MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XX., PART 1.

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CONTENTS.

CHAPTER I.

INTRODUCTORY.

CHAPTER II.

PREVIOUS OBSERVERS.

CHAPTER III.

THE GNEISSIC ROCKS.

CHAPTER XI.

ECONOMIC GEOLOGY.

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

On the Geology of the Madura and Tinnevelly Districts, *by* R. Bruce Foote, F.G.S., *Deputy Superintendent, Geological Survey of India.*

CHAPTER I.

INTRODUCTORY.

Although only the eastern parts of the Madura and Tinnevelly districts have been actually surveyed, with the view to completing the examination of the fringe of sedimentary formations which borders the coast of the Indian Peninsula, yet enough is known about the unsurveyed parts of the two districts to admit of the preparation of a sketch of their geological features.

The topography of the districts is very simple, as they both form part of the tract lying between the water-parting along the axis of the Southern Ghâts and the Bay of Bengal. Except in the north-west part of Madura district, where the Palani mountains stretch to the north-eastward away from the main mass of the Southern Ghâts, the mountain tract belonging to the two districts is very narrow, much which was formerly considered British territory having been ceded by the boundary commission to appease the land hunger of the Travancore Government. Only two spurs worthy of note extend into the

Orography.

Spurs of the Southern Ghâts northern part.

Memoirs of the Geological Survey of India, Vol. XX, Pt. 1.

British territory. The first of these is the Vārshanād ridge which extends into the Ándipatti and Nagamalai hills, which latter die away in the plain a little to the west of Madura town. The second spur to be noted is the nameless mountain mass projecting into the Kambam valley and dividing the headwaters of the Suruli or Shurley-ār from those of the Vaigai (Vygay).[1]

Vārshanād spur. Subsidiary spurs.

The Vārshanād spur branches off from the high Puluvurangan or Kotay peak (6,617′), and throws off three subsidiary spurs to the eastward—the Pémalai (5,575′), west-north-west of Srivilliputur (Shevilputur); the Saddragiri (4,172′), some 15 miles to the north-east-by-north; and the Kudirai Malai (4,262′), further 15 miles to the northward of the last named spur. These side spurs are higher than many parts of the main spur.

Outlying hills.

To the north of the Vaigai river a small number of detached hill masses extend eastward from the Dindigul valley and may be regarded geologically as an extension of the gneissic beds forming the Palani mountains. The principal of these masses are the Sirumalai (4,454′), the Karuntha Malai, the Waggut Malai, the Alagiri, the Nattam hills, and the Prá Malai,—a group of hills remarkable chiefly for their terribly feverish and unhealthy climate.

Of the outlying hills to the south of the Vaigai. The most important are the Parayur hills in Tirumangulam Taluq (Madura). Further south in Tinnevelly district, the Periur hill (1,378′) near Sankaranainar Koil, the Vallanād hills (1,023′) east of Palamcotta and, in Nanguneri Taluq, the very conspicuous Suttu-pottai, a remarkable bare-topped rocky cone, some 1,200′ or 1,500′ high. The other hills shown in the Atlas sheets 62 and 63 are mostly mere low narrow rocky ridges of trifling importance topographically, and of but little more importance geologically considered.

[1] This mountain spur is shown in the Atlas sheet (No. 62) as a "high waving mountain overrun with an impenetrable forest," which forms a very marked contrast to the very thin forest which covers the ridges and slopes of the Varshanād spur.

The Southern Ghâts, central and southern parts.

The central and southern parts of the Southern Ghâts tract require but very brief mention here beyond their general influence on the climate of Tinnevelly District and the fact that they feed the sources of all the more important southern rivers.

Rivers in Madura district.

Hydrology.—The hydrology of the two districts is as simple as the orography, as all the rivers flow to the east or south-east. The Varshalei or Manimutár, the Seruvayal or Up-ar (Salt river; Hoop-aur of sheet 80), and the Vaigai which drain the northern and central parts of Madura district flow into the Bay of Bengal through Palk's bay. The southern part of Madura district is drained by the Gond-ār, which debouches into the Gulf of Manaar.

Rivers in Tinnevelly district.

The drainage of Tinnevelly district is effected by the Vaippār in the north, the Tāmbraparni in the centre, and in the south by three small rivers—the Nát-ar or Kárameni-ar, the Nambi-ar, and the Hanamanadi.

Water-supply of the Tāmbraparni.

Of the several rivers enumerated above only one, the Tāmbraparni, comes really under the influence of the south-west monsoon and obtains a steadily sustained supply of water during the continuance of the summer rains. The reason of this is that the Tāmbraparni, and to a lesser extent its main northern tributary, the Chittar, have their headwaters rising well within the limit of the area over which the rain clouds rest continuously. The positions occupied by the clouds during the south-west monsoon appear at first sight to be somewhat capricious, but they are doubtless in great measure due to currents of air caused by the peculiar configuration of the mountain masses, which mostly terminate eastward in very abrupt and precipitous scarps. The clouds, which cover the mountains, often for weeks together without lifting entirely, lie banked up along the watershed, or extend but little to the eastward of it.

Except in the case of the Tāmbraparni, unfortunately for the Madura and Tinnevelly plains, the watershed is mostly close to, or coincident with, the top of the eastern scarp; hence nearly the whole

of the very heavy rainfall is drained off into the sea or the back-waters of Cochin and Travancore, and forms powerful streams rushing through a wide tract of densely-wooded hill country, while on the east side of the mountains the rainfall is very scanty, and the rivers receive only occasional freshes which cannot be steadily depended on.

Position of watershed.

Thus the Vaigai, the principal river in Madura district, though it rises in a valley surrounded by high mountains covered in great part with dense forests, receives a very scanty and uncertain south-west monsoon supply, from the fact that the monsoon clouds do not proceed eastward beyond the watershed which coincides with the western and southern sides of the Kambam valley. The Vārshanād spur and the lofty Peyá Malai or Pémalai[1] at its southern end, though attaining an elevation of from 4,000 to 5,570 feet, are rainless as compared to the mountains a few miles only to the south-west. Further to the north the Palani mountains, though as nearly as possible equal in their average height to the more westerly mass of the Anai Malai (elephant mountains), receive a greatly smaller water-supply from the south-west monsoon. The chief rainfall in the Madura and Tinnevelly plains occurs during the north-east monsoon, and when this fails partially, as it not unfrequently does, the plains suffer from severe drought. The Tāmbraparni river has from time immemorial never failed in its water-supply, and two enormous crops of rice are raised every year in its most fertile valley. The Vaigai, though a considerably larger river, reckoning size by the area of drainage, can only ensure one crop per annum, the second crop frequently failing.

Water-supply of the Vaigai.

This untoward state of things would appear to be perfectly remediable by a great engineering work known in Madras as the Peria-ār project by which the

The Peria-ār project.

[1] The Pémalai, or devil mountain, as it is popularly called, should, according to Bishop Caldwell, the great Dravidian scholar, be rightly called Peyámalai, or *the rainless mountain*, a very suitable name, as it is often visible under a clear sky when Puluvurangan peak and the main mass of the mountains are completely hidden by the dense clouds of the south-west monsoon and deluged with rain.

water of the Peria-ār (which drains the great plateau south of the Kambam valley) would be brought into the head stream of the Vaigai. This grand scheme which has quite lately been sanctioned by Government will enable about 150,000 acres of land to be irrigated in addition to what is now supplied with water, and the whole to bear two wet crops every year. It is needless almost to say that no greater blessing could be conferred on the district than the carrying out of this project.

Fresh-water lakes.

A somewhat remarkable hydrological feature in South-East Tinnevelly is the existence of three or four small fresh-water lakes formed by the damming back of the local surface drainage by the great hills of red sand which form such conspicuous objects in that quarter. The most important of these lakes is that of Taruvai (Thurva) shown on the Atlas sheet (63) quite incorrectly as a tank with a bund on its northern, eastern, and southern sides. The water is retained simply by the accumulation of sand hills to the south, south-east, and north-east. In favourable seasons it forms a noble sheet of perfectly fresh-water, but when the monsoon fails it runs occasionally quite dry. I mention this fact on the authority of Bishop Caldwell, whose mission station, Edeyengudi (Idaiyarkudi, the shepherd's hut), lies about 4 miles to the south-west. There are two small lakes lying south-west of the Taruvai lake ; the more easterly of the two is not shown in sheet 63, but the western one is again erroneously shown as an artificial reservoir close to Sodi Kavalai (Shootee Coyvella, sheet 63). The true lake character of these basins and of two other ones to the northward of Taruvai lake seems to have been completely misunderstood by the topographical surveyors[1] who have mapped them as common tanks. Of these last two lakes the more southerly, sometimes called the little Taruvai lake, lies about a mile north of the large lake. The other lake lies on the north or left side of the Karameni-ar 3 miles further to the north-east. The waters of these lakes are remarkable for the

[1] The great Taruvai lake is shown on the half-inch map of the Madras Revenue Survey as a mere swamp, a yet far greater blunder than that of the old Topographical Surveyors.

enormous numbers of fresh-water mollusca, especially Melanias, they support.

Lagoons and back-waters (Kayals).

A number of lagoons occurs along the coast in both districts, but they are of no great size nor of much interest. The most southerly of these is the Kalampalli Taruvai which is formed by the belt of coast dunes extending from Manapada up to Tiruchendur. The water of this lagoon becomes highly brackish in the hot weather. The principal group of lagoons is that formed by the Tāmbraparni river on the seaward edge of its delta. These lagoons which are locally termed "Kayals" silt up as the delta extends eastward and new ones appear to form by the surf throwing up successive barriers of sand on which the prevailing winds pile up low dunes. The rate of silting up seems to be rather rapid during the present century judging by the greatly diminished size of the lagoons as shown in the Revenue Survey Map when compared with their appearance in the Atlas sheet (No. 80) which shows their dimensions at the time of the original Trigonometrical survey made about the year 1828. The water of some of these lagoons is sufficiently saline to be used for brine at several salt works. To the north of the Tāmbraparni delta are the lagoons of Taruvai Kulam (Thuroovancolum) and Veppilodai (Vapulaoda). The lagoons and creeks near the mouth of the Vaippar and to the south of Melmandai (Mailmuntha) have also decreased in size considerably by silting up. Along the Rāmnād coast the great tank shown in the map as extending westward from Valimukkam (Vaulimookum) is really a salt water lagoon which is connected with the sea at Valimukkam by a small tidal creek. The great lagoon north of Kilakarai (Keelacurray) is formed by inundations during heavy rains, as is also the lake-like reach of the Vaigai river to the east of Rāmnād town. The lagoon on the north side of Rameswaram island is quite brackish.

Climates of the Districts.

There is considerable similarity in the climates of Madura and Tinnevelly Districts, both being very dry and hot and both being affected by the same monsoons. Of the two districts Tinnevelly is the drier, as it gets less of the north-

east monsoon than does Madura. Except along a narrow tract close in to the foot of the ghāts and in certain places opposite to deep gaps in the mountain range, the south-west monsoon rains benefit neither district to any appreciable extent, except it be by giving rise to the formation in some seasons of severe local thunderstorms which are accompanied by very heavy rains.

According to the rainfall map of India given by Dr. Brandis,[1] the eastern part of Tinnevelly District is very dry, having an annual average of less than 30 inches; but in the western part of the district the narrow tract above referred which gets the benefit of the south-west monsoon rain, enjoys a considerably moister climate with over 30 inches of annual rainfall.

In Madura the dry part of the district lies in the centre (including the Tirumangalam, Madura and Melur Taluqs) and has a moister tract both on the west and the east; the former being a continuation of the moister zone along the foot of the mountains, the latter a tract of country running along the sea-board.

In neither district are the north-east monsoon or winter rains absolutely reliable, and if they fail, the most important dry crops and the wet crops under the rain-fed tanks cannot be raised and much distress ensues. The failure of the monsoon rains in one season is often followed by excessive rains and consequent extensive and destructive floods.

On the whole both districts are very badly clothed with wood. The formerly extensive forests have been recklessly felled, and it will require many years of very earnest conservancy to see the country properly tree-clad once again.

Schedule of geological formations.

The rocks recognised during the progress of the survey may for convenience of description be arranged as in the subjoined tabular statement :—

8. Soils and subaërial deposits.
7. Blown sands, red (teris); white (coast dunes).
6. Fluviatile and marine alluvia, Kankar deposits.
5. Sub-recent marine beds, limestones and grits. Upraised coal reefs.

[1] On the distribution of forests in India, by Dietrich Brandis, Ph. D., Inspector-General of Forests, Calcutta. Reprinted from the Transactions of the Scottish Arboricultural Society, 1873. Edinburgh. M. Farlane and Erskine.

4. Lateritic conglomerates, gravels and sands.
3. Gritty sandstones, (Cuddalore or Rajamandri beds, Conjevaram gravels).
2. Gondwána rocks (Jurassic) ?
1. Gneissic rocks.

Owing to the general flatness of the sea-board in many parts of the country nearly up to the foot of the mountains, the streams all flow in wide shallow valleys, and there is consequently a remarkable want of good sections of the rocks of all ages, —a condition of things which has necessarily rendered the working out of the several formations much more difficult and their correlation so much the less satisfactory.

Note regarding the map.

The whole gneissic area falling within the limits of the map accompanying this memoir has been shown in colour, though not entirely surveyed in detail; the tracts surveyed in detail being represented by a darker tint. The tracts not actually surveyed in detail are however not unknown; many of them are traversed by high mountains and hills, the obvious continuations of gneissic beds well known and carefully examined within the surveyed areas. The eastern scarps and spurs of the Sirumalai, the eastern spurs of the Palani mountains, and the bare scarps of the great Varshanād spur of the Southern Ghâts show innumerable exposures of rock, which even the untrained eye cannot help recognising as extensions of the known gneissic beds. Further south in Tinnevelly district, beginning with the great Saddaragiri spur, great part of the western side of the district was crossed by me in various traverses made during a visit paid to the south in 1869. The country around Srivilliputtur and thence south along the foot of the ghâts to Kuttalam (Courtallum) was traversed, also the line of country lying between Srivilliputtur and Kuttalam *viâ* Sankaranainarkoil. I made various trips among the mountains west and south of Kuttalam (Courtallum)—a traverse from that place to Palamcotta, visits to the upper valley of the Tāmbraparni at and above Papanasam, to Ambur and Shermadevi, to the Singampatti valley and falls, and lastly to Tirukurungudi (Tricknangoody) and up the mountains to the Asambu plateau. Although I recorded no geological observations made during this trip, I became sufficiently acquainted with a

very considerable section of the country, to form a conclusive opinion as to the gneissic age of the main mass of the rocks of which it is formed.

CHAPTER II.

PREVIOUS OBSERVERS.

Greenough's map.

But very little geological information had been collected about either of the two districts here described when the survey was taken up. Both districts had been represented in Greenough's geological map of India ; and like all the other districts with regard to which the map has been tested, the representation was in many ways very far from a true one.

Dr. Muzzy.

Long lists of rocks and minerals observed in Madura district and collected by the Reverend Mr. Muzzy of the Madura American Mission were published in the catalogue of the Madras Museum in 1855. Unfortunately the lists are deficient in detailed information as to the localities of occurrence of many of the rarer minerals, so that they have not been traceable in the short time at my command. The rock specimens too are enumerated from a mineralogist's rather than a geologist's point of view, so that practically the lists are of very little use in explaining the structure of the country.

The District Manual.

The geological notes in Mr. Nelson's very able and interesting manual of the Madura District (which is unfortunately out of print) are nearly all based upon Mr. Muzzy's data.

Dr. Caldwell.

For Tinnevelly district generally even much less had been published than for Madura, and it was only for the extreme south-east corner that a short but interesting sketch, relating chiefly to the more recent deposits occurring there, had been published by the Revd. Robert Caldwell, LL.D., the eminent Dravidian scholar, now Missionary Bishop in Tinnevelly district. Dr.

Caldwell's paper described the triangular area enclosed between straight lines drawn east and south from Nanguneri to the sea. I have unfortunately been unable to obtain a copy of this paper, so can only speak of it from memory after reading it many years since. His paper was accompanied by a sketch map of the country described, on which most of the leading features are laid down very truthfully.

Lieut.-Col. Branfill.

Some interesting observations on the nature and the rate of movement of the teris or red blown sands as distinguished from the white or pale sands of the coast dunes were made and published by Lieutenant-Colonel B. R. Branfill, Deputy Superintendent, Trigonometrical Survey.

Some further information of important character[1] on the rate of movement of the teri sands were given by Lieutenant-Colonel B. R. Branfill in the general report of the Great Trigonometrical Survey for 1873-74, which will be referred to at length when describing those remarkable æolian formations.

A few geological notes are given in the District Manual of Tinnevelly by Mr. A. G. Stuart, C.S., but they are too brief to convey much information.[2]

CHAPTER III.

THE GNEISSIC ROCKS.

The relations of the various great band of crystalline rocks, which are met with over the tract of country lying westward of the belt of sedimentary rocks lying along the sea-board of Madura and Tinnevelly districts, have not yet been worked out fully, nor can they be even approximately settled till the flanks and summits of the Southern Ghâts

[1] Notes on the Tinnevelly District by Captain B. R. Branfill, Great Trigonometrical Survey of India, Dehra Doon, 1869.

An important note on the climate of South Tinnevelly by Dr. Caldwell forms an appendix to Captain Branfill's pamphlet.

[2] A Manual of the Tinnevelly District, compiled by A. J. Stuart. M.C.S., Madras, 1879.

have been examined, for the greater part of the low country occupied by gneissic rocks in South Madura and North Tinnevelly is covered with a wide spread deposit of black cotton soil (regur). The few isolated outcrops of the gneissic rocks met with are far from sufficient to allow of any correlation of even the great bands of granular quartz rocks which form such conspicuous hills and ridges around both Madura and Palamcotta. Nothing more can at present be said of their relationship than that it is possible that both sets of beds may represent one and the same series. The great regur spread which forms the cotton district of Tinnevelly divides the two metamorphic areas so thoroughly that they must be considered and described separately.

(*a*) *The metamorphic Area of Madura District.*

So far as examined at present the gneissic rocks in the Madura district may be divided into six groups—

6. The upper granular quartz rock—Allagiri group.
5. The upper granitoid gneiss—Melur group.
4. The middle granular quartz rock—Nagamalai group.
3. The middle granitoid gneiss—Sikandarmalai group.
2. The lower granular quartz rock—Kokulam group.
1. The lower granitoid gneiss—Tirumangalam group.

Lower granite gneiss, or Tirumangalam group.

1. *The lower granitoid gneiss group,* the lowest of this series, is the set of beds occurring in the great plain forming the Tirumangalam Taluq, which is bounded on the east by the lateritic and alluvial formations. The northern part of the Tirumangalam plain is largely covered with red soil, but south of Tirumangalam town, cotton soil (regur) is met with everywhere, and allows but little of the subrock to be seen. The prevalent form of rock is granite gneiss, important outcrops of which are seen to the north of Tirumangalam at Karadikal (Kurdykul), along the south side of the great Mulang Kulam (tank) and at Nellayur to the north-east. Again to the south-east and south outcrops of very typical granite gneiss are to be seen along the valley of the Gondār and to the south in the Chevvur Kotai hill. The other outcrops are less characteristically granitoid in character, the rocks seen being rather banded massive gneisses

than granite gneisses. The general dip of the rocks over the Tirumangalam plain is north-easterly, corresponding to that of the overlying granular quartz rock. The same prevalence of north-easterly dip is to be noted in the various outcrops of gneiss, which show through the regur plain to the south-eastward between the valleys of the Gondār and the Vaipār. The principal outcrops here noted will be referred to at length further on.

Lower granular quartz rock, or Kokulam group.

2. *The lower granular quartz rock group* forms a low rocky ridge, about 2 miles southward of the great Nagamalai ridge which makes so conspicuous a feature in the landscape around Madura city. I have named it after the village of Kokulam (Cokolum) which stands close to where the ridge is crossed by the high road from Tirumangalam to Sholavandan. This band of granular quartz rock, though of no great thickness, forms a very well marked ridge, traceable, despite some gaps, for many miles. To the north-westward it was observed maintaining its individuality and its parallelism to the Nagamalai for several miles, indeed as far as the eye could reach from the new high road crossing the Nagamalai from Sholāvandān to Tirumangalam. At a point about 2 miles north-west of the Sikandar Malai (Skanda Malai) the ridge trends southward and then eastward again and passes southward of the last named hill, and then after trending south-east for some 3 miles changes its strike to north-east by east, and after a couple of miles is lost under the alluvium of the Vaigai at a point 4 miles due south of Madura. Owing to the coarseness of the rock, which is a typical granular quartz rock, the dip of the bed is not easy to recognise close at hand, but when seen from a little distance the dip is perfectly obvious, indeed strikingly clear. The question of the continuation of this formation on the north bank of the Vaigai river will be referred to again further on when dealing with the overlying Nagamalai granular quartz series.

Middle granite gneiss, or Sikandar Malai group.

3. *The middle granitoid gneiss group.*—Immediately overlying the lowest granular quartz series is a well marked band of typical granite gneiss, especially well seen in the Sikandar Malai 3½ miles south-west of Madura. It shows

well also in a picturesque rocky hill north of Ambalathandi (of map) a village 4 miles west of Madura, and again in some low rocky hills 6 miles further to the north-west close to the Sholavandan-Tirumangalam road. It is largely quarried in the Sikandar Malai, the pinkish grey well-banded rock yielding a very handsome and durable building stone. The bedding is not distinctly seen except from a distance, but is very striking when viewed from the south-east.

Middle granular quartz rock, or Nagamalai group.

4. The middle granular quartz rock group forms the long and important ridge called the Nagamalai (already referred to several times), which for many miles forms the southern side of the Vaigai valley, but dies down under the alluvium 4 miles west-north-west of Madura city. The beds make a great curve south-eastward under the alluvium and re-appear in the Pasumalai (or cow hill), a low bare stony hill to the north of the Sikandar Malai. From these the beds strike east-south-east for 2 or 3 miles and then disappear under the alluvium. These beds were followed up north-westward to the point 20 miles distant from Madura at which the Nagamalai changes its course and trends east by north to west by south. Their further extension south-westward is not yet known geologically. The eastern extension beyond the Vaigai will be described further on. The dip of these extremely coarse granular beds is much obscured by excessive jointing, but it is unquestionably northerly or easterly according to the strike of the beds and at very high angles. Some of the basset edges at the east end of the Nagamalai are weathered into bold tors, many of which present considerable resemblance to buildings and are often mistaken for ruins by travellers along the railway. Except where the mass is much broken down by weather action, the ridges of this peculiar rock are remarkable for their extreme barrenness of vegetation of all kinds. Owing to their very light colour, which varies from extremely pale reddish-white to pale reddish, or yellowish-drab, they show conspicuously to great distances. To the south-east of Madura a group of beds of identical character, which can only be regarded as the easterly extension of the Nagamalai beds, appears on the

left or north bank of the Vaigai and is traceable for several miles further to the east-north-east up to the great rocks west-south-west of Trivadur where the central beds of the group have assumed a very granitoid appearance and contain much felspar. Whether the granular quartz formation dies out here or is merely hidden by superficial deposits and re-appears further to the eastward in the great granular quartz ridge of Vallamalai (Vullamalay, sheet 80) or whether the latter represents the lower granular quartz group (No. 2) are questions yet to be decided. If the latter view is the correct one, then the picturesque rocky Tirumalai (Sacred hill), 6 miles east-north-east of Vallamalai, and the Kunatur (Coonatoor) Trigonometrical Station hill, 10 miles west-south-west of Vallamalai hill station, represent the Sikandar Malai granite gneiss band.

The upper granite gneiss, or Melur group.

5. *The upper granitoid gneiss group* occupies the plain north-westward of the Trivadur Trigonometrical Station ridge and stretches away south-westward down to the alluvium of the Vagai and north-eastward under the alluvium of the Pálár and its tributaries, beyond which it re-appears and extends north-eastward past Tirumayam (Tirmium) to beyond the confines of the map illustrating this memoir.

Characteristics of scenery.

The special features of the granitoid rocks are very strikingly illustrated in many of the hills rising out of this area which show great beauty of form and colour in the noble rock masses they consist of.

View from Pramalai.

Two of the most striking views of this area were got from its nearly opposite extremities. The one is from the southern slope of the western part of Prāmalai (itself remarkable for a splendid scarp, facing south), as you look south-south-westward across the rich and varied palm groves of the Pālār valley which form an exquisite foreground to the scene. The mid distance is occupied by a well-wooded country out of which rise a very considerable number of beautiful rocky hills, several of them surmounted by enormous tors, the back ground being formed by the many picturesque peaks of the great Varshanād spur of the Southern Ghâts. The western side of

the picture is framed by the fine scarps of granular quartz rocks on the flank of the great Allagiri (Allagherry) hill which contrast strongly with the gentle seaward slope of the plains on the eastern side.

The per contra view, which is also very beautiful, though not quite so artistically perfect, is to be seen from the summit of the Perumāl Mallai ridge 5 miles west-south-west of Melur (Mailore) and 12 miles north-east of Madura, and is one which will well reward any geologist or sketcher for the trouble of climbing the ridge. In this view the most striking object is Shomagiri Drug hill ridge which is seen so foreshortened as to be nearly cupola-shaped, while from a spur which branches off to the south-westward rises an enormous tor standing boldly on a much slenderer pedestal. As seen from the plain immediately to the north of the hill, this tor assumes the shape of the head and neck of a beautiful child. I estimate the tor and pedestal at from 60 to 80 feet high. Shomagiri is seen flanked by two other fine granitoid masses, neither of which are shown in sheet 80, from which many other smaller hills are also omitted.

View from Perumāl Malai.

Shomagiri Drug and Tor.

A fine group of these is clustered round the Karrinkalgudi (Kurungálgoody) station about 7 miles north of Melur (Mailore) close to the Madura-Trichinopoly road. The view is bounded to the north by the line of hills extending eastward from the Sirumalai and terminating in the bold and striking mass of Prāmalai.

Other hills.

To the east of Melur are two noteworthy hills, both of them shown on sheet 80 as Trigonometrical Stations, and both of them remarkable for their wild and picturesque rock scenery. The first, Sharangamalai, lies about a mile south-east of Melur, the second called Codathumputty on the map, but locally known as the Periotamalai lies some 7 miles further east and is the highest and most conspicuous point for many miles around. To the south-westward of the Permal Malai mentioned above are several picturesque groups of granitoid rocks leading up to the north end of the Anai Malai or "Elephant" hill, a bold and bare rocky ridge running nearly parallel with the Madura road for close upon 3 miles.

The Elephant hill.

The southern and higher end of the ridge shows, especially as seen from the south and south-east, a very remarkable resemblance to the upraised head of a great elephant, and this doubtless suggested the legend by which the crafty priests of the great temple at Madura explain the origin of this remarkable hill. According to this legend some deity hostile to the goddess Minakshi, the foundress and patroness of the great temple, sent an enormous demon elephant to destroy both the town and temple, but the powerful goddess prevented the intended evil by petrifying the monster. Similar legends have been invented with regard to the Nagamalai (Serpent hill) and Passumalai (cow hill) west and south of Madura (see page 13). In the former case the theriomorphic character of the hill would readily suggest the legend, but in the latter the form of the hill, from no point of view, suggests a resemblance to any animal, and the origin of the myth is by no means obvious.

Nagamalai, Passumalai.

The stratigraphy of the Anai Malai is not at all easy to make out, the bedding being indistinct and also very much contorted. The quartzo-felspathic-micaceous rock is of grey colour banded with pink laminæ. In part it assumes a "blotchy" or coarsely porphyritic structure, and at the northern end of the ridge the beds are to be seen contorted into an imperfect but acute angled anticlinal. A similar sharp contortion of the beds forming the Perumál Malai or Narasingampatti hill referred to above (page 15) has been followed by the intrusion of a short but thick granite vein which forms the crest of the highest part of the ridge.

6. The upper granular quartz rock group.—The relations of the upper granite gneiss group to the great beds of granular quartz rock forming the bold scarp of the Allagiri hill could not be made out quite satisfactorily by the examination of the country close to Allagiri temple. The granite gneiss there appears to dip under the granular quartz rock, and if such is really the case and the succession be not disturbed by any inversion, then the Allagiri granular quartz rock must be grouped as a third or upper series of its kind as I have done. It is possible, however, that the Allagiri beds are really inverted beds, but on this point the evi-

Relations of the Melur and Allagiri groups.

dence of the north-east and south-west extensions of these beds disagrees; the north-east beds seem to dip eastward under the upper granite gneiss series as seen to the north of Kotampatti (Cotaumputty), but the southern extension dips north-westerly. Unfortunately time did not admit of my following up the extension beyond the south end of the Allagiri mass and working out its relation to the great gneissic masses forming the Waggat Malai and the Serumalai. I feel strongly persuaded, however, that the Allagiri granular quartz beds are a *bonâ fide* higher lying group, and will, when an exhaustive survey of that region is made, be found to overlie the granitoid gneiss beds forming the western side of the Serumalai, which beds are really extensions of the upper granite gneiss series of the Melur-Madura plain, the beds of which have trended round on the north side of the Vaigai valley. The rocks overlying the Allagiri beds I am not as yet acquainted with.

Granular quartz rock at Ammanayakanur.

In the south-western corner of the space which lies between the northern part of the Nagamalai and the south-western part of the Serumalai is a great show of granular quartz rock well exposed in strongly curved beds. These are well seen in the low ridge west of the railway station at Ammanayakanur (Ammanaikoor) which extends northward into the much higher Reshmullay Trigonometrical Station hill and south-westward into the Pulianattam (Poolianutthum) hills; the north-westerly extension of the granular quartz beds beyond the two last named hills has not as yet been worked out. The relation of these beds with another rather important outcrop of granular quartz rock 3 miles to the south-east at Ramrajpuram is obscured by the intervening spread of the Vagai alluvium. The extension of the beds seen in the latter outcrop is also speedily lost sight of to the eastward under the superficial deposits.

At Ramrajpuram.

The broad belt of granite gneiss which forms the mass of the Serumalai belongs doubtless to the Melur or third group of that variety of the gneissic rocks. Unfortunately want of time prevented my examining that very hilly tract; the westward extension of the Allagiri granular

quartz group was therefore not followed up, nor could it be traced by the eye for any distance as in the Allagiri itself, where it is visible for many miles.

Gneiss rocks in South Madura not divisible into groups.

The southern part of the gneissic area in Madura district cannot be divided into groups owing to the great extent to which its surface is obscured by superficial deposits, especially by wide spreads of regur, or cotton soil. These latter are to be met with all over the southern half of the Tirumangalam taluq and over the south-western part of the Rámnád zemindary. By far the greater number of outcrops noted were of granitoid gneiss. But it would not be fair to infer from this that schistose varieties of gneiss are not represented in due proportion; the fact being that only the highest points of the different outcrops are as a rule exposed above the superficial deposits, and that the harder granitoid beds show more prominent basset edges than the schistose beds. Very few outcrops of any kind are seen along the line of railway, or the old trunk road, to the south-ward of Tirumangalam, the spread of regur being very thick and un-broken. The outcrops most worthy of note along this line are the Chevvur Kotai hill 6 miles south of Tirumangalam, and the Kalligudi (Cullygody) hillocks 2½ miles west of the railway station of that name, both of granitoid gneiss.

Outcrops south of Tirumangalam.

Kalligudi outcrop.

In the latter case the pale greyish or pinkish-white quartzo-felspathic rock, banded with laminæ consisting mainly of rather pale red or pink garnets of small size with a few spangles of mica, strongly resembles the Cape Comorin rock. The rock is one of great beauty, especially when freshly quarried. At the time of my visit quarrying had been carried on largely, and fresh surfaces of many square yards in extent showed the lamination of the gneiss in very pleasing undulating patterns. The bedding strikes generally nearly west and east, and has a southerly dip of from 60° to 80°. The outcrops form a small group of low rocky hills to the west of the village of Kalligudi (Cullygoody) and about 3 miles westward of the South Indian Railway Station of that name.

About 6 miles north-east-by-east of Kalligudi station at the village of Tirumal is a broad (apparently double) band of coarse white crystalline limestone which may be traced for nearly 2 miles to the eastward, associated with much interbedded tremolite. Much of the surface of the bed has been quarried away, and what remains is not well seen, as the outcrop is very low and much obscured by the local swampy alluvium under the great tank. The dip of the bed (or beds) is doubtful, but in another bed of white crystalline limestone, which is to be seen at the north end of the great tank, ¾ mile to the north-west of Tirumal, the dip is distinctly southward, but at a very high angle. This bed which is only seen for a distance of 30 or 40 yards is fully 30 feet thick, and has a very coarse crystalline (spathose) texture like the Tirumal beds. Two small beds of crystalline limestone with associated tremolite occur a little to the westward of the village of Kok-kulam (Kokolum), a mile to the north-east of the last named limestone outcrop. The limestone is white and highly charged with granules of pale greenish or yellowish-grey coccolite. Two small beds of tremolite rock enclosing many nests of calcspar occur one in the bottom of the tank west of the Tirumal; the other to the north of the village Suddumbakulam on the left bank of the Gondár.

Crystalline limestone at Tirumal.

Crystalline limestone at Kok-kulam.

To the northward of this band of limestones comes a band of granite gneiss which may be reckoned as belonging to the lower granitoid gneiss (No. 1, page 11) of the Madura country. Unfortunately its relations to the more southerly beds of undetermined horizon could not be made out as the rocks were not seen in any juxta-position. Turning southward again along the high road from Madura to Ettiapuram and Tutikorin a good section of very white garnetiferous gneiss (strongly resembling many of the beds near Cape Comorin) crossing the Shevery Kotai-Ár at the ford south of Vakangoondoo.

A band of very typical granitoid gneiss may be traced from the valley of the Shevery Kotai-Ár at Shoilputty south-eastward close down to Tirushulai (Tiru-

Band of granite gneiss west of Tirushulai.

chooly). It is well exposed in the quarries close to Shoilputty, where the rock is of a fine-grained dense variety of mauvey-pink colour, showing the bedding only where freshly broken. The rock is also well seen at Moonooroopoo rock (where it is of a dull reddish-brown colour), and at the Paraikulam rocks west of the Tirushulai tank. At the latter place the rock which is slightly hornblendic is well bedded, the laminæ being of rich pink and grey colours. The dip of the rock is westward in all these three outcrops.

Aruppukotai beds.

About 5 miles west of Tirushulai in and north of the village of Palaiyampatti (Paulayemputty) is a considerable show of rich red granite gneiss beds which would appear from their mineral similarity to be extensions of a very similar rock which forms the small rocky hill west of Aruppukotai (Arpoocotay) 2 miles to the south-south-west. This red rock is very largely quarried and yields a remarkably handsome stone which is in great repute in that region. Here also the beds have more or less easterly dip.

North-westward of this band of granite gneiss and separated from it by an intervening spread of cotton soil from 3 to 5 miles across is a tract of strongly banded gneiss intermediate in texture between granite gneiss and typical schistose gneiss which is particularly well seen at and to the south-west of Mallakanur (Mullakenur) 5 miles east-by-north of Virudupatti. Micaceous beds predominate here as generally throughout the Madura and Tinnevelly gneiss region, but hornblendic beds are also met with, while near Kovilpatti (Covilputty) a mile to the eastward a bed of decomposed serpentinous rock was observed. Unfortunately this serpentinous bed is exposed only in an inaccessible section in the side of a well and could not be examined closely. About 4 miles south-west of Makallanur and a little south of the village of Palavanattam (Kylassapooram of map) a large quantity of debris of a very coarse-grained greyish-white crystalline limestone is to be seen scattered over the surface and rolled in the bed of a small water-course. I was unsuccessful in tracing the outcrop from which this limestone debris was derived.

Serpentinous rock at Kovilpatti.

Kotaiparai Hill.

About 4 miles south of Palavanattam lies a small hill of bare rock rising on the top of the watershed between the valleys of the Virudupatti and Shenkotai rivers. This hill which is known as the Kotaiparai (Koteaupauræ Trigonometrical Station) is remarkable because consisting of dark hornblendic granite gneiss which is a very rare rock in this quarter. It rises out of the middle of a great and unbroken spread of cotton soil.

A great many outcrops of banded granite gneiss of no special beauty or noteworthy colour are to be seen on the high ground at and east and south-east of the village of Kalurani (Kulloornee) 4 miles south-east of Aruppukotai. To the south of Aruppukotai, close to Vala Vangal (Shevandapuram of map), is a show of very perfectly banded granite gneiss, both micaceous and hornblendic, striking north-west to south-east in almost vertical beds.

Pantalagudi crystalline limestone beds.

Four or 5 miles further south of Shevandapuram and a mile south of Pantalagudi (Punthullagoody) the high road cuts across a very large and important bed of crystalline limestone which I traced north-west-by-north for upwards of 3 miles cropping up through the thick cotton soil which covers nearly the whole surface in that quarter. The thickness of the great bed is not easy to ascertain, owing to the extent to which it is obscured by the cotton soil. I paced it at several points where best seen, and found it to average about 50 yards, the narrowest part being 37 and the widest 73. The limestone is generally of very coarse grain, so much so as in parts really to deserve the appellation of calcspar rather than crystalline limestone. This is more especially the case at the southern end where the predominant colour is pale grey or white. In the northern part of the bed its eastern or upper part is reddish or pink in colour and rather close grained. The dip where best seen at the southern end is from 65° to 70° north-easterly. The only included accidental minerals noted were occasional small granules of pale coccolite and spangles of graphite. About $\frac{3}{4}$ of a mile west of the northern end of the great bed is a small outcrop of white crystalline limestone

belonging to a smaller bed having a parallel course. A sufficient prolongation of these beds would connect them very probably with the beds from whence was derived the very similar coarse quasi-spathose debris noticed in considerable quantity at Palavanattam (Kylassapooram) which was referred to at page 20.

Two instances of gneissic rocks cropping out from among the lateritic and alluvial beds at a considerable distance from the main gneissic mass require notice. The one occurs below the western scarp of the Sivaganga laterite tract at and north of Mana Madura; the other along the south-western side of the Muddu Kankulam laterite tract (*see* page 49) immediately east of Kamudi (Kaumoody). In the latter the gneiss is a form (not seen elsewhere in that region) intermediate in structure between a rather ferruginous granular rock and a coarse quartz hæmatitic schist. The beds form a low ridge on which stands the old Kamudi fort. The rock which is of a purple-grey colour dips 45°—50° east-by-north.

(*b*) *The metamorphic Area in Tinnevelly District.*

The northern part of Tinnevelly district is so extensively and thickly covered with cotton soil that outcrops of the underlying rocks are in many places of very infrequent occurrence. It is particularly the case along the line of the railway and the old Tinnevelly-Madura high-road which run closely parallel to each other for the first 15 miles after entering the Satur taluq. Beginning close north of the town of Virudupatti we find a few small rounded masses of granite gneiss showing up through the cotton soil. Four miles south of Virudupatti the high road crosses a gentle rise from which the general pall of cotton soil has been removed by denudation and a considerable band of granular quartz rock beds revealed. The exposure is, however, too obscure to show much of the real position of the beds. The strike of the rising ground is east to west, but the form of the ground gave the idea that the real disposition of the beds was in form of an anticlinal ellipse, the eastern end of which dips under the alluvium of the Virudupatti river. To the southward of this granular quartz ridge numerous traces of the existence of beds of crystalline

limestone are seen along the high road in ditches and water-courses in the shape of large quantities of debris. *The limestone* is of extremely coarse grain and highly spathose in appearance. *The limestone* is of white colour. The country is, as already mentioned, very thickly covered with cotton soil, and I did not, during the cursory examination which alone I was able to bestow upon that particular tract, happen to light upon any outcrop of this rock in this neighbourhood.

Kolarpatti outcrop.

A few important outcrops of granite gneiss were observed further south in the valleys of the Virudupatti river and of the Vaippár, notably a considerable group of low rocky masses on the left bank of the former river a little below its junction with the Korai-Ár and opposite to the village of Kolarpatti (Colaurputty). Another considerable outcrop of banded granite gneiss occurs at the junction of the Virudupatti river with the Vaippár. Considerable exposures of typical granite gneiss, all more or less approximating in colour to the typical Cope Comorin gneiss, may be seen in the bed of the Vaippár at Kolapatti 2 miles east of Satur. Another noteworthy outcrop of similar highly garnetiferous banded granite gneiss occurs in the Waddakarai (Wudducurra) hill 4 miles south of that town and close to the South Indian Railway. The hill is a bare rock which is rapidly being quarried away for railway purposes. The lamination or bedding which is beautifully distinct strikes east-north-east to west-south-west (a very prevalent strike in these regions), while the dip measures 60°—65° north-north-west. The hill which was formerly a station of the Trigonometrical Survey rises very abruptly out of a vast plain of cotton soil.

Waddakarai hill.

Outcrops east of the Vaippár.

On the left side of the Vaippár valley the same wide spreads of cotton soil prevail and allow of but very few outcrops being seen. The most interesting of those noted was a bed of very handsome pink and pinkish-white crystalline limestone seen to the east of Shenkotai (Shencotta) 6 miles south of the great Pantalagudi limestone bed. The Shenkotai bed is exposed in the easterly off-flow channel of

Shenkotai limestones.

the great tank east of the village. It is fully 20 feet thick, but exposed only for a few yards distance in the bank of the channel. The limestone occurs intercalated with dark green hornblendic beds which contain numerous laminæ of pink calcspar. From its course (north-west-by-north to south-east-by-south) and its easterly dip this bed would appear to belong to the same series as the Pantalagudi beds. To the same series belongs also, to all appearance, the coarse reddish semi-granitoid gneiss seen at and north of Nagalapuram (Naugalapooram).

The most southerly outcrops in the gneissic area east of the Vaippár are a black hornblendo-micaceous gneiss at Kodangeputty and a show of granular quartz rock at Bommayapuram which is exposed only in the roadside ballast pits. Some connection will probably be traced eventually between this and the broad belt of granular quartz rock which rises out of the great cotton soil plain to the north of Ettiapooram (Etteyaupoorum) and forms the Minachipuram and Lyungumpatti hills which join the Kovilpatti ridge. This ridge trends south for several miles parallel with the railway, and then strikes south-eastward for fully 12 miles, when it again turns south, but after a course of some 3½ miles further again trends south-east and appears to curve round and form the southern end of an elliptical synclinal basin, the eastern limb of which runs northward through the taluq-town of Ottapiddaram and disappears some 4 miles further on under a great spread of regur. Several ridges of granular quartz rock are to be seen at some distance to the west of the railway between Kovilpatti station and the Maniachi junction, while two or three small granite gneiss hills rising out of the cotton soil plain to the north of Kaddambur station show the granular quartz rock to be here also interstratified with granite gneiss.

Bommayapuram granular quartz rock.

Kovilpatti granular quartz band.

The relations of several detached and isolated outcrops of granular quartz rock occurring south of the Ottapidaram-Kovilpatti band such as that lying west of Kil-Maniachi village (about a mile south-west of the

Outcrops of granular quartz rock south of Ottapidduram.

railway junction) or the band exposed as Timmarajapuram 3 miles south-south-west of Meltattaparai Railway Station are doubtful. So also are those of low granular quartz ridge lying 1½ miles north-east of Sivaliperri (Shevvelperry) which disappears northward under the alluvium of the Chittar. To the same category belong the outcrops forming the low hills to the west and south-east of Pudukotai (11 miles south-west of Tutikorin). It was found equally impossible to correlate these outlying outcrops with the great band of granular quartz rock forming the Vallanād ridge. The granular quartz rock here forms a great anticlinal curve, the eastern limit of which extends south-east towards Sevalai (Shenvetta) and Verankulam in the Tambraparni delta under which it disappears. To the south the western limb of the Vallanād anticlinal curve re-appears south of the river in a gneiss inlier 3 miles west of Pudugudi, but its further extension is lost sight of under a sandy plain. It is possible that the granular quartz rock bed forming the hills west of Vallanād ridge may form part of the anticlinal curve and have its eastern limb represented by the quartzite ridge which disappears under the alluvium of the delta to the north-west of Perunkulam (Perungcolum).

Vallanád beds.

The great double band of granular quartz rock south of Palamcotta forms several very well-marked and conspicuous rocky ridges as the Rettiapatti (Ruttiaputty) hill, the Sevandipatti (Shamiuthaputty), and the Kistnapuram and Thurva ridges at the eastern and western extremities of the band. The western extremity of the southern of these two bands of granular quartz rock crosses the Tambraparni 3 miles south of Tinnevelly town, then rises into the Sangani (Shenganny) Trigonometrical Station hill, beyond which it continues westward for some distance into the unsurveyed tract.

Palamcotta granular quartz rock beds.

The northern of the two bands which form the Rettiapatti ridge dies down suddenly close to Rettiapatti village and cannot be traced any further westward; it is probably cut off by a fault, but this cannot be positively proven owing to

Rettiaputty ridge.

the thickness of the local superficial deposits. At the eastern end of the ridge also the bed cannot be followed up for a considerable distance, but it apparently re-appears in the low but well-marked ridge running north-east by north from Kistnapuram to Pareikulam. The dip of the granular quartz rock in both ridges is northerly. The eastern extension of the Sevandipuram-Sangani band is also obscure and doubtful; the probability is, however, that it thins out greatly and is represented in a small ridgy outcrop running north-east-by-north parallel with the Kistnapuram ridge about a mile to the eastward. This may be the true correlation of the beds, but a gap some 2 miles in length exists between the Sevandipatti hill and the north-easterly ridge, and it is not impossible the real extension eastward of the band might be found in the Karunkulam hill which forms an inlier of granular quartz rock rising out of the alluvial flat of the Tambraparni.

Sevandipuram-Sangani band.

Another very important show of granular quartz rock is to be studied to great advantage in the Melpattam (Maillapantam) Trigonometrical Station hill 2½ miles north-east of Palamcotta. The rocks here form a large and very well marked horse-shoe curve open to the north. The western arm of the horse-shoe seems to re-appear north of the alluvium of the Tambraparni valley and to join the great band of granular quartz rock forming the Taliyuttu-Pottai ridge. The actual junction of these beds has, however, not as yet been traced out.

Melpattam granular quartz rock ridges.

A moderately large well marked bed of granular quartz rock lies close in to the military cantonment at Palamcotta. This bed runs nearly due eastward for about 2½ miles when it is lost sight of under a great spread of gritty red soil.

Granular quartz rock band east of Palamcotta cantonment.

The most southerly outcrop of the granular quartz rock is the south-westerly extremity of the great Vallanād hill band close to the village of Viralaperi. The gneiss region lying southward of this point shows an absolute predomi-

South Vallanad granular quartz rock beds.

nance of granitoid forms of crystalline rocks. As already mentioned when describing the granular quartz rock outcrops in the neighbourhood of Madura, they form from their bright colours and great bareness very conspicuous features in the landscape, especially along the railway from Kovilpatti down to Tinnevelly and all round Palamcotta. The greatest show is made in the rocky ridge south of Kovilpatti, which culminates in the Kurumalai (Trigonometrical Station) a picturesque hill 821 feet high, and in the Vallanād hills (see ante, page 25) which attain a height of 1,023 feet (1,052 feet according to the Madras Revenue Survey map). The thickness of the beds here exposed is very great, and may be estimated at fully 2,000 feet, but the section is not clear enough to allow of actual measurement. To the south of the Trigonometrical Station peak the dip, where distinct enough to be measurable, is from 65° to 70° westward, and the rock approaches in appearance to a glassy quartzite, from which it only differs in the coarseness of the grain, which feature however is much less conspicuous here than in many other outcrops. The prevalent colour here of the least weathered parts of the rock is a dull pale pinkish-brown, elsewhere whitish-drab or very pale reddish-white are the commonest colours. Pale salmon colour was noted in the summit bed of the Pasu Malai near Madura and in the ridge north-north-west of Kotampatti Travellers' Bungalow 15 miles north of Melur and 34 miles from Madura.

Vallanād section.

Texture and colour of the rock.

Owing to the economically useless character of this rock it is hardly ever quarried to sufficient depth to show its real texture and composition. In most outcrops the only mineral seen to occur in the minute spaces between the different quartz granules is an earthy (? decomposing) hæmatite. It was nowhere so well seen as in the bed north of Kotampatti, just referred to. This is often absent having either been weathered out or having never existed in those spaces. In some examples the rock shows small cavities filled with white or pale pink decomposed felspar, and in one case I found traces of much decomposed greenish hornblende. This was in stone

Mineral character.

brought apparently from the lowest granular quartz band to the north of Tirumangalam in Madura district. In another case in the south of Trichinopoly district traces of dark blackish-green mica in extremely small scales could be made out. Although the bedded character of the rock is generally very obvious, these quartzose beds have often been mistaken for large reefs of vein quartz and have given rise to many hopes of their turning out auriferous. In the proximity of these beds the general surface of the country is often largely covered with very characteristic reddish angular debris. Such is very markedly the case all round Palamcotta. Beds of similar character were noted in Northern Travancore by my colleague, Dr. King, and in Southern Travancore by myself.

Intercalation with granite gneiss band.

As in the Madura country, the Tinnevelly granular quartz bands are always found to be under and overlaid by bands of various thickness of typical granitoid gneiss, which owing to its greater susceptibility to weather action has almost everywhere been more extensively denuded, and is therefore very frequently marked by the superficial deposits. Outcrops of the granite gneiss are to be seen at Paraipatti (Pauraeputty) 2 miles north of the Kadambur Railway Station and to the west of Ottapidaram within the apex of the triangle described by the granular quartz beds (*vide* map). Granite gneiss beds are exposed also in several places, south-east and south-west of the apex of the triangle just named, *e.g.* at Dalavaipuram (Thullavaupoorum).

Cape Comorin type of granitoid gneiss.

As already stated above, the gneiss of the region south of the Sangani-Sevandipatti and Vallanad granular quartz bands is pre-eminently granitoid. The most noteworthy type among the granitoid gneiss is a pale quartzo-felspathic banded rock with a small quantity of black mica (very rarely of hornblende and very numerous small pale red or pink garnets. From its having been first noted near Cape Comorin where it occurs very largely, I designated it the Cape Comorin type. Granitoid gneiss of this type is also very common in the tract south of Tirumangalam intermediate between the Madura and Tinnevelly granular quartz bands. Striking examples of

this often very beautiful rock are to be seen in the low hills west of Kalligudi Chuttrum Railway Station again to the north-east and east of Satur and in the Waddakarai hill south of that town (see page 23). At the first and last of these localities the rock can be seen to great advantage as extensive quarries have exposed considerable surfaces of unweathered gneiss. The distinctness of the banding and the bright colours of the rock—white, grey, and pink—produce an effect which is very pleasing to the eye.

Gneissic outcrops in South Tinnevelly.

Of the outcrops of gneiss in the south of Tinnevelly not very much can be said, for except close in to the mountains they are neither numerous nor important. By far the greater number show beds of well-banded quartzo-felspathic gneiss, abounding in small red or pink garnets, of the Cape Comorin type in fact, the strike being west-north-west to east-south-east. They form part of several synclinal and anticlinal foldings whose westerly extensions may be traced in the Ghâts, while their eastern extensions disappear under the broad band of more recent rocks which fringes the south-eastern littoral. Many of the larger outcrops may be correlated with the great synclinal ellipse embracing the southern half of Travancore and having its eastern focus in or near the Mahendragiri, the most southerly of the great peaks of the Southern Ghâts, a noble mountain attaining a height of 5,419 feet.

Great synclinal ellipse of Mahendragiri.

Singikulam outcrop.

The most noteworthy of the outcrops are the following :—(*a*) The Singikulam (Shingacolum) Pottai, a low but boldly rocky ridge of typical granite gneiss 10 miles south-south-west of Palamcotta. Its western extension crosses the Pachiyar (Puchaur) and forms some considerable rocky hills which appear to be connected with the beautiful Kolunduma Malai, one of the finest isolated masses in Tinnevelly district. The bedded structure of the gneiss on a great scale is admirably displayed in that fine hill which rises high over the surrounding country. A number of picturesque rocks and low bare hills of granite gneiss diversify the country some miles south-west and south of the Singikulam ridge,

and a couple of miles further south rise the several fine sharp-peaked hills forming the Narayanan Pottai ridge north of the road leading from Nanganeri to Kalkad (Calcaud). Narayanan Pottai, which must be at least 1,000 feet high, consists of a garnetiferous granite gneiss offering no special characters. The beds have a well marked southerly dip. Outcrops of the easterly extension of this series are to be seen 4 miles to the east-south-east of Nanganeri at Pottaiyadi, and 6 miles further on to the north and east at Vijayanarayanam (Visionaurainum) where the strike of the beds trends from east-south-east to east-north-east.

Narayanan Pottai outcrop.

About 2½ miles south of Nanganeri rises another ridge parallel with the last named. In the hill forming the western part of the ridge a series of typical "Cape Comorin" gneiss beds is exposed; the beds lying at remarkably low angles only from 10° to 20° south. As seen from the north, the bedding is so wonderfully clear and well preserved that it is very difficult to realise that one is looking at beds of a highly metamorphic rock. The easterly extension of the ridge shows an underlying set of highly granitoid beds in which the bedding is by no means strikingly developed. To the south of the Tirukurungudi (Tricknaungoody) river and west of the high road from Nanganeri to Panagudi (Punnaugoody) is a remarkable cluster of bare rocky hills of banded granite gneiss, the most south-westerly of which the Suttu Pottai, or Tirukurungudi hill, forms a noble conical mass rising from 1,200 to 1,500 feet above the plain. It is the most nearly perfect cone I have ever seen in crystalline rocks, and to all appearance quite inaccessible; a legend exists, however, that it was once scaled by a young native at the instigation of the Trigonometrical Survey people, who followed him up by means of ropes and established a Trigonometrical Station on the top. No remains of the station are now visible from below. The bedded character of the gneiss is made visible by bands of different colour crossing the bare rocky base of the cone on the northern side. Good shows of similar banded

Outcrops south of Nanganeri.

Tirukurungudi hills.

gneiss are to be seen in the rocky hills at Valliyur (Vullioor) and Teka Valliur (Theeka Vullioor) and at Kallikulam (Kullycolum) 4 miles to the east-south-east. The dip of the bedding in the Suttu Pottai appears to be southerly, and in the Valliur hill a little to the south it appears to have changed and become northerly. These dips agree well with the requirements of the easterly extension of the great synclinal ellipse spoken of above (page 29). Further south still the general dip of the rocks is northerly as it should be to suit the ellipse theory. The predominant form of gneiss in the south is a quartzo-felspatho-micaceous rock, but several outcrops of hornblendic gneiss were also noticed, *e.g.*, the Manpottai (Great Trigonometrical Station) 4 miles south of Panagudi (Punnaugoody), and others at Erukanturai (Irkunthoora) 7 miles to the south-east, and again at the north of the Viziapatti (Vissiavethee) creek. One of the hornblendic beds at this place contains wollastonite, with coccolite and calcspar. The hornblendic gneiss here runs out into the sea forming a small reef visible for some hundred yards at low water. At several other places the gneiss rocks jut out a little distance into the sea, *e.g.*, at Kuttankuli (Kothaungculle) 2 miles to the north-east, at Idindankarai (Iddingekurra) 1 mile to the south-west. Rather more than a mile to the west of the latter place a narrow strip of granite gneiss shows for about 3 miles along the coast. Its western end is due south of the Kudankulam Trigonometrical Observatory which is the southern extremity of the Cape Comorin base line.

Valliur outcrops.

Manpottai and Erukanturai hornblendic beds.

Viziapatti hornblendic granite gneiss.

There appears to be no connection between these gneissic beds and the reefs which stretch along this coast, as the latter always run parallel with the coast line from which extensions of the gneiss beds would diverge very widely. These reefs are partly ridges of marine sandstone now in course of formation, partly coral fringing reefs, and will be separately treated of further on.

No connection between gneiss ridges and existing coast reefs.

A very remarkable feature in the gneissic region south of Trichinopoly

is the almost entire absence of intrusions of trappean rocks which are so common in more northern parts. Only three trappean instrusions came under my notice in the south, of which only two were of trap rocks *in situ*. These were a tiny dyke of diorite a few inches thick and a few yards long running nearly due north and south exposed in the dry bed of the Tumalpadi tank south of Tirushulai in Rāmnād zemindari. The second case is in the narrow coast strip of gneiss at the south end of the Cape Comorin base line. Here a number of large weathered blocks of diorite are scattered about among the blown sand hillocks. They looked as if they had been much surf-worn and were probably derived from the marine beds, the remains of which stretch away to the northward. The third case did not occur actually within the limits of the present Memoir, but in the Travancore country a few miles to the westward. Here a very narrow sharp cut dyke of tachylite is seen cutting through massive granite gneiss. The dyke which is exposed for a distance of between 100 and 150 feet in length is only 4 or 5 inches thick. It has weathered somewhat faster than the granite gneiss it cuts through, and is therefore rather sunk, and forms a small channel across the face of the rock.

Absence of trappean intrusions.

Only 3 cases seen.

Granite and quartz veins are also of rare occurrence throughout the southern gneiss area east of the Ghâts, and mostly far too small in size to admit of their being shown on the map, or to be worth enumerating in this memoir. The largest in point of size is one already adverted to (page 16) as occurring on the summit of the Perumal Malai ridge 13 miles north-east of Madura, where it has been irrupted in the axis of a very sharp anticlinal fold. The granite is a pale flesh-coloured binary compound of quartz and orthoclase felspar.

Rarity of granite and quartz veins.

Some fair-sized veins of a ternary granite may be seen cutting across the granite gneiss ridge close south of the Trivadur Trigonometrical Station 5½ miles south-south-east of the Perumal Malai. These veins occupy planes of jointing with a southerly dip crossing the strike of beddings nearly at right angles.

Granite veins in Trivadur ridge.

One group of these veins shows near the end of higher part of the ridge, and when seen from a little distance present a striking resemblance to beds of conglomerate intercalated among sandstones.

South-west of Palamcotta.

About 3 miles south-west of Palamcotta numerous veins of granite are seen permeating the gneiss in a very irregular way. They appear to anastomose throughout the general mass of rock, but are very ill-seen among nearly flat sheet-like outcrops of gneiss; both rocks being moreover very greatly decomposed.

Quartz veins.

The only quartz veins that I noted occur on the western slope of the Serumalai east and south-east of Ammanayakanur Station. They consist of pure white quartz without any included minerals, and are very short and small, only a few yards being exposed in each case. They contain as far as my observation went no accessory minerals of any kind, and have in miner's parlance a decidedly "hungry" look.

CHAPTER IV.

UPPER GONDWANA OR JURASSIC ROCKS.

Before the survey of the Madura and Tinnevelly district was taken up, it was thought very likely that the broad belt of country lying between the area of the gneissic rocks and the fringe of alluvium, which skirts the coast line, might contain representatives of the jurassic and cretaceous rocks which form such interesting features in the geology of the seaboard of the central and northern parts of the Carnatic. Unfortunately no rocks were found which could be regarded as unequivocally representative of either system. Two outcrops of rocks, bearing strong petrological resemblance to some members of the jurassic system forming the Upper Gondwana series of the Geological Survey of India, were certainly found in the Sivaganga country (Madura district), but unfortunately neither outcrop yielded any fossil

remains, by which to identify them with the similar northern beds in Trichinopoly, Madras, and Nellore districts, many of which are rich in remains of plants associated with marine fossils.

Ammersenpatti outcrop.

These two outcrops of possible Upper Gondwana rocks were met with to the northward of Sivaganga town, the first at Ammersenpatti (a small village not shown in the map) 10 miles to the north-east-by-east and near to Moodechemputty. The petrological resemblance of the shales found here to some of the hard shales found at Sripermatur (27 miles south-west of Madras) and Vemáveram (14 miles north-east of Ongole, Nellore district) is very great, but no organic remains rewarded a very close search. The shales are not seen *in situ* having been dug out of the bottom of a small tank which was full of water at the time of my visit. A considerable quantity of shale was, however, exposed in clean condition on the tank bund, so that the colour and texture of the rock could be well studied. The prevalent colours were buff and yellow mottled with white. Some quantity was also noted of pink colour ranging to red. A band of white about $\frac{1}{8}$ to $\frac{1}{4}$ inch in thickness, from which the colour had been discharged by some bleaching agency, borders the lines of jointing, which are quite sharply cut. About a mile south-east of Ammersenpatti much debris of a hard shale mixed up with lateritic debris was noticed on the surface of a small opening in the heavy scrub jungle traversed by the cart-road leading south-south-east to Kalayarkovil; there was, however, no shale rock exposed *in situ*, nor could I find any fossils.

Outcrop north of Sivaganga.

Very faint traces of similar shales of drab or buffy colour were noticed on the bund of a small *urani*, or drinking-water tank, close to the west side of the road leading from Sivaganga to Tripatur, and about 2 miles north of the former town. The *urani* was too full of water at the time of my visit for any rock to be visible, and I was unable to find any fossils among the small quantity of shale exposed on the bund.

My examination of the last two localities was but cursory, and no opportunity occurred for re-visiting them; future observers will it is

hoped re-examine these localities, and perhaps have the good fortune to find organic remains which will admit of settling the geological horizon to which these shales belong.

Boulder beds.

To the Rajmahal series it will, perhaps, be best to refer certain remarkable boulder beds resting on the surface of the gneiss on the high grounds north-east of Sivaganga and north-west of Seruvayal (Seruvial). These boulder beds appear to be due to the action of surf beating on shoals; for not only do many large and well-rounded pebbles and small boulders strew the surface, but the surfaces of various protuberances of the coarse granular gneiss are worn and rounded *in situ*. These beds are very thin, mere remnants in fact of more extensive formations. They bear a greater likeness to the boulder beds found at the base of the Rájmahál series near Utatur (Trichinopoly District), Sripermatur (Chingleput District), and Ongole (Nellore District) than to any boulder conglomerate in the cretaceous system or in the Cuddalore sandstone and lateritic series. These boulder beds are best seen along the road leading from Natarashenkotai north-north-westward to Kallayar Mangalam. Their extent could not be exactly ascertained owing to the great developement of thick scrub jungle, the absence of all available land marks, and to the badness of the map (sheet 80) which is there utterly wanting in definition. They lie at a considerably higher level than much of the gneissic area to the west of them. No section was met with showing the position of these boulder beds relatively to the overlying lateritic beds.

CHAPTER V.

THE GRITTY SANDSTONES (CUDDALORE SERIES?).

All along the coast of the Carnatic from the valley of the Godavery southward to that of the Cauvery occur at intervals deposits of coarse and generally rather friable sandstones and grits with occasional conglo-

merates which, excepting in one locality near Pondicherry,[1] have proved perfectly devoid of fossils. To these sandstones, which in South Arcot district, where they were first studied, rest unconformably on the cretaceous rocks, the name of Cuddalore sandstones was given by Mr. Henry F. Blanford,[2] who was inclined to think them of tertiary age. Sandstones of identical characters occur largely near Madras and in Nellore districts, while to the south of the typical spread near Cuddalore a large extent of them stretches away from the valley of the Vellár to the northern side of the Cauvery delta. These sandstones have not been mapped separately from the overlying laterite, as they are only exposed over very small areas with generally very ragged boundaries. Moreover, it very often happens that from the base of the lateritic formation being of similar gritty character, it is quite impossible in the absence of any organic remains to draw a boundary line between the two formations. South of the delta similar soft sandstones and grits reappear in the neighbourhood of Tanjore and Vellam, while outcrops of them are met with at intervals in the territory of the Tondiman or Pudukotai Maharaja. The two last or southernmost of these outcrops fall within the limits of the present memoir and map, and therefore require full description. The first of these outcrops occurs on the western slope of the low jungle-covered rising ground 7 miles east of Tirumayam (Tirmium), known locally as the Shenkarai hill. Here an extensive series of rain gullies exposes, but unfortunately only to a very small depth, a considerable surface of gritty conglomerate which dips east-north-east or east-by-north at angles of from 12° to 15°. False bedding prevails but only to a small extent for so coarse a rock. The conglomerate is of mottled brown to pinkish and whitish less frequently reddish-yellow colour and tolerably compact with gritty matrix including quartz and gneiss

Shenkarai section.

[1] At Tiruvakkarai (Trivicary) where silicified stems of large trees, some of them coniferous, are to be seen imbedded. The coniferous wood has been described under the name of *Peuce Schmidiana* by Schmidt and Schleiden in their treatise Ueber die Natur der Kiesel Hoelzer, Jena, 1855.

[2] See Mem. G. S. I., Vol. IV.

shingle (from the size of a cocoanut downwards) in moderate quantity.

Ayangudi section.

The second section of outcrops occurs 2 miles further south-west and about a mile south-west of Ayangudi in the middle of an extensive scrubby jungle. The beds are unlike those east of Shenkarai, as they are rather friable conglomerates of very coarse texture. The matrix, which varies from red to brown-red in colour, is semi-lateritic and vermicularly cellular to some extent. The enclosed shingle is mostly large and well rounded, chiefly quartzose, and all apparently of gneissic origin. The lowest bed is mottled and more gritty in texture with fewer enclosed pebbles. The dip is southerly at low angles, and the section here, as at Shenkarai, penetrates the strata but a few feet vertically. The base of these beds is not seen, but there can be little doubt that it rests upon the gneiss, which crops up at both Shenkarai and Ayangudi.

Ammagudi section.

Eleven miles to the east-by-south of the Ayangudi section, and close to Ammagudi is a section at the edge of the gentle scarp overlooking the Vellár valley in which gritty sandstones are seen peeping out from below the surface laterite. Brown and purple sandstones occur here of sufficient hardness to be worth quarrying into coarse flags for local use. As in both the former cases, the exposure is of very limited extent.

Sections south of the Vellár.

Traces of these gritty beds are to be seen in the tank below the Padi Kasa Nada Kovil (temple) which stands on the bluff overlooking the Vellár river opposite the south end of the Shenkarai hill. Mottled gritty beds are exposed in the Teppa Kulam (square temple tank) at Pallatur (Pullatoor) 4 miles further south. So also 2 miles to the westward of the latter place at Suragudi (Shooragoody) where approximately horizontal beds of mottled grits occur under the laterite. The grits which are exposed in the temple tank only are very clayey in parts and mottled white, pink, and pale buff to yellow. Mottled white and yellowish-brown grits are exposed in rain gullies east

of Shahkotai (Shawcotta) and in the streets on the western side of the town where the ground falls steeply. The whole of this tract of country is thickly covered with massive laterite which masks all the underlying rocks; indeed not a single natural section was seen in which the relations of the laterite to the Cuddalore beds could be studied, while the artificial sections in temple tanks and wells were far too limited in depth and extent to be really satisfactory, even where the presence of water did not prevent the base of the sections being visible.

The most southerly outcrops of grit beds within the limits of the Shahkotai tract was seen at Oodoopooputty 10 miles south-west-by-south of Shahkotai where a white and yellowish-brown mottled grit is exposed underneath the laterite in various small rain gullies. The grits are exposed only to a depth of 4 or 5 feet at the utmost.

No gritty beds were seen in the Seruvayal (Serruvial), nor in the northern and eastern parts of the great Sivaganga tract. In the western part, however, are several outcrops of sandstone and grits referable to the Cuddalore group. The first of these requiring to be noticed occurs about 1½ miles south-east of the town of Sivaganga. Here several beds of hard thick-bedded grit crop out from below the general lateritic covering of the country. In colour the rock is dark purplish-grey with brown bandings, and the dip is about 20° to the north-east. Much diagonal or "false" bedding is seen in the freshly-broken rock, which is overlaid conformably to the eastward by less compact dark-brown and yellow-brown gritty sandstone. The hard grits, which are largely quarried, are so tough as to require blasting. Unfortunately the relation to the lateritic beds cannot be ascertained as the latter are locally absent. About 5 miles to the south-south-west of Sivaganga is a considerable exposure of brown gritty sandstone which forms the upper part of the low scarp overlooking the narrow strip of gneiss rocks which there divides the grits and laterites from the great alluvial flat of the Up-Aru (Hoop-Aur) and Vaigai rivers. It is a sandstone of very peculiar appearance, a

Sivaganga Section.

Section south-south-west of Sivaganga.

curious system of shallow quasi-conchoidal pittings, and the pittings affecting the successive laminæ so as to show on weathered edges a columnar series of pittings super-imposed one above the other with a fair approach to verticality. The pittings often leave shallow inter-laminar spaces which are lined with a shining black film of oxide of iron. The dip of the beds is not very clear, but they appear to dip generally to the eastward at very low angles. They are covered up to the eastward by thick, deep red, highly ferruginous soil which is followed still further east by large spreads of massive laterite which covers all the high ground up to the new high road between Sivaganga and Mana Madura. To the south-east of the brown sandstone outcrops the ground continues high, and forms a long-stretched down running south-east for 7 or 8 miles.

Section 5 miles south of Sivagunga.

Where the Sivaganga-Mána-Madura road approaches the crest of this down from the north side, the laterite, which is greatly developed, has the character of a very coarse conglomerate which lies on an equally coarse conglomerate with gritty matrix. Both conglomerates contain many large and small pebbles and some small boulders of granular quartz rock. The grit conglomerate is only exposed in a small well 12 to 14 feet deep near the 5th milestone south of Sivaganga. The lateritic conglomerate which shows a maximum thickness of about 10 feet rests on a much eroded surface of the grits, so that the two formations are certainly unconformable at this place, whatever their relations may be elsewhere. The grit contains many *quasi*-vermicular aggregations of coarse white or mottled clays.

Manambákkam section.

A small show of coarse white or mottled grits occur in the bed of a rain gulley running westward into the Up-Aru, about half a mile northward of Manambākkam (Manambaucum), but the high ground to the east only show here and there very fair sections of the lateritic conglomerate and the grits are not exposed. The southern slope of the long down above referred to is thickly covered with very richly ferruginous hard red loam which is largely overgrown with low scrub jungle.

Māna-Madura sections.

To the east, and especially to the south-east of Māna-Madura, is a large show of grits of white or yellowish or mottled colours. Though a large surface of the grits is exposed, the sections are very shallow ones, and afford little information about the formation. The beds dip east at very low angles or roll about gently. Near Pikulam (Pecolum) the overlying lateritic beds have escaped denudation, and they pass below the alluvium, thus masking the grits which are however seen in one or two places in irrigation channel sections south of Vunneygoody, the most southerly exposures of the Cuddalore rocks in Madura district.

The gritty sandstones which occur at intervals along and near to the coast of the Rámnád zemindari are all of unequivocally marine origin, as shown by the numerous marine organisms they include, and no connection is known to exist between them and the sub-lateritic series in this quarter, though there is in many cases very great petrological resemblance between the whitish or greyish varieties of both series.

Section determining the age of the Cuddalore sandstones as sub-recent.

In the far south, however, one section was met with in the right bank of the Yellava Odai, a tributary of the Nambi-Ár in which a very decided connection exists between one of the sub-recent marine beds abounding in fossils and a very typical whitish grit having the strongest possible resemblance to the grit beds at Mána-Madura, and in many sections of the Shahkotai patch. If the petrological similarity between the typical Cuddalore grits and these South Tinnevelly grits be accepted as sufficient evidence to identify them, then the age of the Cuddalore and Rajahmundry beds is established to be not tertiary but recent. This section will be described a little further on.

Sections in Tinnevelly district at Pettakulam.

The most northerly occurrences of beds supposed to be of Cuddalore age seen in Tinnevelly district occur in the south-western part of the Tenkarai taluqs to the north-east, east, and south-east of Pettakulam (Vaulacolum of map.) The grits are exposed only in well-sections, the general surface of the country being thickly covered by blown sands or by local alluvia. The grits

exposed in the wells are coarse, mottled reddish-yellow and white, in generally horizontal beds. Not the slightest trace of any organism could be detected.

Nambi-Ār section.

The next outcrop of the gritty sandstones requiring notice is one to be seen 8 miles further to the north-west-by-north, at the junction of the Nambi-Ār or Tiruk-urungudi river with the nalah rising in the Anaikulam tank. The grit is mottled and much false bedded, and petrologically, as well as in the absence of all traces of fossils, greatly resembles the Nagarkoil beds in Travancore. Only a small exposure of this grit is seen resting on the very uneven surface of the gneiss, but it probably extends a considerable distance under the wide alluvial spread east of the Nambi-Ār. It is overlaid by a highly kankarized, and therefore much altered, pebbly sandstone, of probably alluvial origin.

About a mile to the north-east of this, and about half a mile west of the hamlet called Thopevella in the map, is a considerable show of typical whitish grits very like those seen at Nagarkoil, and described in my paper on the geology of South Travancore (Records G. S. I. Vol. XVI 1883, page 28). These grits are overlaid by a bed of sandy clay full of sub-fossil shells of recent species of Ostrea, Arca, Cytherea, &c.

Yellava Odai section.

The section is small and not very satisfactory, but at one place a band of the clayey sand is distinctly included in the gritty sandstone and appears positively to settle its age. The clayey band encloses many specimens of *Arca granosa* and of a Cytherea (? castanea). Unfortunately, petrological identity excepted, there is no evidence that the gritty sandstone is positively a representative of the Cuddalore series, else the question of the age of the Cuddalore beds might be taken as settled for good and all. As it is, further evidence will be necessary before this point can be regarded as definitely settled. If the Cuddalore grits are really of marine origin, and from their geographical position this seems highly probable, it is certainly strange that they have been found to be unfossiliferous over such extensive areas.

Grits of similar colour, but finer texture, are exposed in a well-section south-east of Pakaneri (Paukanary), and about $1\frac{1}{2}$ miles north-west-by-west of the mouth of the Nambi Aru (Naut Aur).

At Pakaneri.

Some 7 miles to the south-west of the Yellava Odai section occurs another outcrop of typical grits in the low cliff (12′—25′ high) immediately east of the village of Idindan Karai (Iddinge Kurra). These grits, which are mottled, are rather soft, and yield much more readily to the action of the surf than does the overlying hard calcareous shaly sandstone. The consequence is that the base of the cliff gets considerably undermined,—a process which continues till a cliff-fall occurs, and creates a temporary breakwater against the surf. The base of the grits is not exposed, but the bed is probably not more than 12 or 15 feet at the outside, as gneiss beds show through the beach sand at a very small distance to the south-west close to the village. The section is about half a mile long. A small sketch showing a transverse section through the cliff will be found further on (page 58). The grits appear in this section as conformably overlaid by the shaly marine sandstone.

Idindan Karai cliff section.

Mottled reddish grit is exposed to a small extent in the rain gully traversed by the path just north of the marine limestone plateau lying between Kudung Kulam and the sea. The grit bed is cut into only about 3 feet, so its thickness is problematic. The shaly gritty sandstone seen eastward of Kudung Kulam village is very much altered in its appearance by infiltration of tufaceous lime (kankar) in large quantities.

Kudung Kulam outcrop.

A gritty calcareous sandstone, of which only a few feet in thickness is exposed, is to be seen on the right bank of the estuary of the Amman Aru (or Panagudi nallah) a little to the north of the village of Perria Manal. The grit, which is unfossiliferous, is badly exposed and greatly weathered.

Perria Manal outcrops.

Various sections reveal the presence of gritty beds under the

alluvium of the Amman Aru, and further west under the great red soil deposit which flanks the spur of the Kathadi Malai stretching south towards Cape Comorin These are of precisely the same character as the grit beds described in my notes on South Travancore (Rec. G. S. I. Vol. XVI, page 29), of which, indeed, they are extensions. In colour these grits are white, pale drab or grey, mottled with red and brown in various shades. Among the best sections of these grits are those to be seen in the bed of the Kothan Aru and its various small tributaries, especially one (not shown in the map) which flows parallel with the old *saleh*, or avenue of trees, leading from Panagudi to Cape Comorin for about half a mile. Another good section is to be seen in a channel cut through the thick red soil to convey water to the Comaraveram tank about $\frac{3}{4}$ of a mile to the south-east. The beds have a general dip to the southward, but roll about a good deal on a small scale; they show a good deal of local false bedding. The grits are exposed also in numerous garden wells, but all the sections are very shallow, and in no case was the base of the formation seen.

Sections north of Cape Comorin.

Eastward of the Kothan Aru are other gritty sandstones of grey and drab colour, but more friable and shaly and of a decidedly younger aspect. They are exposed in the bed of the Panagudi nalah at and above Perangudi (Perrungoody).

Sandstones of doubtful age.

Of equally doubtful position is a brown gritty sandstone considerably affected by infiltration of kankar, which is exposed to some extent in the shallow bed of the stream which flows out of the large tank north of Nedden Kulam, 4 miles west by north of Shatankulam (Shalaungcolum) in Tenkarai taluq. As the bedding is nearly horizontal, the thickness exposed in the very shallow section amounts only to 2 or 3 feet. This brown sandstone, in which I was unable to detect any fossils, bears little or no resemblance to any member of the grit series which came under my notice in the south, but beyond that there is no reason why it might not be a remnant of the former extension of the Cuddalore for-

Nedden Kulam outcrop.

mation, as might also be a patch of yellowish-brown, coarsely shaly, sandstones exposed in a well-section a little east of Tiruvanguneri, 3 miles north-north-east of Shatan Kulam. Both patches lie in slight hollows which may well account for their having escaped the general denudation which removed so great a part of the Cuddalore group.

No traces of lignite met with in Madura and Tinnevelly.

In none of the outcrops or sections of the Cuddalore rocks or of the unfossiliferous sandstones of the Madura or Tinnevelly district have any traces of lignite been found as yet. In Travancore, however, in the Warkilli beds (which Dr. King believes to be the equivalents of the Cuddalore beds), lignites are a feature of some importance, especially in the lower part of the series. The south-eastward extension of the Warkilli beds at Kolachell also contains small quantities of lignite.

The mottled gritty beds as a rule strongly resemble the typical mottled grits exposed in the low scarps of the Cuddalore sandstone and laterite plateau south-west of Cuddalore town, from which locality their name was originally taken. The whitish grits bear a very strong petrological resemblance to the white grits so well exposed in the low cliffs overhanging the Corteliar river, where it flows round the north-western end of the Red hills plateau to the north-west of Madras.

CHAPTER VI.

THE LATERITIC FORMATIONS.

Similarity to lateritic formations elsewhere.

The rocks which I class under this heading are very similar in general to those assigned to the lateritic group in the more northerly parts of the Carnatic. They consist of ferruginous conglomerates, gravels, and sands, which as a rule follow each other in that succession from west to east. The conglomerates and gravels occupy the higher grounds along the western side of the lateritic area which forms a band of very irregular width lying between

the gneissic area and the coast alluvium, while the sands cover the eastern slopes and extend down to and disappear under the western edge of the overlying alluvium.

By far the greater part of the area, which in the map accompanying this memoir is shown as occupied jointly by the Cuddalore and the lateritic series, belongs to the latter.[1] In the northern part of the country under description the most marked feature of the lateritic rocks is their great richness in iron, chiefly in the form of earthy red hæmatite. To the south-westward and southward, however, of the Vaigai river a great change takes place, and the quantity of iron in the gravelly or sandy beds becomes smaller and smaller, and the series is finally represented by a very thin bed of gravel, mostly of gneissic origin, in which the percentage of iron is so small that it has only sufficed to give the quartzose gravel a cinnamon-brown stain.

Change in mineral character as followed southward.

The great band of lateritic rocks has been cut up by the local alluvial spreads of the rivers into various minor tracts, which may for convenience be designated according to the chief places situated within their limits. Beginning at the north-eastern extremity of the lateritic area we find—

Sub-division of the great band of lateritic rocks by intervening alluvial valleys.

1, the Arrantangy tract lying north of the Vellār river ;
2, the Shenkarai tract between the Vellār and the Pambiār ;
3, the Shah Kotai (Shawcotta) tract between the valley of the Pambiār and the Vershalay Aru (Manimut-Ar or Tripatur river);
4, the Tripatur tract ;
5, the Chattrasingara Kotai tract ;
6, the Serruvayal tract between the Vershalay Ar and the Upp-aru (Hoop Aur) ;

[1] It was found impossible to draw any boundary line between the two formations, owing to the obscurity of the sections in which they were exposed. In a few sections the lateritic beds appear distinctly unconformable to the Cuddalore series, but in others the grits forming the mass of the latter series appears to pass upwards into the former without any visible break.

7, the Sivaganga tract extending from the Upparu down to the Vaigai river;

8, the Mudukan Kulam (Moodoocuncolum) tract which occupies the slightly rising ground between the alluvium south of the Vaigai river and that of the narrow valley of the Gundár;

9, and lastly, the Parnalli tract between the Gundár and the coast alluvium on the north side of the Gulf of Manar.

To the south-westward of the Vaippár (Vypar) in Tinnevelly district only faint traces of the lateritic beds occur, too ill-defined and scattered over the surface of the older rocks to admit of their being mapped. These will be referred to again a little further on.

Arrantangi tract.

With regard to the Arrantangi tract (No. 1), there is nothing more to be said than that it shows the typical conglomeratic form very well along the high-ground on the left (east) bank of the Vellár to within about a mile of Arrantangi fort. Further east it rapidly becomes more and more sandy, and finally so strongly resembles the reddish sandy alluvium seen near the sea, that it is extremely hard to say where the boundary between them should be drawn.

Shenkarai tract.

In the second, or Shenkarai tract (No. 2) the conglomerate is very thick and massive over an area of several square miles in extent and remarkably rich in iron, as is clearly indicated by the rich red colour of the wheel tracks passing over the great bare sheets of rock which are a very characteristic feature of the rock in that immediate neighbourhood. South of Ayangudi a considerable iron smelting industry seems to have existed at some not very remote period, if one may judge by the size and condition of some very large heaps of slags which are there to be seen.

Shah Kotai tract.

By far the greater part of the Shah Kotai tract (No. 3) is occupied by the hard laterite which is often more homogeneous than conglomeratic in texture and covers the surface of the Cuddalore sandstones in extensive and continuous sheets of very dark reddish-brown (almost black) colour. These are specially well seen at Kilanelli Kotai (Keelanelli cottah), where the walls of the

old Poligar fort are entirely built of the massive rock quarried close at hand. They are also very well displayed on the top of the bluff overlooking the Pambiār valley at Neddengudi, and again on the high ground between Shuragudi (Shooragoody) and Kárágudi, and to the westward and south-westward of the latter place ; also in the south-eastern part of the tract to the south and south-east of Amarāvati. The sandy form of the lateritic deposits is much less developed here than in the Arrantangi tract. The sands on the eastern side measuring only from 2 to 3 miles across instead of 7 or 8.

A small inlier of pale reddish sands which rises from out of the alluvium of the Vellár a little south-west of Avadiar Kovil (Avadear Covil), I have with great doubt mapped as of lateritic age. It rises only a few feet above the surrounding alluvium, and is of rather darker colour, but presents no other special feature.

Tripatur tract.

It will be convenient to describe at this place the Tripatur tract (No. 4) which lies to the north and north-west of Tripatur town, the only important place in the vicinity, and forms a narrow strip about 8 miles long and a mile or $1\frac{1}{4}$ mile across at its widest part.

Chattrasingara Kotai tract.

The dense and highly ferruginous form of the lateritic conglomerate is not found largely in this tract, but a less ferruginous and less compact form including large quantities of gravel of gneissic origin. This description will also apply well to the lateritic beds seen in the Chattrasingara Kotai tract (No. 5).

Serruvayal tract.

The Serruvayal patch of laterities (No. 6) is also a small one lying between the Tripatur river and the Upparu[1] (Hoop Aur). The highly ferruginous conglomeratic form is very largely developed to the north and west of the village

[1] Upparu, or "salt river," is a very common name for small rivers whose water becomes very brackish before they finally dry up. There are three rivers of the name in this part of Madura district : one which forms the headwater of the Tripatur river, that now under reference, and a third smaller one which falls into the Vagai, 8 miles south-south-west of Sivaganga.

of Serruvayal. The sandy variety occurs only at the extreme south-eastern extremity.

The Sivaganga tract.

South of the Serruvayal tract comes the Sivagunga one (No. 7), the largest we have to describe. The spreads of the hard ferruginous conglomerate, though very common everywhere except on the extreme eastern side where a band of from 2 to 3 miles in width of sands prevails, are less extensively continuous and more frequently covered with thick red soil. This appears to be due to some extent to the greater extension of agriculture, in favour of which the surface of the conglomerate has in many places been broken up with picks or crowbars to expose the softer sub-rock which, if not allowed to solidify again by the action of rainwater, weathers into a fairly fertile soil. The most typical developments of the conglomerate near Sivaganga occur to the north-west and north of the town. The environs of Kalayar Kovil (Calliar Covil) also show very typical spreads of conglomerate and of the deep red fertile soil derived from it under favourable circumstances.

Conglomerate at Kalayar Kovil.

A very typical spread of hard laterite conglomerate covers a large area on the high ground lying 2 or 3 miles west of Mangalam (Mungalum) and extends north-eastward along the new high road from Shembanur to Sivaganga. The high ground south-west and south of Sivaganga, and its southerly extension past Mana-Madura almost down to the southernmost apex of the Sivagunga tract, is covered with very typical laterite conglomerate, which at intervals shows its true character very markedly by including considerable numbers of rolled pebbles (large and small) of gneissic origin. This may be very well seen a little to the south of the 5th milestone on the new road going direct from Sivaganga to Mana-Madura. The laterite conglomerate here rests unconformably on the eroded surface of an old gritty conglomerate which on stratigraphical and petrological grounds I have referred to the Cuddalore series (see page 39). The laterite conglomerate attains a thickness of fully 10 feet and includes many well-rounded

At Mangalam.

At the 5th milestone Mana-Madura road.

masses of granular quartz rock, some of them large enough to deserve the appellation of small boulders.

A couple of miles to the south-west the laterite also shows many included pebbles of granular quartz rock lying about on the surface (apparently washed out of the mass).

At near Mana-Madura.

I noticed also sundry angular fragments of a brown chert foreign to that part of the country. Similar angular fragments of an identical chert were noted also in rain-gullies on the top of the scarp of the laterite plateau to the east of Pikulam (Pecolum) 3 miles south-south-east of Mana-Madura. The extreme south end of the Sivaganga tract of laterite rocks is skirted by the Vaigai river, but unfortunately no section has been formed by the river.

Outliers of laterite on the gneiss north of the Vaigai.

There is a very considerable overlapping of the laterite formations on to the gneissic rocks westward of the boundaries of the various tracts now enumerated. Scattered shingle forming the debris of one continuous bed is widely spread over many parts, while patches of the hard ferruginous conglomerate are also to be seen in various places. Considerable remains of such shingle beds are to be seen to the west and north-west of Melur, *e.g.*, at Mankulam (Mauncolum) 6 miles to the west, and again a little to the south and south-east of the great Allagiri temple at foot of the Allagiri hill. The shingle here, which is very coarse, is stained of a deep red, proving that it was once embedded in a highly ferruginous matrix. It is scattered over an area of several square miles in extent. Many patches of ferruginous conglomerates are scattered over the gneissic plains to the north-west and west of the Sivaganga laterite tract.

Lateritic shingle west of Melur.

North of Madura.

To the north of Madura town considerable remains of a very typical highly ferruginous laterite conglomerate rest on the surface of the gneiss north of the Tallakulam (Tullahcolum) tank at a level high above that of the alluvium of the Vaigai river. A great quantity of shingle of gneissic origin is mixed with the ferruginous gravel, and in some places compacted by a ferruginous cement

into typical conglomerate. Associated with the shingle are occasional flakes of brown, buff, or greyish chert of foreign origin, some of which certainly seem to have been trimmed for use as scrapers or knives.

Mudukan Kulam tract.

Coming south of the Vaigai we reach the Mudukan Kulam (Moodoocumcolum) tract (No. 8) which I have named after the village giving its name to the only trigonometrical station shown on the map (sheet 80) in that region, as no more important place lies within the limits of the patch in its typical and unmistakable portion. The tract is a long and narrow one lying between the alluvial valley of the Vaigai and that of the Gundár and extending a distance of about 36 miles from north-west to south-east with an average breadth of 8 or 9 miles. Thoughout by far the greater part of this tract the lateritic beds show a gravelly or sandy and but slightly ferruginous character. The hard conglomeratic variety occurs only in small patches here and there, all in the northern half of the tract. None of these patches are worth separate mention, but they are indicated in the map by letters. The sandy parts consist generally of pale reddish or reddish-white sands with a variable quantity of ferruginous pellets of concretionary origin. Included gravel or even coarse shingle is frequently met with in the northern part, not so much in distinct beds as distributed through the general mass of sand.

Prevalence of gravels and sands.

Former western extension of gravelly beds.

These gravelly beds had formerly a very much greater extension westward, and considerable remnants of them remain scattered over the gneissic rocks, but in patches too ragged and too much interrupted by protruding masses of the gneiss to admit of their being separately mapped on the small scaled map (4 inches to the mile), which alone is at present available for the Madura country. Several such patches of gravel are noteworthy on either side of the Gundar valley close up to Tirumangalam and at intervals for some 3 or 4 miles northward of that place.

Nature of the gravels.

By far the greater quantity of this gravel consists of rolled granular quartz rock derived from some of the many outcrops of that very peculiar member of the gneissic

series to which so much attention has been drawn in foregoing pages. Other gneissic rocks have also furnished a few pebbles, and a few stray ones of chert and one or two of agate were noted as well.

Concretionary and accretionary ferruginous pellets.

Besides the concretionary pellets of earthy hæmatite with a smooth and often glazed surface which are of common occurrence wherever the sands or gravels are richly ferruginous, there is another form of pellet of very frequent occurrence even in the less richly ferruginous beds. This differs from the other in consisting of a mere aggregation of grains of sand by a ferruginous cement which shows no concentric arrangement. This form of pellet is almost always rough on the surface from the projection of numerous grains of sand, and the gravel it forms is invariably due to deposition of ferruginous matter by water at various levels. Where this action has been long enough continued the pellets are aggregated into a quasi-conglomeratic mass, the real origin of which is sometimes not very easily discernible.

Pale gravels at Abiramam.

As might be expected, the gravels in the more easterly part of this tract are much less coarse than those occurring at higher levels and further inland. In the extreme south-easterly part near Abiramam (Abramum) the gravels are but very slightly iron stained, and the pebbles of rolled granular quartz rock, which form fully 95 per cent. of the whole, are of a pale cinnamon colour tending to pale ochrey yellow.

The Parnalli tract.

The last and most southerly tract which I have called the Parnalli tract (No. 9) shows like the foregoing one a much smaller development of the ferruginous forms of lateritic rock than do the tracts north of the Vaigai river. This tract differs from all the others in that its surface is to a very great extent masked by a thick and, in the southern part especially, almost unbroken sheet of regur or cotton soil. Owing to this extremely thick covering and the great paucity of sections, the area of the tract as shown on the map must be received as only a very rude approximation to the truth.

Great spread of regur.

In the northern part of the tract the pall of cotton soil is wanting, and

there the reddish sands of ordinary type prevail with one or two small patches of hard dark coloured highly ferruginous laterite conglomerate.

Outlying gravel beds at Mantapa Salè.

A considerable area of the gneissic country north-west of the Parnalli tract is covered with a broken and discontinuous sheet of gravel and shingle of lateritic age, which covers a small plateau extending from the great tank at Parallache, north-westward to a little beyond the American Mission station at Mantapa Salè (Mundagashaulay). Here and there the gravels are cemented by a ferruginous conglomerate into a true coarse conglomerate, but in general they are non-compacted. The mass of the gravel consists of granular quartz rock well rolled, but with a fair sprinkling of other pebbles of gneissic origin. A considerable number of rude flakes and some good-sized angular lumps of a brown or greenish brown chert with almost very smooth surfaces were also noted.

Pale gravels at Parnalli.

In the southern part of the Parnalli tract only a few tank and well sections show a pale granular quartz gravel. The most important of these exposures, and really very trifling ones, *per se*, occur at and a little to the west of Parnalli village, and a slight terrace rise of the ground which sweeps round both north-east and south-west of the village appears to show the emergence of this gravel from below the great alluvial spread to the south.

Pale gravels near Velati Kulam.

Occasional traces of similar pale yellow or cinnamon coloured gravels show at intervals over the gneissic tract westward of the Parnalli lateritic tract, but there also the face of the country is greatly masked by thick cotton soil, and the gravels are exposed only in artificial sections as wells, tank bottoms and the ballast pits along the high road to the north of Velati Kulam (Vullauticolum). The gravels are often largely mixed with gravelly kankar (small nodular tufa).

South of the Vaippar (Vypar) there is a long stretch of country over which no sections exhibiting gravels were met with, though they very likely occur in detached patches under the surface of the wide spreading sheets of cotton soil which cover so large an area in Eastern Tinnevelly.

The first show of gravels noted south of the Vaippar occurs at Timmarajapuram, south-south-west of Meltattapparai station on the

South Indian Railway. A good deal of shingle shows also on the low granular quartz ridges east of Timmarajapuram and thence southward at intervals for a mile or a mile and a half south of Vagai Kulam along the road from the railway down to the delta of the Tambraparni. Here and there these gravels are much mixed with impure red hæmatitic gravels, and then get solidified to a great extent. They are everywhere very thinly scattered over the gneiss with too many outcrops of the latter protruding through them to allow of their being separately mapped on a small scale.

Patches of shingle at Timmarajapuram.

South of Vagai Kulam.

A few extremely small traces of these gravels were met along the eastern foot of the Vallanād hill, while a few of the masses of granular quartz forming the rather extensive talus on the same side of the hill show distinct traces of rounding and polishing by water action. There can be no doubt that during the period of depression when the various gravel beds now enumerated were being deposited, Vallanād hill and many of the other hills rising out of the plains of Madura and Tinnevelly districts must have been islands either in the sea or in some very widespread fresh-water lake or lagoon, and that the talus of debris surrounding the various islands must have been exposed to considerable wear by local surf action. Such surf-rolled taluses are well known further north in the northern half of the Carnatic, *e.g.*, the great shingle banks along the south flank of the Nagari mountain in North Arcot district, and similar banks along the eastern base of the Vellakonda mountains, or Eastern Ghats in Nellore district. The hard and durable nature of the dense varieties of the quartzite has caused the shingle formed from it to maintain its true character despite long continued weather action. The brittle character on the contrary of the granular quartz rock will readily account for the degradation of the coarse shingle talus which must have been formed round the islands standing up out of the lateritic sea or lake. Traces of such shingle were noticed also near the base of the Sangani hill (Trigonometrical Station), south of Tinnevelly and on the Pasu Malai south-west of Madura.

Gravel talus of Vallanād hill.

To the south of the Tambraparni river hardly any traces of the pale non-ferruginous gravels remain. One very faint sprinkling of such gravel was noticed about half a mile east of the village of Mananjapatti (Keel Monunjaputty), 14 miles south-by-east of Palamcotta. Very little also of the ferruginous conglomerate is seen south of the Tambraparni except in the southern half of the Nanganeri taluq, where numerous patches are to be found scattered over the surface of the gneissic rocks, *e.g.*, along the high road from Valliur (Vullioor) to Radapuram (Rauthapoorum) and the salt-pans (now abandoned) on the Vijayapatti (Vissiavethee) creek. Much similar ferruginous conglomerate is to be seen along a parallel line of country about 3 or 4 miles to the westward. Some of these patches of laterite may be of sub-aerial origin, but it is very difficult and often impossible to distinguish them from the sedimentary rock during a cursory examination, and the formation is certainly not one of sufficient importance, either geologically or economically, to justify the expenditure of much time in settling the question in the case of small and obscure patches.

Gravels at Mananjapatti.

Lateritic conglomerate near Radapuram.

None of the lateritic deposits met with in Madura or Tinnevelly threw any light on the debateable question of the marine or fresh-water origin of the sedimentary laterite, as none of the tracts surveyed yielded even the faintest trace of any organism. To my mind the marine hypothesis still seems to present the smaller number of difficulties, but I will not attempt to enter upon any further discussion of the question here.

Marine or fresh water origin of the laterite still unsettled.

In conclusion it may be well to draw attention to the general resemblance of the non-ferruginous shingle and gravel beds of the south to those occurring in the neighbourhood of Madras and described by me under the name of Conjeveram gravels in the memoir on the geology of Madras published in Volume X of the Memoirs of the Geological Survey of India,—see also Manual. The most marked resemblance to this Conjeveram gravel is presented by the shingle exposed at the western end of

Resemblance between pale gravels and Conjeveram gravels.

the small laterite tract of Tripatur (see page 47), in the non-ferruginous parts of which the pebbles are greatly bleached and much mixed with a whitish clayey grit. Allowance has, of course, to be made in contrasting these formations for the different character of the rock forming them. In the case of the Conjeveram beds the gravel consists most largely of hard quartzite derived directly, or indirectly, from the vast quartzite beds of the Kadapa series, while the southern shingle beds are made up of rolled pieces of the granular quartz rock which plays so important a part in the metamorphic country south of Trichinopoly.

CHAPTER VII.

THE SUB-RECENT MARINE BEDS.

A very interesting series of marine rocks, generally more or less calcareous grits, forms a narrow and rather broken fringe along the coast from Cape Comorin to the Pamban (Paumben) channel. These beds can in great part be regarded only as the ruins of a once far more widely extended formation, by far the greater portion of which has been removed by denudation. Here and there outliers and patches of these beds have been left, which testify to the fact that since their formation under the sea the country must have undergone an elevation of close upon 200 feet, if not more; others of the marine beds, however, have been upraised to a very much smaller extent, or were, what seems even more probable, deposited at a later period while the elevatory action was still in progress. Despite this very great difference in the level of the several marine formations belonging to this group, it was found impossible to assign them to more than one group, and as far as my examination of these two stages of marine formations and their organic contents went, I was unable to perceive any biological grounds for their separation, for both contain only species such as are now found living in the adjoining sea.

In describing the several patches of this marine group, it will be

simplest to take them in geographical sequence from south-west to north-east, the order in which I worked them out myself. Three exposures of similar beds which occur in the Travancore territory along the coast between Cape Comorin and the Tinnevelly frontier will be found described in my paper on the Geology of South Travancore (Records, G. S. I. Vol. XVI, 1883, page 30). The two first patches of recent marine rock met with along the Tinnevelly coast are to be seen on either side of the strip of land between the estuaries of the Kothan-Ār and Hanamanadi. The calcareous gritty beds here seen are raised but a very few feet (2′—5′). above the present sea level, and are ill seen, while the paucity of organic remains included in them makes them of very small interest. It is possible that the strips of red and white blown sand which skirts the coast for 4 miles westward, between the mouth of the Kothan-Ār and the richly fossiliferous patch of limestone at Kannakapur may conceal the eastward extension of the latter beds, if not other marine beds as well. The small patch of calcareous grit lying east of the Amman-Ār has its eastern side covered up by the end of a small teri, or blown red sand-hill, which extends eastward for about 3 miles parallel with the coast line.

Peria Manal outcrops.

To the north of this red sand-hill rises a small limestone plateau about 2 miles long from west to east, and about three quarters of a mile wide at its greatest width. On the highest part of this plateau stands a small masonry building, which was the southern observing station of the Trigonometrical Surveyors when engaged upon the Cape Comorin base line. The elevation of this station is given by them as 159 feet above sea level. A small and narrow valley cuts off this plateau to the eastward from another limestone plateau of about the same elevation at its western end, but sinking very gradually to within a couple of hundred yards to its eastern end, when it slopes rapidly down to the mouth of the Viziapatti (Vissiavethee) creek. This plateau becomes so narrow at its eastern end above Idindan Karai (Iddinge Kurra) that it might perhaps be preferentially called a ridge. It is

Kudung Kulam western plateau.

Kudung Kulam eastern plateau.

here also much obscured by considerable accumulations of teri sand and along the coast, by the ordinary dunes.

The limestone varies from a typical variety weathering to an almost chalky surface to a slightly calcareous grit. The prevalent colours are greyish-white and drab to light brown. The more gritty variety of the limestone occurs at the south-western extremity of the eastern plateau, where it forms a capping bed fully 4 feet thick. The most gritty parts of the bed contain a large percentage of coarse quartz grit and sand. The dip of this bed and of the beds in many parts of the western plateau is northerly at very low angles, or else the beds are horizontal. Fossils are not very easy to distinguish in the limestone, nor are they numerous in an entire condition, although large quantities of comminuted marine shells are common in some beds. I failed in finding a section showing the relation of the limestone to the gneiss, but in one section along the path leading direct south from Kudung Kulam there is a small exposure of pale mottled grit which underlies the limestone. Whether this grit, which is unfossiliferous locally, re-appears below the limestone along the south side of the plateau, I was unable to ascertain, owing to the amount of talus resting on the scarp overlooking the strip of gneiss which here forms the coast. I estimated the thickness of the limestone from 50 feet to 60 feet or more. Near the observatory and in the village of Kudung Kulam I noticed some fine blocks of a dense cream-coloured limestone of considerable beauty, but could not find out, despite many enquiries, where this variety had been quarried. A rather different and more shelly (comminuted shells) cream-coloured limestone was crossed in following a path leading from Kudung Kulam to the west of Idindan Karai (Iddinge Kurra).

The fossils collected were some few oysters and a number of large and long Balani. These were found at the extreme western end of the eastern plateau. The specimens collected at the north-eastern corner of the western plateau about half way up the limestone slope, were as follows :—

Purpura persica.
Mazza rapa ?
Lithodomus, sp.

There can be no reasonable doubt of the northward extension in former times which has been referred to above, but I had not the good fortune of finding any remains of the limestone on the north side of Kudung Kulam valley; but as the whole of the north side of the valley is thickly covered with red soil, it is quite possible that remains of the plateau may yet lie hidden there. As already stated above, the limestone of the Kudung Kulam eastern plateau slopes gradually but considerably to the east, but is unfortunately very much masked by the blown sand of a small teri and by a considerable formation of impure tufa underlying the teri formed by evaporation of calciferous rain-water filtering down from the highest part of the ridge. Like the recent tufa (travertine) described as occurring at Cape Comorin (see Records, Vol. XVI, p. 30), this formation contains very large numbers of the living Helix vittata in a fossil condition. This travertine extends down to the slope of the ridge, and to the very edge of the low cliff which extends for about one-third of a mile east-ward from Idindan Karai (Iddinge Kurra) village. Underlying this travertine is a bed of hard calcareous sandstone of whitish

Idindan Karai cliff section.

Idindan Karai cliff (diagrammatic).

or drab colour, and containing large numbers of marine shells of living species. Of the shells some appear perfectly fossilized, others are but very slightly altered and retain part of the natural colouring. The latter lie within reach of the constant action of the surf spray; the former lie above it, and are exposed to the bleaching action of the sun. This calcareous sandstone attains a maximum thickness in the eastern and central parts of the cliff section of about 10 to 12 feet, but thins out to the westward till close to the village where it is covered by blown-up beach sand. Its connection with the gritty limestone of the eastern end of the Kudung Kulam east plateau could not be traced, being obscured by the teri sand and surface travertine above spoken of, besides which the surface is much hidden by thorny scrub. If this low level calcareous sandstone is an extension of the higher lying gritty limestone, there must be a considerable southerly roll of the bedding to the north of the cliff section, for in the latter the bedding is horizontal. The relation of the two formations must for the present remain undecided. One point, however, in favour of their being of the same age and horizon consists in the remarkable similarity of the rather soft mottled grit underlying the calcareous sandstone at Idindan Karai to the mottled grit exposed below the Kudung Kulam limestone plateau on the path leading from the village to the beach (see page 42). In both sections the mottled grit appears to be conformable to the overlying calcareous formation. The base of the grits is not seen at Idindan Karai, being hidden by the beach sand and being close to the edge of the surf, which during high tides, or in rough weather, breaks against the foot of the cliff and undermines it very considerably owing to the great hardness and tenacity of the calcareous sandstone, which projects for several yards beyond the soft grit bed. Occasional falls of the sandstone take place, and the fallen masses form for a time a very effectual breakwater against the further encroachments of the surf. The cliff showed smaller traces of the destructive action of the surf than might have been expected from the very exposed situation which it occupies on the coast. This is no doubt due to the protective action of a reef

which runs along the coast at a small distance from the shore. A small ridge of gneiss also runs out into the sea immediately south of the villages and checks very greatly the force of the heavy rollers which break on this coast during the south-west monsoon.

The shells and corals obtained from the calcareous sandstone are the following:—

Turritella.	Arca, sp.
Trochus.	Ostrea, sp.
Nerita albicilla.	Balanus, sp.
Ancillaria albifasciata ? .	Astrea, sp.
Euchelus carinatus.	Porites, sp.

Most of these were got from the upper part of the beds along the ridge of the cliff. The fossils seen plentifully in the lower part were out of reach of hammer and chisel unless a ladder had been available. Many were also exposed along the lower surface of the bed where undermined by the surface, but to extract them by hammering, unless the projecting mass had been carefully shored up with strong timbers, would be very dangerous, and pretty though they are they are not worth risking one's life for, even if time allowed of one's trying to obtain them.

Viziapatti limestone.

Immediately north and east of the mouth of the Viziapatti creek, and only about a quarter mile east of the eastern extremity of the Kudung Kulam eastern plateau is a patch of dark, impure, marine limestone abounding in shells of living species. The limestone lies on a flat and is greatly hidden by a dense thicket of Acacia planifrons and other thorns, and by the village which stands on it. This limestone seems to rest directly upon the gneiss, reefs of which appear close by in the bed and at the bar of the creek. I was unfortunately unable to spare the time to re-visit this patch and make a collection of the enclosed shells. From its position this limestone may very likely be an extension of the gritty limestone at the easternmost end of the Kudung Kulam plateau.

Nambi-Ár section.

The next show of marine beds is at the mouth of the Nambi-Ár 4 miles to the north-east of Viziapatti. The beds consist of calcareous grits and sandstones of

various degree of coarseness, the finer beds being generally the richest in fossils, which are all of living species. Except when exposed by weather action, the fossils are difficult to extract in recognisable condition owing to the hardness of the matrix. The gritty beds show a good deal of false bedding locally, and the beds exposed on the eastern side of the estuary have in one place a strong easterly dip as if they had been uptilted, but this only extends for a short distance and may have been due to the action of a strong local current prevailing at the time of deposition. Only a narrow strip of the marine beds is exposed on either side of the river and southward for about half a mile along the coast. A teri hides the western extension of the beds on the western side of the estuary, and the western ends of the coast dune and a parallel teri do the same for the shelly beds east of the estuary. I was first introduced to this interesting patch of marine beds by the Right Reverend Bishop (then Dr.) Caldwell in 1869, when I devoted several hours to collecting the fossil shells, which had all to be chiselled out of the hard rock. On the occasion of my second visit in 1882, I found that the teri and dune sands had covered up much of the sandstone surface before exposed. The fossils obtained from the Nambi-Ár beds were as follows:—

Cypræa Arabica.
„ sp.
Conus punctatus?
Purpura persica.
Turbo, sp.
Trochus, sp.
Cerithium, sp.
Ostrea, sp.
Arca granosa.
Cardium, sp.
Cytherea, sp.

Yellava Odai section.

In the section near the bank of the Yellava Odai (an affluent of the Nambi-Ár), described at page 41, is a bed of calcareous clayey sand abounding in marine and estuarine shells of living species resting upon, and in one place distinctly intercalated between white gritty sandstones of typical Cuddalore aspect. The grit is nowhere seen to be fossiliferous. The patch of marine beds is but ill-exposed owing to a thick covering of sandy soil. It is only in the south bank of the Yellava Odai and in the banks of a rain-gully opening into it that the beds are exposed continuously for a few

hundred yards. The depth of the section is also very trifling, and nowhere exceeds 4 or 5 feet vertically. The calcareous sandy clay, which is of yellowish or brownish ochrey character, is richly charged with large and small oysters; Arcas, closely allied to, if not identical with, *A. granosa* and Cythereas, possibly referable to *C. castanea*. The oyster bed may be traced for fully a mile to the north-west as a thin fringe lying in spreads and patches on the surface the gritty sandstone which itself rests on the gneiss.

Puliman Kulam outcrop.

About 1¼ mile east-by-south of the junction of the Yellava Odai and the Nambi-Ar, and about the same distance south-south-west from Puliman-Kulam pariah village, is a tiny outcrop of grey limestone showing in the middle of the teri. I did not observe any fossils in the limestone, but close by I picked up two large subfossil oysters of the same species as that occurring in the Yellava Odai oyster bed.

Tissianvilai section.

The next occurrence of the marine beds following them in a north-easterly direction is at Tissianvilai (Teggayamvella) in a well-section in a garden on the west side of the high road as you enter the village from the south. The well is revetted, but at the time of my visit a small heap of the excavated rock lay close by and showed a purple-brown, coarse, but rather friable, grit with many marine shells. The only entire ones which I was able to extract were valves of the little *Venus scabra*, of a small Arca and a specimen of *Dentalium octogonum*, all of them shells very common at the present day in the Gulf of Manaar.

Bishop Caldwell's quarry.

To the north of Tissianvilai, as the ground begins to rise on approaching the south end of the great Sathan Kulam teri, is a patch of hard calcareous rock, varying from a nearly pure shelly limestone to a very coarse grit, cemented by a calcareous cement and almost quite devoid of fossils. The limestone would be almost entirely hidden by the teri sand, but for numerous pits which have been dug to allow of the quarrying of the rock which is carried on on a rather large scale, there being a considerable

demand for troughs, pillars, &c., &c., cut out of the more purely calcareous parts. The beds show strong signs of having been accumulated in the presence of considerable currents, there being much false bedding in the gritty parts of the rock and also considerable drifting together of comminuted shells. Most of the shell fragments are too small to be recognised with any certainty. The most conspicuous fossil is a large and long Balanus, which must have been extremely common as its fragments make up a large part of the shelly masses. It appears to be identical with that occurring so commonly at Kudung Kulam. The bedding is nearly horizontal where normal. The dip, if any exists, is at an extremely low angle south or southward. The general colour of the limestone is creamy, darkening to a warm pale brown. Besides the Balanus just mentioned, entire specimens of which show numerously here and there, only a few oysters and a single specimen of a pectinoid shell were observed, but owing to the great toughness of the rock it is almost impossible to extract any of the fossils in entire condition. It was from this quarry that Bishop Caldwell got the stone of which he built the noble gothic church at Idayangudi.

Mottled yellowish-white sandstones show in well-sections some little distance to the northward, along the path leading to Suviseshapuram Mission Station.

Outcrop in Satan Kulam teri.

In the map accompanying his paper on the geology of south-east Tinnevelly, Bishop (then Dr.) Caldwell shows a small patch of the marine beds as exposed near the centre of the great Satan Kulam teri. I have no doubt as to the perfect correctness of this observation, but was unable to find the patch in question which has most probably been covered up by the advance eastward of the sands which is considerable in the high parts of the teri. It is very probable that some future observer will find this patch of the marine beds re-exposed by the onward march of the blown sands.

Outcrop north of Taruvai lake.

Two or three miles east of the teri and about a mile north of the Taruvai lake I came across an exposure of estuarine beds full of subfossil shells laid bare by the

trenches of limeburners in search of the shells which are largely used for lime making.[1] The bed laid open by the diggings is an impure shell marl abounding in well preserved shells of Cytherea and Potamides.

The surrounding country for miles consists, except where the small lakes already referred to occupy small hollows, of thick red sands which may in great part be considered as unheaped up teri sands. Unfortunately these sands so completely mask the face of the country that it is quite impossible to correlate in any satisfactory way the marine or estuarine beds exposed in only the far distant outcrops and exposures now under description.

Outcrop at Elanjuné.

A couple of miles to the south-south-east at Elanjuné, a small fishing hamlet on the coast, which was used by the missionaries of the S. P. G. and C. M. Societies as a sea-bathing sanatarium in the days before railways had reached Tinnevelly, is an outcrop of gritty sandstone underlying the coast dunes and extending eastward into the sea in the shape of a small spit (not shown on the map) which appears to join the reef running with a few short breaks parallel with the coast all the way to Manapadu headland. No fossils were seen in the sandstone exposed at foot of the cliff. The reef has the effect of keeping off sharks to a great extent, so that sea-bathing was practised here by Europeans for many years without any accidents occurring. This is also one of the few places on the Indian coast resorted to by dugongs; they have often been seen by the visitors, but the animals are exceedingly shy and wary and will not allow any one to approach them.

Christianagaram sections.

The next exposure of the marine beds, taking them as they follow in a north-easterly direction, occurs at Christianagaram about 4 miles north-west-by-north of Manappadu headland. Here a well sunk a few dozen yards east of the S. P. G. Mission house cuts a white shelly limestone several feet thick

[1] Owing to the great faultiness of both the Atlas sheet and the Revenue Survey Maps in the matter of names, I found it impossible to identify any of the hamlets and villages on the northern side of the lake.

and made up almost entirely of separated valves of *Venus scabra* drifted together. A little to the east of the village is an exposure of shelly marl containing innumerable valves of a Cytherea and many shells of *Helix vittata* and *Nanina tranquebarica*. From its position this shelly marl may be inferred to rest upon the Venus bed.

Manapadu and Trichendur sandstones subaerial.

An estuarine deposit seems in course of formation in the bed of the back-water running along the coast from Kulasekhara-pattanam to Trichendur. Great masses of sandstone occur at Manapadu and at Trichendur, but they seem to be mainly subaerial in their origin and will therefore be considered further on when treating of the coast dunes. The base of the cliffs in both cases are surrounded by a narrow fringe of reef which presents the appearance of fringing coral reef, but I could not see any live coral growing in either.

Panamparai quarry sections.

To return to the unquestionably marine beds. The next outcrops to be recorded occur 7 miles to the west-north-west of Christianagaram or Kalan-Kudi Iruppu (Kaulungcoode-irripoo), at a place called Panamparai (Pannumpaura). The beds here seen strongly resemble those already described as occurring at Bishop Caldwell's quarry at Thisianvilai (Teggayamvella) and are like them a shelly calcareous grit. Being greatly in demand as a building stone they have been largely quarried, but the quarries have not been worked deep enough to expose the underlying rock. They have furnished the material for the construction of the very fine church at the Church Mission Station of Megnanapuram, 3 miles to the east. The beds lie horizontally or dip at a very small angle to the south-east. False bedding on a small scale is common, and the accumulations of fossil shells present the appearance of having been found by drifting currents. As at Tissianvilai, the fossils are very difficult to extract in a whole condition. All that were determinable belonged to living species, but many were far too much comminuted to allow of even generic determination. The Balanus which is the most characteristic fossil at Tissianvilai is common also at Panamparai. The prevalent

colour of the calcareous grit is a brownish cream colour, ranging to decided brown in some cases, and to whitish drab in others. That these beds extend north-north-eastward under the sands of the great Megnanapuram teri is proved by shelly calcareous grits having been cut through in sinking a well through the sand about half way between Megnanapuram and Nazareth. An outcrop of brown calcareous grit occurs at a considerable elevation above the general level of the country about 2½ miles south of Nazareth and in the high part of the teri close to the track leading from Nazareth to Kayampulli (Koyambully). As the masses of rock here exposed are low and lie in the furrow between two high waves of the loose red sand, it is very likely that they may be covered up and lost sight of at some future time. This is the last exposure of the recent marine beds seen south of the Tambraparni river.

Outcrop in the Teri near Nazareth.

To the north of the Tambraparni only two patches of this marine formation were met with in Tinnevelly territory; of these the first was one of considerable extent and importance; the second far too small to be shown on the map.

The first lies along the edge of the high ground which slopes up westward from the coastal band of alluvium to the southward of the Malattar odai (nullah). The rock is here also a calcareous gritty sandstone resting apparently on the gneiss, the junction with which however was not seen owing to the thick stratum of cotton soil which here covers the whole country. The most southerly indications of this bed of grit are found in well-sections lying some distance south-west of the little village of Dalavaipuram (Thullavapoorum) 9 miles north-by-west of Tutikorin. From the shape of the ground, however, there is every reason to believe that the grit extends a mile or more to the south-westward under the cotton soil. It stops short, however, of reaching the Tutikorin-Ettiapuram high road. To the north-east the grit extends up to the village of Vedanattam (Vaidanuthum) and then dies down under the alluvium of the Malattar odai. The best sections of this bed are to be seen in

Vedanattam calcareous grit beds.

the large pits a little south-east of Vedanattam in which the stone is extensively quarried. A few small pits along the road running southward from the village and a few flat outcrops (bed surfaces) where the cotton soil has been denuded away are the only other sections by which to study this grit. As seen in the great quarry at Vedanattam, the beds which roll about slightly consist of fine or coarse gritty calcareous sandstone of pale whitish or pinkish-brown colour and showing here and there "false bedding." Marine shells and Balani are not uncommon and are well preserved, but difficult to extract unbroken. Many of the shells were broken before being imbedded. Much of the stone, which is very well adapted for building purposes, is carried to Tutikorin.

Melamandai section.

The second occurrence of a rock referable to the recent marine series to the northward of the Tambraparni river was noted a few hundred yards south-west of Velayudapuram, a small hamlet $1\frac{1}{4}$ miles south-west of Melamandai (Mailmuntha). Here a few square feet of brown gritty calcareous sandstone are badly exposed in a small roadside pit. No traces of fossils were seen in this case.

Sections in Madura district.

Continuing to follow the marine beds in a north-easterly direction, the succession in which they were really worked out, we now pass out of Tinnevelly into the Rāmnād zemindari which form the south-eastern portion of the Madura district. The first outcrop of the marine beds met with in the Rāmnād territory is immediately south of the ford over the Gund-Ār (Coond Aur) and on the right bank of the river. Here a low cliff has been formed by the river cutting into a bed of rather soft gritty sandstone abounding in fossil shells, all of living species. The sandstone is exposed for about 300 yards to a depth of from 10 to 12 feet. The base of the section is hidden by the water or very recent alluvium. The following list of fossil shells includes all that I was able to collect :—

Gund-Ār ford section.

Terebralia telescopium.	Arca, 3 sp.
Pyrazus palustris.	Cardita antiquata.
Cuma sacellum.	Venus scabra.
Eburna, sp.	„ squamosa.

Oliva, 2 sp.	Nucula.
Sigaretus, sp.	Donax.
Terebra, sp.	Cytherea.
Ostrea, sp.	Corbula.
Plicatula, sp.	Tellina spengleri.
Pecten, sp.	„ sp.
Cardium, sp.	„ sp.
Pectunculus, sp.	Meroe picta ?
„ tenuistriatus.	„ sp.

Gondār estuary section.

A broken outcrop of the gritty beds may be traced for some distance below the ford cliff section, but a gap of about half a mile or more intervenes before reaching the estuary of the river, which reveals two bands of hard, more or less shelly sandstone forming very low causeway-like ridges, which stretch nearly across the backwater formed by the bar at the mouth of the river. The strike of the beds is east-by-south to west-by-north, and the dip varies from 5° to 10° south-by-west. The beds have been cut through in several places by the erosive action of the river when in flood, and several small islands have thus been formed. All the fossil shells seen belonged to living species. The path leading to Mukkurpatanam (Mookoorputnumchary) crosses these beds.

Valimukkam cliffs.

The next show of rocks containing living species of marine shells occurs at Valimukkam (Vaulimookum), some 9 miles to the eastward of Mukkurpatanam, in the form of a low rocky spit jutting out into the sea for fully two-thirds of a mile. I refer these rocks with some hesitation to the present group, as I am not quite sure whether they may not owe their origin to sub-aerial action rather than to deposition on the bed of the sea. In parts certainly they bear a strong resemblance to a consolidated coast dune. The distinction is one not always easy to make, and the cursory examination I had to be content with did not suffice to settle the question to my satisfaction. On the northern side of the spit, the beds show a coarse shelly friable sandstone of brown colour, mostly horizontally bedded, and showing but little false bedding. The included shells are mostly comminuted. The beds are exposed in a low cliff facing north, but are completely covered up by blown sands to the

southward, which is unfortunate, as it prevents one's tracing their connection with another series of sandstones which occur on the south side of the spit. These latter beds which show a southerly dip of from 10° to 15° or more, consist of hard massive sandstones of varying colour and composition.

In parts these sandstones are nearly purely silicious, in others they are highly calcareous, because including a large percentage of comminuted sea shells. In some places the sandstone contains no shelly fragments, but consists solely of laminæ of quartz and magnetic iron sand, mixed or distinct, as the case may be. A general admixture of garnet sand, sufficient in quantity to give the whole rock a ruddy colour, is common, but the garnet sand does not often form distinct laminæ by itself. Some beds are found in which a four-fold mixture prevails. The sandstones are best seen close to the surf by which they are occasionally undermined. They have also been very largely quarried at some former time. At the extremity of the spit an identical sandstone contains many shallow little basins, in a good number of which a growth of coral is now taking place. The question to be solved with regard to these sandstones is whether they represent a true sub-aqueous deposit which has been upheaved to an elevation of from 2 or 3 to 12 or 15 feet above the present sea level, or whether they must be regarded as a local induration of the beach sand and overlying small dunes such as the sandstones exposed at Manapadu and close to the Tiruchendur Temple and already referred to above. I should incline to regard the Valimukkam and other similar sandstones at many places along the Rámnád coast as indurated dune sands like those at Manapad and Tiruchendur, were it not that in Rameswaram island unquestionable evidence exists of a considerable elevation of the land in very recent times, geologically speaking. This evidence is afforded by existence of an upheaved coral reef, very extensive indications of which occur round the northern coast of the island. This reef will be described further on.

A small patch of this hard sandstone fringing the beach was noticed some miles to the westward at Narripurpattanam (Nurripoorputnumchary), while long stretches of

The sandstone "quay" along the coast.

it forming a regular quay wall are to be seen eastward of Kilakarai (Keelakurray) and especially between Muttupettai (Moottupettah) and the spit of land opposite Pamban (Paumben). The rocky barrier or reef which stretches very nearly across the Pamban strait consists also of this sandstone. There is strong geological evidence to prove, that this barrier was once continuous. The sandstone quay runs westwards along the coast on the north side of the Toniturai spit as far as Pillai Maddam (Pillay Muddum).

Pamben barrier.

The upraised coral reef referred to above is a striking feature of the north coast of Rameswaram (Ramesarum) island, and is worthy of much closer study than the time at my disposal enabled me to bestow upon it. It shows best along the beach beginning a couple of hundred yards west of the zemindar's bungalow, where it forms a little irregular scarp about a yard or 4 feet high against the foot of which the waves break in rough weather. Of its true coral reef origin there can be no possible doubt, as in many places the main mass of the rock consists of great globular meandrinoid corals or of huge cups of a species of Porites which, beyond being bleached by weather action, are very slightly altered, and still remain in the position in which they originally grew. The base of the reef is not exposed as far as I could ascertain, not having been sufficiently upraised along the beach, but in a well-section a little to the south of the Gandhamāna Parvattam Chattiram the thickness of the coral reef exposed above the surface of the water is at least 10 feet, and probably much more. The great swampy flat forming the north lobe, as it were, of Rameswaram island consists, I believe, entirely of this upraised reef hidden only by a thin coating of alluvium or the water of the strongly brackish lagoons which cover the major part of the surface, but do not form a single continuous sheet of water as shown in the map. I came upon masses of coral protruding at intervals through the alluvium in the very centre of the flats north-westward of the great sand hill crowned by the Chattiram just named. The raised reef is very well seen to the north-eastward of Rameswaram town, where it forms a miniature cliff from 3 to 4 or

Raised coral reef on Rameswaram island.

possibly 5 feet high, and continuing along the coast after the latter turns and trends to north-west. Time did not admit of my actually following it up to Pesausee Moondel Point, but I went to within a mile of the point and could see no change in the character of the coast line on examination through a strong field glass. The raised reef shows strongly also along the western side of the flat northward of Ariangundu (Aureyangoondu). The south side of the reef is along the north coast, completely covered up by the great spreads of blown sands which occupy the greater part of the surface of the island. On the east side of the island the reef does not extend close up to the great temple, but stops short abruptly about 300 yards to the north-east, and does not reappear on the coast of the bay south of the temple. South of Pamban town also there were no signs of any upraised coral, nor could I see any indications eastward along the south coast as far as the eye could reach from Coondacaul Moondel Point, while the great south-east spit terminating at the point called on the map Thunnuscody is covered by a double ridge of great blown sand hills. An important series of trial sinkings made by the Port Officer at Pamban right across the island, from north to south, about 2 miles east of the town, in order to test the feasibility of the proposed ship canal,[1] did not reveal any southerly extension of the raised reef. The probability is that it forms a mere narrow strip along the beach from Pamban to Ariangundu, but widens out thence to the north-eastward to form the northern lobe of the island.

Parts of the reef lying between collections (colonies as it were) of the great globular or cup-shaped coral masses form a coarse sandstone made up of broken coral, shells and sand (mostly silicious), a typical coral sandstone.

[1] Through the kindness of Mr. Baker, the Port Officer, I had the opportunity of seeing a series of the rocks obtained by him from the sinkings above referred to. The rocks were all very modern-looking varieties of grit and sandstone imperfectly consolidated, and would certainly offer no obstacle to the cutting of a ship canal if ever that wild scheme should be carried out against the sound advice of the marine authorities. The present channel, if dredged rather deeper, will answer all purposes for the coasting trade, while large ships should never trust themselves to the many dangers of an increasingly shoal sea like Palk's Bay.

At the Pamban end of the raised reef it shows a slight northerly dip, and masses of dead coral apparently *in situ* protrude through the sand below highwater mark. Reefs of living coral fringe the present coast, but these I was unable to examine, so cannot say whether the corals now growing there are specifically allied to those which formed the reef now upraised, but all the mollusca and crustacea I found occurring fossil in the latter belong to species now living in the surrounding sea.

Westward of the Strait the native fishermen assured me the living coral reef extends only as far as Pillai Maddam (Pillay Mudum). This statement, which I had no opportunity of testing, is on the face of it very reasonable, as it is a well ascertained fact that coral reefs never form near the embouchures of large rivers, as the influence of the fresh water flowing into the sea and of the fine silt borne by it is most unfavourable to their growth. A glance at the map will show that coral reefs could not extend westward without coming directly within the influence of the flood waters of the Vaigai. The fishermen, several of whom I cross-examined independently, all agreed that no coral reefs occur further north on the coast of Palks Bay,—a fact borne out by the charts of that region, and due doubtless to the numerous rivers and streams falling into it.

Absence of coral reefs on west side of Palks Bay.

All the small islands occurring along the Tinnevelly and Madura coast appear to consist of sand based upon coral reefs which are largely exposed at low tide. The published large scale charts of Pamban Straits show extensive coral reefs surrounding the five most easterly islands; Moossel, Munnauli, Pullee, Pulleevausel and Cooresuddy. The only one I was able to visit, that on which stands the Tutikorin lighthouse, shows no coral on the surface, which is sandy; but the island immediately to the north supplies large quantities of dead coral, which are used in the town as a rough building stone. Similarly, large quantities of dead coral are brought over to the mainland from several of the central group of *tivus* (Thevoo) or islands along the Madura coast.

Coral reefs off the coast of Tinnevelly and Madura.

It is quite evident from the occurrence of the old coral reef on Rames-

waram island that the latter must have been upraised several feet within a comparatively recent period, but unfortunately there are no data by which to calculate the exact amount of the upheaval. The upheaval which affected Rameswaram island doubtless affected the adjoining mainland, and by upraising the coast exposed the sandstones which have been described above as forming a low wall-like cliff bordering the beach as if a built quay. A piece of evidence connecting the old coral reef directly with the "quay" sandstones is afforded by the occurrence, about half a mile east of Kilakarai (Keelacurray, a small seaport 26 miles west of Pamban Straits), of an isolated mass of coral exposed in the sandstone cliff. The coral which in appearance and condition is identical with that of the old reef east of Pamban occurs as a rudely conical agglomeration of meandrine masses measuring about a yard in diameter and 4½ feet to 5 feet in height with the sandstone deposited regularly around and over it. This isolated coral mass evidently remains *in situ* as it had grown.

Connection of coral "quay" sandstone at Kilakarai.

It is impossible to resist the speculation that it was this upheaval which gave rise to the formation of what is known to the Hindus as Rama's bridge, and to Mussalmans and Christians as Adam's bridge, the long narrow isthmus which once united Ceylon to India. As soon as the surface of the old reef become dry land, it would begin to arrest the currents, and the surf and wind action around the coasts would throw up the sand dunes which now so thickly cover both Rameswaram island and the long narrow peninsula known as the Tonitoray spit on the western side of Pamban Straits. To this same elevatory action may also safely be attributed the formation of the long line of islets running parallel with the south coast of the Madura district, and trending southward as the Tinnevelly coast is approached. Local tradition, if not history, claims that Rameswaram island was once completely joined to the terra firma on both sides, and that both the Pamban Strait and the various breaches to the eastward have since arisen by a catachysm in the form of a tremendous storm which breached the narrow rocky barrier about the year 1480 A.D. The chief of Ramnad (properly Ramanada-

Formation of Adam's Bridge.

Its destruction.

puram, the city of Rama's district) bears as his highest title the name of Sethupathi or "keeper of the bridge."

From the description given in the "Bengal Pilot" of Adam's bridge, the shoal ridge connecting Rameswaram island with the island of Manar and with Ceylon, it consists of precisely the same gritty calcareous sandstone as the Pamban barrier and the sandstone quay cliff of the Rámnád coast.

Jointing of the sandstone; its effect.

Owing to a system of jointing which crosses the Pamban sandstone barrier nearly at right angles, the action of the waves has broken it up into a series of large flat blocks which so strongly resemble a series of gigantic stepping stones that it is impossible to wonder at the imagination of the author or (in analogy with the Homeric epos) authors of the Ramayana that the rocky ridge was really an old causeway of human construction.

A similar system of jointing shows, though not very distinctly, in the sandstone "quay" cliff at Valimukkam, 36 miles west-by-south of Pamban Straits.

The legend of Rama's bridge.

According to the famous old Hindu epic the construction of this bridge was due to the industry and enterprise of the great army of monkeys and bears led by Rama and his long-tailed friends Sugriva and Hanuman to the invasion of Lanka in their war with Ravana, the king of the demons and the abductor of Sita, Rama's wife. The engineering part of the undertaking was specially entrusted to the monkey Nala, a son of Visvakarma, the famous architect, he having the special power (which would in many cases be much coveted by the commanding R. E. of a modern army) of making blocks of stone to float on the water. There is no apparent reason why the proved up-heaval of Rama's bridge may not have taken place within the semi-mythical time preceding some invasion of the heretical Buddhist kingdom of Lanka (Ceylon) by the Brahmanical Aryans of the mainland and their Dravidian allies.[1]

[1] That such an invasion of the island of Lanka (Ceylon) from the mainland may have taken place in bygone ages along the recently upheaved isthmus is well within the limits of historical probability. Such elevation of the sea bottom would unquestionably be regarded as a miraculous event and be ascribed to superhuman agency, and the fervid imagination of successive Aryan bards may be easily credited with sufficient powers of invention to have evolved all the marvellous mythical details that have been superadded by way of embellishment.

CHAPTER VIII.

THE ALLUVIAL FORMATIONS.

Effects of long continued wet cultivation.

A large area of the region described in this memoir is occupied by the marine and fluviatile alluvia, but there is little to say about them relatively to the superficial extent, as very few sections were met with, and as nearly the whole surface has been greatly altered by the vast scale on which wet cultivation has been carried on for many centuries. Practically the greater part of the alluvial surface is "made ground," the long continued operations of irrigation having in many parts, both of the great and small irrigated valleys, extensively raised the general surface of the country by a process technically known as "warping."

No deep sections.

Of deep sections furnishing any real idea of the beds composing the alluvial deposits in depth, not a single one was met with, nor do any of the rivers afford sections more than a few feet in depth. Over very large tracts of country the surface is completely hidden by paddy-fields or by the waters of the very numerous irrigation tanks, many of which are of very large size.

The soil thrown out of the bottoms of these tanks and piled up to form the "bunds" sometimes affords some clue as to the local character of the superficial alluvium, but even this is very often hidden by the piles of humus and silt that have during the course of ages been thrown out when the tanks have been cleared.

Unaltered alluvium of Pālār.

In some of the smaller rivers, however, the character of the alluvia is not so utterly disguised by cultivation, as for example in the case of the Pālār (the upper part of the Tirupatur river in Madura district). Here the unusually high banks generally reveal a reddish loam derived from the red soil of the gneissic tracts in which it rises to the north-east of the Siru Malai.

Prevailing type of river alluvium.

As far as the great spreads of irrigated cultivation allow of recognition of the true character of the surface beds of the alluvium, there is a very great similarity in composi-

tion in the alluvia generally, as indeed might be reasonably expected from the fact that nearly all the rivers rise on the gneissic tracts in or at the foot of the Southern Ghāts. The prevailing type is a pale red or reddish white or pale brownish sandy loam passing into clay or nearly pure sand in some places.

Exceptional character of the alluvium of Virudupatti river.

An exception to the rule is the alluvium of the Virudupatti (Virduputty) river (the main northern tributary of the Vaippār) in North Tinnevelly, which flows through great tracts of typical black soil or regur, and which has covered the low level of its valley with a thick bed of washed-up regur. The alluvium near the mouth of the Vaippār shows the effect of the dark particles of the regur it has carried down, in the dark grey or grey-brown fine silt it has there deposited. Intermediately the sandy and locally somewhat gravelly character of the alluvium prevails as may be well seen to the north-west of Velāti Kulam (Vullauticolum).

Alluvium of the Vaigai.

The alluvium of the Vaigai like that of the rivers to the north of it is generally a very sandy loam. Near to Madura it is here and there gravelly, and near Rāmnād extremely sandy. Here and there the beds vary to coarse grit or even fine gravel or quartz and rolled kankar.

Owing to the great offtake of water from the Vaigai by irrigation channels it rapidly dwindles in size below Permagudi and evidently flows only during heavy freshes.

Of the Tambraparni.

The alluvium of the Tambraparni which chiefly drains tracts covered with light red gritty soil is of a pale reddish colour and very sandy. Large quantities of calcareous tufa (pipe kankar and nodular kankar) show in the sandy banks of the river to the south and south-east of Tinnevelly town, and have solidified the otherwise highly sandy beds into a hard and almost rocky consistency. At and above the bridge between Tinnevelly and Palamcotta is a considerable spread of coarse tufaceous conglomerate forming a low platform in the bed of the river on which some small temples have been built; the conglomerate includes much gneiss debris.

The sandy tufa of the banks appears to be highly adapted to contain organic remains, but unfortunately none showed at the time of my visits, though they were very carefully sought for. The tufa looks so likely for them that it is highly desirable the banks should be from time to time carefully examined. No mammalian or reptilian remains were found in any of the fluviatile alluvia in the south. The rivers flowing into the sea south of the Tambraparni carry down sand and fine gravel as sediment, but they also carry very large quantities of calcareous matter in solution, and form large deposits of tufa in their banks or beds. The tufaceous deposits thus formed are mostly massive (sheet kankar), but they all here and there form small quantities of the vermicular and nodular varieties. This latter form is developed to a remarkable extent in the valley of the Nambi-ār opposite to Chittoor, at its junction and its southern tributary, the Anaikulam nullah.

Great tufaceous limestone deposits generally massive in character.

The great spreads of massive alluvial tufa, which are more extensive and remarkable in South Tinnevelly than in any other part of the Indian peninsula that I am acquainted with, deserve special enumeration, and may for convenience be taken in order from north to south:—

More important than in any other southern district.

1. The valley of the Sevandipatti (Shaminthaputty) nullah, 6 miles south-east-by-south of Palamcotta, shows a very large spread of this rock which extends up and down the valley near Sevandipatti village, and shows also very largely above Ayanapatti (Iyanauputty). There is a considerable show of it also to the south of Sevandipatti resting on the gneiss directly.

Tufa deposits at Sevandipatty.

2. The Karseri tank overflow channel shows a great quantity of the massive kankar to the north of the village, and there is a noteworthy show of it also in the southern branch of the nallah which flows past Arasakulam (Urshacolum).

Karseri.

3. On the western side of the great Megnanapuram teri and a little to the westward of Yelluvaraimuki (Yellavoormookee) there is a considerable show of massive

West of the Megnanapuram teri.

tufa which recurs at intervals along the cart track going south-south-eastward to Adayal and Mudalur (Moothaloor). The tufa is largely developed in the bed of the Kārāmeni-ār at the ford.

North of Sathankulam.

4. A great spread of the tufa occurs 3 miles west-north-west of the ford just named opposite the large village of Sathankulam (Shattungcolum) and covers many hundred acres.

At Neddunkulam.

5. At and to the south of Neddunkulam (Neddungcolum), 4 miles west-north-west of Sathankulam, are also notable spreads of massive tufa, a good deal of which appears also still further south in the bed of the Kārāmeni-ār near Pudukulam (not in the map).

West and south of the Sathankulam teri.

6. In the broad shallow valley skirting the western side of the Sathankulam teri occurs the largest development of the massive tufa known in Tinnevelly district. It occupies nearly the whole valley, occurring either on the surface or showing in every well-section visible, and at Vaganeri forms a thick sheet of solid limestone hard enough and compact enough to be thought worth quarrying. It is found continuously down the valley past Selva Marudur (Chella Murdoor) and Iddayangudi to within a mile or so of the west end of the Taruvai lake.

In the valley of the Yellava Odai.

7. Proceeding west hence there are great shows (extensive sheets of limestone) of the tufa in the shallow valley of the Yellava Odai branch of the Nambi-ār at intervals along the course of the stream past Vadacheri (Vuddachary) and Samugarangapuram (Shummoorungaveram), and for several miles up to the branches of the nullah westward of the latter place. The thick bedded massive limestone character of the tufa is very remarkably seen in a small tank close to the old salé (avenue) east of the village. Here too the tufa encloses small segregations of semi-transparent brown chert, having a very flint-like appearance.

At Samugarangapuram.

In the Radapuram valley.

8. South of the valley the tufa recurs again in very large quantity in the Radapuram nullah, especially to the south and south-west of Udayattur (Woothathoor), and

for at least 2 miles southward down the valley. A large show occurs too just above the estuary. The valley of the small stream above the saltpans at Kuthankuli, 3 miles east-north-east of Viziapattī, is also occupied by a large show of massive tufa.

In the valley of the Annam-ār.

9. The valley of the Hannamnadi (Annam aur) is not wanting in tufaceous deposits, but the massive variety is less strikingly developed here.

Curiously enough all this great development of tufa did not yield a single fossil organism, though it was closely searched in many places by myself and a very smart collector. Nor does Bishop Caldwell, who is intimately acquainted with the formation as seen near Iddayangudi and Sathankulam, appear to have been a whit more successful.

Origin of the tufa.

There can be no doubt as to the origin of these extensive and interesting tufa beds; they were formed by the deposition of lime by evaporation of the waters which brought the calcareous matter in solution from more distant sources.

Sources whence the calcareous matter has derived.

What those sources were I am not prepared to say as yet. The gneiss of the low country contains, as far as my observations went, no conspicuous beds of crystalline limestone, nor do many hornblendic beds occur which could have yielded a large supply of lime. It is very probable, however, that such beds do occur on the tops and flanks of the Southern Ghâts, which remain as yet unsurveyed.

Marine alluvia much masked.

Of the marine and estuarine alluvia it is impossible to say much, for they are almost entirely covered up along the Tinnevelly and Madura coasts by the blown sands, whether red or white, which are so largely developed in these regions. Moreover, these formations require much longer study than could be devoted to them during a rapid general survey. The rate at which they increase, the direction in which such increase takes place, or the converse, the rate at which, and the direction from which, they are destroyed by encroachment of the sea, are all questions of considerable interest, but

questions for the answering of which the data have to be collected by careful and often long continued observations. So far as my observations went, I came to the conclusion that nowhere is the sea making any serious encroachments, and that the advance of the land by silting up of shallower parts of the coast has been much greater than the recession by general wear and tear of the coast. A very manifest advance of the alluvium of the Tambraparni delta has taken place during many centuries, as will be shown presently, and the increasing shoalness of Tutikorin harbour shows clearly that the silting up process is still continuing.

Marine erosion small.

It is a well known fact that the coasts of the Indian peninsula are swept by great marine currents running up or down the coast accordingly to the prevailing monsoon, whether it blow from the north-east or south-west. These currents flow with pretty equal force, but owing to the longer duration of the south-west monsoon, it produces the greater effects, and all the rivers flowing into the Bay of Bengal have a tendency to extend their deltas in a north-easterly direction. This tendency, it will be seen, is manifested in the case of the Tambraparni as well as in that of the Vaigai, Cauvery, Vellar, and other more northerly rivers.

Action of the great monsoon coast currents.

The historical proofs of the sea-ward advance of the Tambraparni delta have been worked out with great research and learning by Dr. Caldwell, Missionary Bishop in Tinnevelly district. The proofs of the advance of the delta obtained by the Bishop are the identification of the sites of two famous old seaports—the "Kolkoi Emporium" of the author of the Periplus Mare Erythreum and of the geographer Ptolemy, and the "Cail" of Marco Polo, the famous Venetian traveller. The "Kolkoi" of the Greeks Bishop Caldwell identifies with Korkai, a place now nearly 5 miles inland, which was the capital of the Pandyan kingdom as early as the year 600 B.C. The tradition of its former greatness as the capital and as the centre of the pearl trade was found by

Advance of the Tambraparni delta.

Sites of "Kolkoi" and "Cailth" determined by Bishop Caldwell.

Bishop Caldwell still to linger among the inhabitants, while evidences of its former littoral position are not wanting. As time passed on Korkai decayed because the sea receded, and a new town, Kayal, sprung up on the coast and became known to the world as the "Cail" of Marco Polo. "Cail" was at the time of Marco Polo's visit in 1292 the great emporium of the east coast, and continued so during the middle ages. It also decayed and was forgotten till its site was re-discovered by Bishop Caldwell in 1861 and made public in Colonel H. Yule's beautiful edition of Marco Polo's Travels[1]. From the identification of these two sites it becomes clear that since the time when Ptolemy wrote the coast has gained on the sea by nearly 5 miles, while since the visit of Marco Polo to Kayal in 1292 the coast line had advanced fully 2 miles. Considering the very moderate size of the Tambraparni, the enormous quantity of fine silt retained to raise the general surface of the irrigated valleys and the constant dispersion of the sediment brought down in suspension by the floodwaters of the river by the strong up and down currents prevailing during the alternate monsoons, the rate of growth has certainly been considerable, being just about 18 feet per annum.

The advance of the delta alluvium to the east is very striking in the case of the long spit of land forming the south side of Tutikorin harbour, which now extends out much nearer to the islands east of the harbour than it did when the Trigonometrical Survey was made (in 1828).

Marine alluvia at Kolasekharapatanam.

To the marine alluvium I reckon some thoroughly unconsolidated beds full of marine and estuarine shells which underlie the long Kalampalli Taruvai or lagoon running northward from Kolasekharapatanam to Tiruchendur. The beds are of a dark clay abounding in Cytherea, Arca, Potamides, &c., &c., all of living species. Two other exposures of beds containing estuarine shells imbedded in dark clay were observed, the one a little west of Melmandai in Tinnevelly, and the other just across the border at Sevalpatti (Shevalputty) in Madura district. In both cases the organic remains had been turned out of the bottoms of

At Melmandai and Sevalpatti.

[1] If ever any book deserved the title of Thesaurus Geographicus, it is this noble edition of the Travels of Ser Marco Polo, edited as a labour of love by Colonel Yule, whose acutely critical skill has rescued from unjust obloquy the memory of a really great traveller.

deep *uranis*, or square drinking-water tanks, and in neither was the marine bed seen *in situ*. The Melmandai section yielded a large Cytherea, probably *C. castanea*, while the Sevalputti bed showed numerous specimens of Pyrazus, Cytherea, Cardita, and Ostrea.

Submerged forest at Valimukkam.

One more alluvial deposit deserves to be noticed,—a submerged forest which occurs at the western end of the Valimukkam bay. The forest shows about half a mile north of Valimukkam village in the form of a considerable number of tree stumps standing up out of a bed of soft and tenacious black clay containing oysters and other marine shells imbedded in it. The whole occupies about half an acre in extent, and is just above water at or near high tide. The general appearance of the forest reminded me forcibly of parts of the well-known submerged forest which forms so conspicuous a feature on the beach south of Swansea in South Wales, with this difference that at Valimukkam no leaves or fruits appeared to be preserved, but only the stumps and detached branches and twigs imbedded around the stumps. The wood is of the colour of bog oak, but is in a far softer and more pulpy condition. The specimens I collected were utterly ruined by slight pressure before I could dry them. The disposition of the roots with regard to the stems was not sufficiently characteristic to allow me to recognise the trees represented, but they seemed all very similar. Oysters and other marine shells were, as already mentioned, seen in the black clay, but I picked up on the beach,

A bone ornament out of the forest bed.

or rather out of the ripple of the wavelets, a small bone ornament, a pendant very much like a rude ear pendant, perforated at the smaller end, and with a couple of lines incised all round, each at some little distance from the end. This pendant—the only quasi-prehistoric bone ornament I have found in South India—was, when found, partly surrounded by the black clay and presented every appearance of having been washed out of it very recently. It was very late in the day when I made this find, and I was too weary to make any further search at the time, besides which I had many miles yet to march to a new camp. Unfortunately I had no time to re-visit Valimukkam bay, gladly though I would have done so, for it is a spot that certainly calls for very

close examination as it may yield prehistoric remains of man, if nothing else. The tree stumps have a diameter of from 1½ to 2 feet at base of the bole which is broken off in all cases seen by me. The natives of the place said the stumps were those of a tree called "Kanna Maram" which I have not been able to identify. From the position of this submerged forest two inferences may be drawn, either that there has been a depression of the ground since the forest was in full growth, or (what is less likely) that the trees grew in a hollow below sea level which was fomerly rather inland, for trees of such size were not likely to have grown close to the sea.

South of the muddy bottomed creek which opens into the sea to the north of the village is a very low bank of dark coloured clay, full of Potamides and other littoral marine shells, in very excellent preservation. It is just raised above highwater mark.

CHAPTER IX.

SOILS.

In most regions the soils forming the surface of the country are reckoned as amongst the youngest geological formations recognisable. In Tinnevelly, however, this is certainly not so as concerns one of the two principal varieties of soil, which variety (the red one) is distinctly older than some of the æolian or wind formed rocks.

Two groups, red and black.

The two great groups into which the soils found in Tinnevelly and Madura may be divided are the red and the black. Other varieties occur, but they may safely and conveniently be reckoned to one or other of the great sections. Of the two, the red soils are certainly the older section as will be shown in the next chapter. In point of extension the red soils occupy by far the the larger area, but the area of the black soils is also very large and very continuous in the southern parts of Madura and north-eastern parts of Tinnevelly.

The cotton soil area.

The south of Tirumangalam taluq and south-west of Rámnád zemindari in Madura and

the Satur, and nearly the whole of Ettiapuram zemindari in Tinnevelly are occupied by cotton soil, which also extends over the minor zemindari tracts near the mouth of the Vaipar and well down into the Ottapiddaram taluq. A number of small isolated patches of regur occur scattered over the alluvial beds of the Vaigai valley, and four small but well marked patches are to be seen resting on the gneiss to the south of Palamcotta. These are the Rettiapatti (Ruttiaputty), Sevandipatti (Shaminthaputty), Karseri (Caursary), and Monanjapatti patches, of which the last is the largest but only covers between 5 and 6 square miles of surface.

Outlying patches south of the Tambraparni.

Over the great area occupied by the lateritic and alluvial formations to the north-eastward of the Gundār, which river is, roughly speaking, the eastern boundary of the great regur spread, but few small patches of black soil are to be seen, and all are of small size. Some, if not most of them, are not true regur, or old forest humus, but are the remains of old swamps or jhils, and the bottoms of old irrigation tanks which had become disused and gone to ruin; all these lie in very low positions, often in regular hollows. The old forest humus on the contrary is constantly found in greatest force on the higher grounds and along watersheds. No connection between the regur and the underlying rocks was found anywhere, and in this respect the southern regur agrees perfectly with the great spreads further north in the Carnatic, the Ceded Districts, the Raichur Doab, and the South Mahratta country.

Patches of black soil over the alluvial area east of the Gundār.

In the matter of colour there seems to be a slight difference between the general appearance of the Tinnevelly regur and that of some of the most typical spreads in the Ceded Districts and South Mahratta country; the former is as a rule less intensely black than the latter, and as far as can be judged from rather cursory inspection generally of lesser average thickness. The greatest measured thickness of true regur noted was at Wadda Karai hill south of Satur (Chatur) in Northern Tinnevelly and very nearly in the centre of the great regur areas. Here about 14 feet of pure regur was

Thickness of the regur spreads.

cut through in making an excavation for some railway work.[1] The average thickness is far smaller, and may probably be set down at about 4 feet or rather less. The base of the regur bed is here as in other places often highly calcareous from the presence of a large accumulation of small gravelly kankar.

No fossils in the regur.

No organism of any kind was seen in the regur of Madura and Tinnevelly districts.

Varieties of red soil.

The red soils being generally the product of decomposition *in situ* of underlying ferruginous rocks, vary considerably in character. Over hornblendic and other ferruginous forms of gneiss they are very ferruginous. Near the great and conspicuous beds of granular quartz rock the soil is very gritty and of pale red colour. The soil derived from the decomposition of the highly silicious variety of gneiss, such as that which I have called the Cape Comorin type, is very sandy and of pale reddish colour. A very remarkable formation of deep red loamy soil occurs in a band several miles in width along the foot of the Southern Ghâts, especially in the bay-like recess formed by the great curve of the mountain-range to the north and west of Kuttalam (Courtallum). This is very probably a pluvial deposit brought direct down from the mountain flanks, but it has not been sufficiently examined (because mostly out of the limits of the area surveyed up to the present) to have enabled me to form any positive opinion as to its origin.

Red loam along the base of the Ghâts.

White-ants' nests.

A very remarkable feature connected with the red loamy soil, which covers so much of the surface in the south-western part of Tinnevelly District, is the enormous number of white-ants' (Termites) nests. They are often so numerous as to affect very strikingly the character of the fore-ground of the landscape as their generally large size and bright red colour make them very conspicuous objects. They attain a height very generally of from

[1] I am indebted for this fact to Mr. Spalding, C.E., of the South Indian Railway, who further had the kindness to lay down the course of the railway on my maps with far greater correctness than it is given in the last edition of the Altas sheets.

5 to 8 feet, and occasionally even more, and are two or three shades brighter in colour than the general surface they stand on. Especially conspicuous are they on the tract running south along the foot of the ghâts nearly to Cape Comorin. Termites flourish here as nowhere else in South India to my knowledge.

Denudation by wind.

The surface of all the soils is considerably affected by the violent winds blowing over Tinnevelly during the south-west monsoon, and fresh ploughed fields especially are strongly denuded by the almost incessant south-westerly gales. Great clouds of red sand and dust are carried eastward towards the coast, and there meeting with the fresh sea breeze are dropped and give rise to the red sand hills or teris which will be described further on.

Origin of the teris.

These teris form a line along the coast from near Cape Comorin to a point several miles south-east of Rāmnād. The red dust carried by the south-west monsoon is known to have reddened the sails of coasting craft passing through the Pamban channel; it has also visibly reddened the pale calcareous grit stone (from the Panamparai quarry), of which the great Tiruchendur temple is built.

Great red dust clouds.

During a visit to Kuttalam (Courtallum) in 1869, I noticed on several occasions that the eastern horizon seemed to be on fire, so vividly did the evening sun light up the great clouds of red dust driving before the south-west monsoon gale. Enormous tongues of flame leapt up in the air while the non-illuminated parts of the dust clouds simulated smoke, and the whole scene bore a marvellous resemblance to a terrible forest fire for which, indeed, I mistook it at first, but was informed of its real nature by a friend intimately acquainted with the whole Tinnevelly country. These clouds of red sand and dust are clearly the source of the line of teris which stretches along the Rāmnād coast from Melmandai to Muttupetta.

White and saline soils.

The saliferous white soils which are so common in other districts, though not unknown in Madura and Tinnevelly, are not of sufficient importance to require any special notice here.

CHAPTER X.

ÆOLIAN FORMATIONS.

Blown sands, teris and coast dunes.

Red sands or teris; white sands or coast dunes.

There is no part of the south of India in which blown sands play so large and important a part as in Tinnevelly district and along the south coast of Madura. They are of two kinds, differing both in colour and origin—the red sands or teris, and the white which are ordinary coast dunes. Of these the former are the more interesting as well as the more important,—the more interesting as some obscurity has hitherto attached to their origin, the more important as occupying a considerably larger area than do the coast dunes.

I have already in the foregoing chapter mentioned my belief that the teris owe their orign to the action of the heavy and continuous gales prevailing during the south-west monsoon on the broad belt of deep red loam which skirts the eastern base of the ghāts. By these fierce winds the dry surface of the loam is swept clean, and vast clouds of red dust carried away to the eastward and dropped near the coast. These gales blow in some years for nearly four months without ceasing, so their effect is far greater than that of the north-east monsoon, which is much less violent and often fixes the loose sands by heavy showers. The teri sand is mainly composed of grains of quartz with an admixture of fine red clay dust in very variable quantity. A small and varying percentage of minute grains of magnetic iron is also of general occurrence in the teri sand. From the red colour of the sand one might not unreasonably expect to find a large quantity of garnet sand in it, especially as small garnets are of such extreme commonness in the gneiss of Tinnevelly district. In reality, however, garnet sand does not occur in pure teri sand, at least I have examined scores of specimens from many teris with a pocket lens and never noticed a speck of garnet among the quartz grains.

The red colouring of the quartz grains is entirely superficial, a coating of ferric oxide probably derived from the deep red loam in which

they were originally imbedded, and is easily removed by hydrochloric acid. The grains of sand are well rounded.

From the description given of the red sands of the Nefûd or great desert in northern Arabia, by Palgrave and by Lady Anne Blunt, and quoted in the paper on these sands read before the Geological Society of London (Quar. Jour. Geol. Soc. London 1882, Vol. xxxviii), it is clear that the teris bear a great resemblance, though on a very much smaller scale to the hills of blown red sand of the Arabian desert. The "fuljes" or horse-shoe shaped hollows do not occur characteristically in the teris, probably because of their much smaller extent and dimensions as compared with the vast ridges and hills in the Nefûd. It is unfortunate that the notes on the Arabian red sand tract contain no hints to help in explaining the origin of such deposits.

Teris known only in two other regions.

Teris, as the red sand hills are locally termed in Tinnevelly, are unknown in many districts of the south, and have been described by the geological surveyors from only two other districts—the north-western part of Nellore district and the southern part of Travancore.[1] In the former case they are of very small extent, and in the latter they appear to be rapidly losing their character as true moving sands, owing seemingly to the exhaustion from some cause or other of the supply of fresh sand.

Kotapalle teri.

The most southerly teri we have to deal with in Tinnevelly is a narrow strip close to the coast beginning at the extreme south point of the district 5½ miles north-east-by-north of Cape Comorin. The southern part of this strip stretches for nearly a mile south-westward into the Travancore State. This narrow ridge is about as high as the equally narrow ridge of white coast dune which lies between it and the beach. There is hardly any intermixture of the two sands, and the two ridges run on together with hardly any break for some 5 miles to beyond

[1] See Mem. G. S. I., Vol. XVI, p. 101 on the Geology of the East Coast from Lat. 15° N. to Masulipatam, by R. B. Foote, and Records G. S. I., Vol. XVI, p. 31, on the Geology of South Travancore, by R. Bruce Foote, F. G. S., Deputy Superintendent, Geological Survey of India.

the village of Panjell; there the coast dune becomes rather discontinuous, but the teri continues in a very narrow strip skirting the south side of the western limestone plateau at Kudung Kulam. It then becomes rather intermittent, but re-appears feebly to the north of Idindan Karai (Idding Kurra).

Kuttan Kuli teri.

Beyond the Viziapatti (Vissiavethee) creek both the coast dune and teri reappear in force on its north side, and the former rises to the height of some 80 feet above sea level as it approaches the village of Kuttan Kuli (Kothaungculle). This teri is of the darkest red colour that I saw, and the sand much the most highly ferruginous, containing as it does a very large percentage of magnetic iron sand. The height of the teri appears to have been considerably greater at one time, but has in parts been greatly and visibly diminished by wind action. Many of the palmyras or fan palms which grow on the teri have had the sand denuded away from around their roots till they now

stand perched on great cones of fibrous roots 6 to 10 feet high, as shown in the diagram sketch.

In several places where the teri has been deeply cut into by wind action, banks of dull Indian-red loam are seen to be exposed, which show distinctly their true æolian origin by the peculiar false bedding, often at very high angles, observable among blown sands. This teri, like most of those in South Travancore which I described in my paper on the geology of South Travancore,[1] is in a state of degradation; only a thin sprinkling of sand on the surface of the teri is now affected by the wind. The main mass has been partially solidified or fixed by the action of rain water percolating from the top aided by the action of heavy showers, which have fallen on the surface and washed the lighter clayey and smaller, though heavier, ferruginous particles down the slopes or into hollows where on drying a fairly hard, often slightly glazed surface of dark red loam has been found. This loam is very fairly fertile, and soon becomes covered with vegetation, which further helps to defend the surface against wind action. The loose sand when deprived of the clayey and finer ferruginous particles, unless unusually coarse in grain, is carried off by extra high winds, or remains on the surface in shallow barren wreaths of lighter red colour. This Kuttan Kuli teri shows more of the fixed loam formation than any of the other teris eastward of Cape Comorin, and less of the rich loamy form of the loose sand.

The teri north of Kuttan Kuli saltpan creek offer no special features worth noting. It runs up to the estuary of the Nambi-ár, and has greatly covered up the shelly grit beds occurring there.

Iddayangudi teri.

Immediately on the east side of the Nambi-ár estuary begins the great Iddayangudi teri which extends north-eastward for fully 15 miles, and increases till it reaches the south end of the Taruvai lake. At its western extremity it is a mere narrow strip, but increases in width after a couple of miles, and then runs on with an average width of about 2 miles till it

[1] On the Geology of South Travancore, by R. Bruce Foote, Deputy Superintendent, Geological Survey of India. Records, G. S. I., Vol. XVI, pt. 1, 1883, page 32.

touches the Taruvai lake. Beyond that it narrows considerably, and to the north-eastward of Sittankudi sinks down into the red sand plain. This sand plain, however, consists equally of the red sand and covers a large area on either side of the Karameni-ár as shown in the map.

The elevation of the eastern part of the Iddayangudi teri is considerable, probably not less than 150 to 180 feet above sea level. How much of this is absolute sand is hard to estimate, but it seems likely that it is in part underlaid by a ridge of marine grits like the Kudung Kulam plateaus, a view which is supported by the fact that an outcrop of limestone was noted about a mile and a quarter east of the Nambiár end of the teri, and at a considerable level (50 or 60 feet) above the alluvial plain to the north.

The Taruvai lake.

The fact that the Taruvai lake is due to the natural dam formed by the sands of the teri which surround it on three sides has already been adverted to (page 5). The view across this lake from the high teri to the south-east of it is a very remarkable one and possibly unique. I came upon it suddenly when crossing the teri northward from the coast between Elanqué and Talai (Periatulla) early in the morning of a beautifully clear day in April 1881, and bitterly regretted I had no sketching materials with me. The immediate foreground consisted of a long slope of pure red sand studded with a few palmyras and banyan trees, and stretching down to the blue and silvery surface of the lake which was framed to the north and west by the rich and varied greens of the great forest of palm trees so eminently characteristic of south-eastern Tinnevelly. The south side of the lake was formed by the continuation of the red sand slope broken here and there by clumps of palmyras and small banyan trees which seem to thrive very fairly in the sands. In the mid-distance rose above the palm forest a line of high red sand hills, the Ittamoli or Sathan Kulam teri, then a widespread plain also densely covered with palm forest stretching away 20 miles to the foot of the mountains, of which a glorious chain stood up blue and sharply cut with

the peak of Mahendragiri and its magnificent twin cliffs[1] in the centre. Nowhere else have I seen a landscape in which pure and intense red forms such bold contrasts to the green of the mid-distance and the varying blue tints of the back ground and sky. It must be seen to be realised. The red sand of the teris is of a very vivid colour in general, especially when seen in bright sunlight at a moderate distance. On this occasion the sands in the foreground could only have been represented by shades of subdued scarlet, those in the mid-distance by slightly paler scarlet with a dash of rose madder. The whole scene was one of extraordinary brilliancy and beauty.[2]

Ittamoli or Sathan Kulam teri.

The Ittamoli or Sathan Kulam teri is, though not quite the largest, certainly the finest and most picturesque of all the teris. It is also (I believe) the highest, having an elevation of 219 feet at the Great Trigonometrical Station in its centre. Its superficial extent cannot be much less than 20 square miles; so there is abundant room for the display of all the peculiarities of æolian formation. The movements of the sand would appear to be more active here than in any of the other teris. Certainly at the time of my visit to its highest part I noticed many more freshly-formed drifts than in any of the other teris. The sand waves on the higher parts of the teri do not average more than, if so much as, 20 feet in height, and are far from regular in shape or direction of advance; the distribution of the sand in falling over being evidently much affected by eddies in the wind.

I have already mentioned above (page 63) that I was unable to find the inlier of marine limestone mentioned and mapped by Bishop Caldwell, which was doubtless covered by one of the sand waves I saw. The approximate locality for that inlier to be found at is not very

[1] These two splendid cliffs which are bare faces of gneiss 1,800 to 2,000 feet in sheer heights are really the east end of a great spur, but as seen from the east seem part of Mahendragiri itself.

[2] In the hope of getting a sketch of this very remarkable landscape, I re-visited it in the beginnnig of this year, but the weather was unpropitious and dull, and the mountains showed very faintly; so half the charm of the view was gone.

far from the highest part of the teri, it follows, therefore, that the teri has been deposited upon and around a mass of marine limestone elevated not much less than 200 feet above sea level, consequently the true thickness of the mass of red sand is certainly in parts very much less than the apparent mass.

Megnanapuram teri or Kudirai Moli.

The great teri north of Megnanapuram, also known as the Kudirai Moli, is rather larger in superficial extent than the Ittamoli teri just described, but it is less elevated, and showed at the time of my visits (in January 1883) many fewer signs of recent movement of the sandwaves. It also appeared to me of a rather less vividly red colour than any of the other large teris.

Thickness of the teri.

Here too there are signs that the sand rests in part at least on an elevated mass of the marine sandstone series. Still I think it will be safe to estimate the maximum thickness of the sand at somewhat over 100 feet.

Drainage of the teri.

Kudirai Moli, as this teri is called on the map accompanying the District Manual, shows markedly a phenomenon common to all the teris, namely, the issuing from their base of springs of some size due to the percolation from above of all the rain falling on the surface. It is only in exceptionally heavy rains that any water flows off the surface of the sands; all other rainfall is absorbed at once and flows out around the base quietly and continuously. Along the northern side of the Kudirai Moli advantage is taken of these springs, and channels are excavated to some depth, sometimes as much as 12 feet or more, to meet these springs and conduct their water for irrigation purposes to fields and gardens in the neighbourhood. These channel sections reveal that in many places the percolation of the rain water has given rise to a cementation of the mass of ferruginous and silicious particles into a quasi-lateritic agglomerate.

Teris north of the Tambraparni.

The teris north of the Tambraparni river are quite small and unimportant comparatively speaking. The little teri north of Panavalli church is low and ill-defined. The next to the northward, which lies not far west of the large mis-

sionary station (S. P. G.) at Sawyerpuram, is like the Kuttankuli teri in a wasting condition. It is of considerable interest, however, from the fact that it contains proof of the residence of pre-historic man in that quarter. On the southern side of the centre of the teri is a hard loamy surface exposed by the removal of some 15 or 16 feet of the blown sand. On this surface I had the good fortune to find numerous small cores and flakes of a reddish chert quite foreign to these parts, and with them fragments of burnt pottery showing a distinct pattern. A few flakes of limpid quartz were also found. The cores are of the same pattern as those found near by Jabalpur and described by Sir Charles Lyell. This teri is highly ferruginous.

Sawyerpuram teri.

Find of chert cores.

A considerable spread of quite low hillocks of deep red sandy loam is traversed by the road from Palamcotta to Tuticorin, after crossing the small Madagiri river.

To the north-west of Tuticorin the road to Ettiapuram passes through a tract of low wavy mounds of loamy red soil which have a rather teri-like aspect.

North of the Malletar Odai or Veddanattam river the line of teris rends north-eastward and continues more or less parallel to the coast to its further end.

The Kollatur and the western part of the Melmandai (Mailmuntha) teris, though quite unmistakable in colour, are generally very low and greatly overgrown with thorny scrub jungle. The north-eastern end of the Melmandai teri is considerably more elevated, and though much jungle covered, there are several wreaths of brilliant red sand showing over the jungle.

Kollatur and Melmandai teris.

The Sivalpatti (Shevelputty) teri is by much the largest in the Madura country, but is much overgrown with thorny scrub. The south-westerly corner, however, close to the village and crowned by a small American Mission chapel, forms a conspicuous ridge of very ferruginous red sand, from

Sivalpatti teri.

which a very extensive view is obtained over the great alluvial flat to the north. The northerly ridge of the Sivalpatti teri continues high and well marked for some miles, but then sinks down with the alluvial plain. Sivalpatti village is incorrectly shown in the map; it stands on the east side of the Up-Ar (Hoop Aur) nullah.

The small teris at Sailagudi (Shoylagoody) on the banks of the Gund-ār and at Selvanallur (Mala Shelvanellor) require no special notice,

Rajakapallem teri.

but the Rajakapallem teri requires some attention from its remarkable length and narrowness, and also from the fact that the colour and constituents of the sand ridge show that the great purity of the red sand prevails no longer as the source of the same is left behind more and more. The sand has become considerably calcareous, and a tendency to solidification by concretion with a calcareous cement becomes visible. The very vivid red colour is decreasing, and this decrease continues as the ridge is followed past Yeravadi to Kila Karai, while to the eastward of the Kova Kulam (Covacolum) creek the teri sands gradually become paler and paler, and finally can no longer be distinguished from the impure coast dune sand of the Tonitorai peninsula. The most easterly sand hill that I have mapped as a teri is a ridge some 4 miles south-east of Rāmnād, the sand of which can only be termed reddish.

The only organic remains found in connection with the teris were some

Fossil wood, &c., in a teri.

fragments of calcified exogenous wood discovered on an exposed mass of hard red loam in the hollow between two great sandwaves on the high teri about $2\frac{1}{2}$ miles east-south-east of Nazareth. The fossil wood was accompanied by some fossil shells and casts of the living *Helix rittata*, the common snail of this part of India.

That the advance of the teri sands has from time to time caused

Movements of the teris.

mischief by burying fields and gardens and occasionally houses, is well known, but much has been done to check its advances by extensive planting, and much more may yet be done; it may not be too much to say, that as the population

increases, the whole waste will eventually be reclaimed, for the teris are by no means barren sand heaps. Mixed with the silicious grains is very frequently a percentage of fine red clayey matter large enough to make in the presence of sufficient water a very fairly productive soil.

Rate of advance of teris.

The rate of advance of the sands on the Ittamoli (Sathankulam) teri has been conputed by Lieutenant-Colonel Branfill, Deputy Superintendent, Great Trigonometrical Survey, to have been 1,000 yards, or nearly 17 yards a year during the 60 years which elapsed since Colonel Lambton (in 1808-9) fixed his Trigonometrical Station (Red Hill Station of Atlas sheet) on the top of the teri. In the four years, however, from 1869 to 1874, the advance was only at the rate of 6 yards a year. In both series the direction of the advance was the same, namely, towards the east-south-east.

Coast dunes at Manapād.

The greatest developments of the coast dune sands in Tinnevelly has been along the coast from a village called Talai to Manapād point. Here the sands, which form a high ridge and are extremely calcareous from the great quantity of comminuted shells they contain, have been to a great extent solidified in some places perfectly, and others imperfectly. In many places the action of the high westerly winds has carried away the loose sand from the consolidated part and left the latter standing up in strangely shaped masses. This process of consolidation has gone on much more strongly near the eastern end of the ridge probably because exposed to heavy spray drifts during storms in both monsoons. The rock formed here, which often contains marine shells as well as specimens of *Helix vittata*, is hard enough to be used for building purposes.

Consolidation of sands.

The Manapād sand ridge must be fully 100 feet high or more. The sands on the north side of the ridge are quite unconsolidated, and in the village of Manapādu (Manah paud) they have been heaped up amongst the houses and churches in such a way as to render some of them almost untenantable. Some small buildings are said to be quite

covered, and among them the grave of the celebrated Jesuit Missionary, Father Besche, who, though an Italian, became so proficient in the Tamil language as to write in it poetry of such excellence as to give him a high rank among Tamil poets.

Tiruchendur dunes.

Another important coast dune is that at Tiruchendur, 9 miles to the north-north-east, on and against which has been built the famous Subramania temple, the most important in the district, whose great gopuram is a landmark both by sea and land for many miles around.

The sand-hill rises fully 50 feet above sea level, and has been considerably consolidated by infiltration of calciferous water, and at its seaward end has been converted into a coarse sandstone of sufficient stability to form a low but well marked headland which offers some resistance to the action of the surf that breaks at its foot. It has been cut into a steep cliff, at the base of which is exposed a bed of hard gritty sandstone of similar character to that forming the "quay" along the Madura coast as described above.

The dunes south of Tiruchendur for about 2 miles are much higher than usual, but show no signs of consolidation.

Dunes of the Madura coast,

The coast dunes along the Madura coast nowhere attain any great height; very few, if any, attain an elevation of 50 feet. The highest noted was the dune on the south side of the salt-water lake opposite to Nallatanir Tivu (Nallattume Thevoo). Some large sand-hills occur also to the south of Ervadi (Yervaudy), and to the west of Kila Karai. A great many sand-hills occur at Rameswaram island, and in fact occupy the greater part of the surface there. A great part of them is too much overgrown by trees and shrubs to allow of any appreciable movement, but in the southern part of the island there is a considerable extent of moving sands, while the long spit running out to the south-east is occupied by a double line of high sand-hills which are perfectly bare of vegetation, and therefore subject to the influence of any high wind that blows.

And of Rameswaram island.

The highest point on the island is the great sand-hill north of the

town on which stands the Gandhamāna Parwattam Mantapa, from which an extensive view is obtained, and a very good idea of the extent of upraised coral reef. Some small islets, apparently part of the Adam's bridge shoal, were seen to eastward.

CHAPTER XI.

ECONOMIC GEOLOGY.

The enumeration of the economic mineral products met with in the Madura and Tinnevelly districts may unfortunately be comprised within a few pages; in other words, both districts are poor in valuable minerals.

Iron the only metal.

The metallic minerals are represented by iron ore only, and that not of the highest class. Abundance of an earthy form of hæmatite is to be found in the lateritic rocks in the northern parts of our area, and there are traces of a considerable smelting industry having been carried on at no remote period at Ayangudi in the southern part of Pudu Kottai State (see page 46). The ore treated is clayey red or brown hæmatite of fair quality, of which an endless supply could be obtained in any of the lateritic tracts north of the Vaigai. I could find out nothing about the smelting industry at Ayangudi, which seemed to have been entirely forgotten by the people now living. The country is too bare of forest now to support even the small native smelting works, but it is well known that at the time of the conclusion of the Poligar war in 1803, this region was covered with very extensive jungles through which our armies had to cut roads with great labour, *e.g.*, at the siege of Kalayar Kovil.

Old smelting industry at Ayangudi.

No signs of any iron smelting industry on a large scale, even for native smelters, were seen any where further south, nor did my enquiries obtain me any information of such having existed elsewhere.

The other economic minerals used have been building stones and limestones for making cements and mortars. Of the former there is no lack in most of the gneissic regions, and for coarse work a supply is obtainable in many of the north-

Building stones.

ern laterite tracts, where the hard and massive forms of the rock abound and have been largely used for many purposes, such as walls of temples, and the revetting of the teppa kulams, or temple tanks.

Laterite as a building stone.

Massive laterite was used almost exclusively in building the fine old fort at Kilanelli Kotai, also the fort at Arrantangi in Tanjore district (see page 46). It has also been largely used as road material.

In the Shenkarai and Shahkotai tracts are lateritic quarries in which masses are raised measuring as much as $8' \times 1\frac{1}{2}' \times 1'$, a very large size for a lateritic stone. This is by far the best and most reliable form of laterite I have seen in South India.

The gneisses furnish a great variety of stone, but the most valued forms are the reddish or pinkish-grey granitoid varieties. The quarries most resorted to in Madura for example are those of Tiruparai-Kundram at base of the Sikandur Malai, whence the stone used in building the great Minakashi temple has been procured. Not only is the stone a very handsome one, with its pink and grey bandings, but if well selected it is susceptible of being carved with great delicacy. Masses of almost any size can be quarried.

Gneisses as building stones.

Quarry on the Sikandar Malai.

The westerly extension of the Sikandar Malai beds has been considerably quarried close to the village called Ambalathandi in the map.

About 27 miles to the southward of Madura are the quarries of Arupukotai, where a rich red granite gneiss of great beauty is largely raised, being in much request. Masses of great length, even of 18 to 20 feet, have been procured. The stone if polished would equal the very finest Peterhead granite in beauty.

At and near Arupukotai.

A similar but rather duller red stone has been worked at the Moonooroopoor quarry, 6 miles north-east of the last named. A very handsome, rather purplish-grey massive granite gneiss is procurable from the quarries at Shayalpatti (Shoilputty), 2 miles north-west of Moonooroopoor rock. Handsome banded gneiss of high quality has also been quarried on a rocky hill a mile west of Tirushulai (Teruchooly).

Massive black hornblendic gneiss is quarried at Kotaiparai (Koteaupauræ) hill, 6 miles west-by-south of Arupukotai. At the time of my visit a large monolithic male figure some 10 to 12 feet long was lying in the quarry, having, as I was told, been rejected for some reason or other by the authorities of the Rameswaram temple for whom it had been carved. The figure, which represented one of the minor divinities worshipped at Rameswaram, was a fine specimen of stone cutting, and showed the fitness of the rock for such purposes.

At Kotai parai.

To return northward for a little there is a large quarry of handsome banded gneiss at Puliarpatti, 4 miles east by north of Tripatur; blocks of large size can be quarried here. I measured some nearly 30 feet in length. As the rock is easily quarried and moderate in price as well as very handsome, it is in demand. Large pillars for temple cloisters or for mantapams measuring $12' \times 3' \times 1'\ 6''$, and roughly dressed, were procurable for Rs. 30 on the spot.

At Puliar patti.

The fine black polished pillars in the Judge's room in Tirumal Naik's palace in Madura, and the dark hornblendic rock out of which are carved some of the very elaborate and often bold statues in the great Pagoda, must have been brought from quarries I did not come across, as I saw no rock of the kind. I made personal enquiries of the head temple trustee as to whence they came, but he either could not, or would not, give me any information on the point.

Carved and polished stones at Madura.

Some of the finest and boldest carvings, both of statues and scroll work that can be met with in Southern India, are to be seen at the Avadiar Kovil (temple) in the southernmost corner of Tanjore district, which just comes into the limits of the map accompanying this memoir. The great mantapam in front of the temple gate is an architectural work of great beauty and noble proportions, and well worth the attention of photographic artists, though unfortunately much out of the beaten tract and therefore but very little known. The stone used here is said to have been brought from Tirumayam (Trimiem) and Trikonem in

At Avadiar Kovil.

Pudukotai State, but is more hornblendic than any of the rocks seen at those places.

Turning to the south again, the beauty of the pale highly silicious granite gneisses of the Cape Comorin type, such as those quarried near Kalligudi Chatram Railway Station and at the Waddukarai rock near Satur, have already been mentioned above (page 23).

In many places in both districts are the beds of granular quartz rock quarried but only for road material or for rough stone, as it is perfectly useless for any other purposes.

Crystalline limestone of Pantalagudi, &c.

No use, except as rough stone, appears to be made of the fine crystalline limestone at Pantalagudi (page 21), 35 miles south of Madura, nor of any of the other fine limestone beds at Tirumal (14 miles south-south-west of Madura) or at Shenkotai, 8 miles south of Pantalagudi, though these beds could easily be made to yield an inexhaustible supply of beautiful pale grey, grey and pink, pink, and pink and green marble of high quality.

The Pantalagudi marble had been noticed already in pre-historic times, as blocks of it had been carried at least 3 miles distance to be used with blocks of gneiss and others of laterite in the construction of a group of Kurumbar rings lying to the south-west of Pantalagudi.

The hard sandstone of supposedly Cuddalore age, which lies a couple of miles south-east of Sivaganga, is quarried to some extent as a building stone. The very coarse ferruginous, quasi schistose, sandstone which occurs on the west side of the Sivaganga laterite tract and about north-east of Mannambakkam has been used in long pointed slabs to form small "menhirs" or upright stones in the centres of some Kurumbar rings, the other stones of which consist of rude laterite blocks. The tallest of these three menhirs stands about 7 feet out of the ground.

Coarse schistose sandstone flags used for Menhirs.

The gritty calcareous sandstones and the shelly limestones belonging to the recent marine series are quarried in many places, some of which have already been incidentally named, but others have now to be enumerated. Beginning at

Marine sandstones and gritty beds.

Rameswaram, with the exception of a few statues made of gneiss, the whole of the great gateways and cloisters which surround the inner temple are built of such sandstones. The fine-grained sandstone, of small blocks of which the east and west gopuras are built, I did not see *in situ*, nor did I find out whence it was procured, but the coarser gritty form of which many of the pillars in the cloisters are made, as well as much of the flagging, bears a very striking likeness to the rocks on the Valimukkam spit (page 68) where an immense quantity of quarrying has been done, and the stone raised shipped away. The places left in the rock there are very frequently such just in shape and size as would have been made in quarrying the cloister pillar blocks. Similar quarry remains were noticed in the sandstone "quay" east of Kila Karai, but on a much smaller scale and in an inferior kind of rock.

Rameswaram temple.

Quarries at Valimukkam.

The fine blocks of gritty calcareous sandstone raised at Vedanattam to the north of Tuticorin are largely used for building in that town. Fine cattle troughs, &c., &c., are also made at the quarries.

At Vedanattam.

For rough building purposes the Tutikorin people employ large quantities of coral rock which is procured from the island to the north of the lighthouse.

The fine cream-coloured or brownish calcareous sandstone or grits obtained at Panamparai on the south-western side of the great Megnanapuram church has been employed in the construction of the great temple at Tiruchendur already referred to, and also in the building of the stately gothic church designed and erected at Megnanapuram by the late Revd. J. Thomas of the Church Missionary Society. The same quarry is now furnishing very fine stones for the rebuilding of the church at Mudalur by the Revd. H. B. Norman of the S. P. G.

At Panamparai.

When completed, this will be the third large gothic church built in this quarter, the second being the fine church built at Iddayangudi by

Bishop Caldwell from the cream-coloured calcareous grit quarried near Thissianvillai on the south side of the great Ittamoliteri. These three noble churches show the capabilities of the stone used to great advantage, for they are buildings of which even large towns in England might justly feel proud. The churches are built almost entirely of stone.

At Thissianvillai.

The last locality to be mentioned where these marine beds are being quarried is at Kudungkulam, where some of the stone is equal to that from the quarries just named. Only smaller objects, such as verandah posts or lamp posts, door frames and steps, troughs, &c., &c., were being turned out at the time of my visit.

At Kudungkulam.

The massive tufa, of which so much was said above, is only used as rough stone, or for burning into lime. Elsewhere lime is obtained by burning the nodular tufa or kankar.

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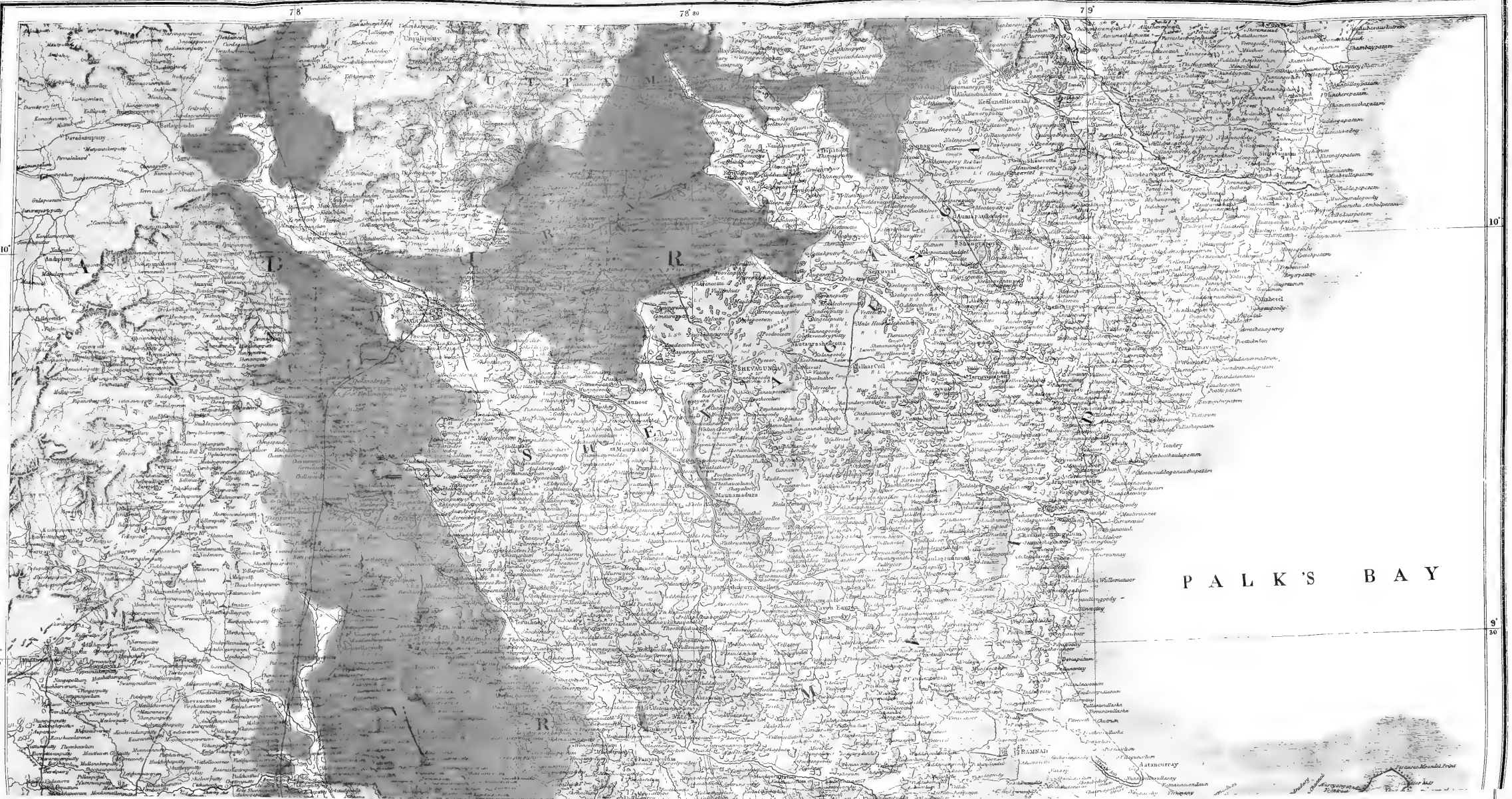
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Manamadura
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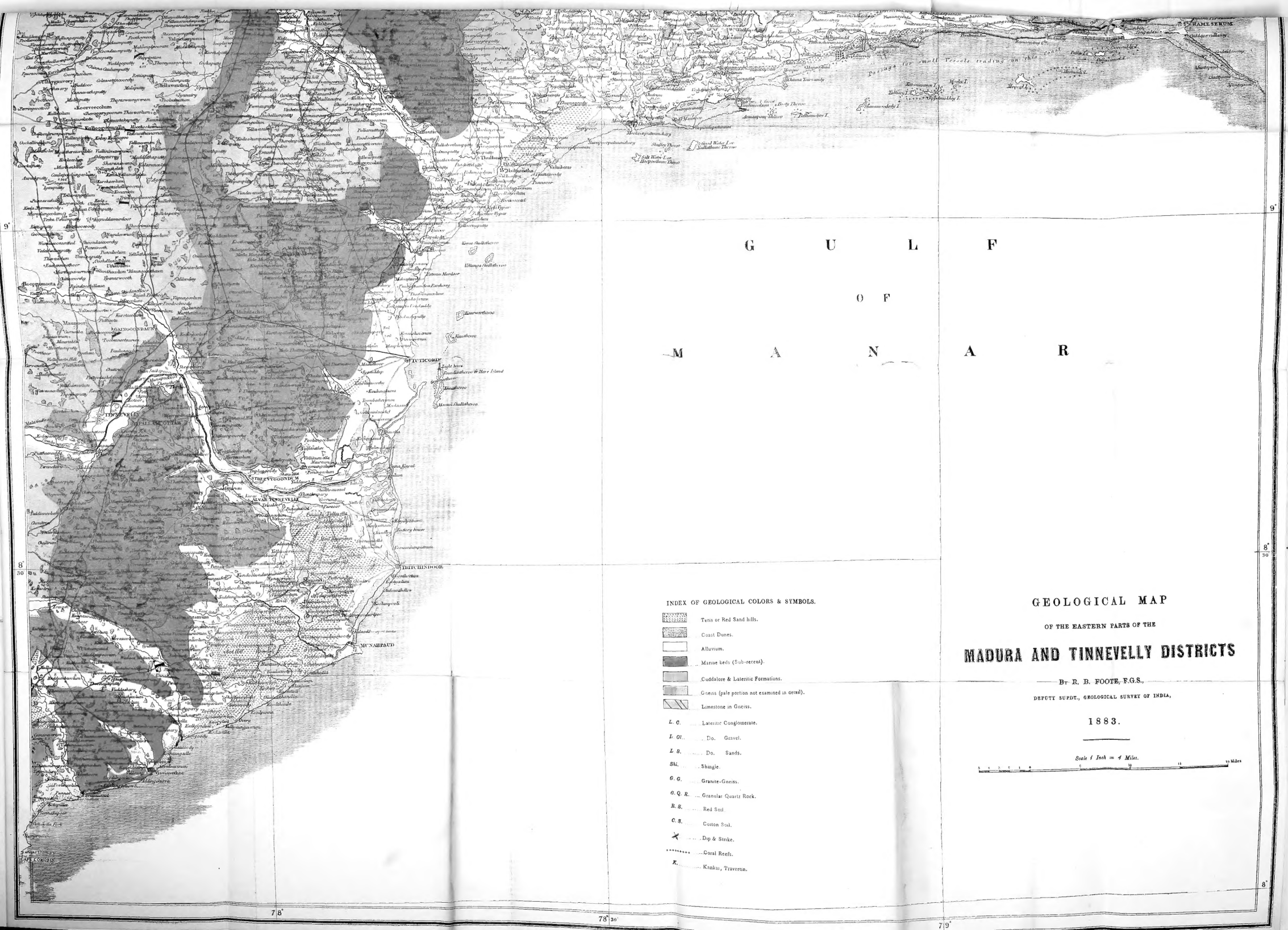
G U L F
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M A N N A R
INDEX OF GEOLOGICAL COLORS & SYMBOLS.
Teris or Red Sand hills.
Coast Dunes.
Alluvium.
Marine beds (Sub-recent).
Cuddalore & Lateritic Formations.
Gneiss (pale portion not examined in detail).
Limestone in Gneiss.
L. C. Lateritic Conglomerate.
L. Gl. Do. Gravel.
L. S. Do. Sands.
Shi. Shingle.
G. G. Granite-Gneiss.
G. Q. R. Granular Quartz Rock.
R. S. Red Soil.
C. S. Cotton Soil.
Dip & Strike.
Coral Reefs.
K. Kankar, Travertin.
GEOLOGICAL MAP
OF THE EASTERN PARTS OF THE
MADURA AND TINNEVELLY DISTRICTS
By R. B. FOOTE, F.G.S.,
DEPUTY SUPDT., GEOLOGICAL SURVEY OF INDIA,
1883.
Scale 1 Inch = 4 Miles.
9°
8° 30'
78°
78° 30'
79°