. McLaughlan who was on sentry duty on the beach at North Fremantle, noticed in the dim light an object which he at first took to be a snake, but which on closer examination proved to be a remarkably elongated fish of a bright silvery colour. Mr. F. H. Peck who passed by a little later, offered to preserve the specimen on ice until it could be forwarded to the W.A. Museum in Perth, at which institution it was duly received on February 7th. It proves to be an example of the genus Evoxymetopon, Poey, which was founded in 1863, for a fish obtained at Havana now in the United States National Museum. The only other specimen referred to the genus was obtained at a depth of 70 fathoms off Mauritius about the year 1887. Hence the discovery of a third specimen is an event of considerable interest. The literature dealing with this genus of fish is as follows:—

Gill in the Proc. Acad. Nat. Sci. Philadelphia, 1863, p. 228, described the original specimen obtained by Poey at Havana, adopting Poey's name of Evoxymetopon taeniatus for the genus and species. The specimen was figured in the An. Soc. Espan. Hist. Nat., 1873, Plate V.

Gunther in the Sci. Res. of the Voy. of H.M.S. Challenger. Zool. XXII., p. 39, described the example from Mauritius as Evoxymetopon poeyi, and figured it on Plate XLIII.

Goode and Bean in Oceanic Ichthyology, Washington, 1895, give a description of Evoxymetopon taeniatus, apparently founded on a re-examination of the type. They also give a very poor figure (Fig. 214).

I have not traced any later references.

To the present example I propose to give the name of *Evoxymetopon anzac*, sp. nov.

Photo by G. Pitt Morison.

Fig. 1

Head of Evoxymetopon anzac ($\frac{2}{3}$ nat. size.)

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It differs from both *E. taeniatus* and *E. poeyi* in its much greater relative length and in the larger number of rays in the dorsal fin. The chief differences are shown in the following table:—

——	*Evoxymetopon taeniatus*, Poey. (Goode and Bean).	*Evoxymetopon poeyi*, Günther.	*Evoxymetopon anzac*, sp. nov.
GREATEST HEIGHT : Total length ...	$\frac{1}{12}$	$\frac{1}{13}$	$\frac{1}{28}$
LENGTH OF HEAD : Total length ...	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{12}$
DIAMETER OF ORBIT : Length of head ...	$\frac{1}{6}$	$\frac{1}{5}$	$\frac{1}{8}$
Spines of dorsal ...	87	93	c 120
Spines of anal ...	19	x + 20	14+

Unfortunately the fins are a good deal broken, and it is impossible to count the rays of either the dorsal or anal with accuracy, no doubt these breakages occurred when it was washed ashore, and if the large spine at the commencement of the dorsal found in *E. poeyi* was ever present it has disappeared. In other respects the example agrees in its structural features with Günther's description, the postanal spine is exposed evidently owing to the abrasion of the skin in that region and just behind it there is a large oval scale similar to that described and figured by Günther. There is no trace of the six narrow reddish bands which Poey describes in *E. taeniatus* and if one may judge from Goode and Bean's figure, the ridge on the forehead is not nearly so high as in that species, but agrees with that of *E. poeyi*

The radial formula is: B7 Dcirca 120, A14+, C17, P12, and the dimensions of the specimen are: Total length 1415 mm., length of head 120 mm., greatest height, 50 mm., diameter of orbit 15 mm. It is thus intermediate in size between the Havana specimen which is only 100 mm. long and the Mauritius specimen which is 78in. in length.

The specific name of Anzac was suggestd by Mr. Peek as being specially suitable for a fish found in Australian waters and nearly related to the famous Frost-fish (*Lepidopus caudatus*) so well-known in New Zealand.

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