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Captain Newbold

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ART. VII.—*Summary of the Geology of Southern India.* By
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Kurnool.

[Read June 15, 1844.]

PRELIMINARY PHYSICAL SKETCH.

AREA AND GEOGRAPHICAL POSITION.

THE area, the geological features of which it is purposed to attempt a description of, so far as known, comprises peninsular India from Bombay on the west, and Ganjam on the east coast, to Cape Comorin, lying between the 8th and 20th degrees of north latitude. Its northern limit is skirted by the Sub-Vindhyan ranges, and the plains of Central India; while the remaining sides are washed by the ocean, and lie within the 72nd and 86th degrees of east longitude.

GENERAL PHYSICAL FEATURES.

The prominent physical features of this extensive tract have originated in the elevation of two mountainous ranges, marking irregularly the coast lines, and termed the Eastern and Western Ghauts; which support on their Atlantean shoulders, and inclose as in a massive framework, the intermediate table lands, at an altitude varying from 500 to 3000 feet above the sea's level.

From the basis of both these chains tracts of low land, with irregular and often abrupt elevations, varying from a mile to seventy in breadth, extend to the sea, and have been expressively styled by Mahomedan writers Payeen Ghaut, or land at the feet of the Ghauts, in contradistinction to the table lands, which they name Bala Ghaut, or land above the Ghauts.

WESTERN GHAUTS.

The elevation of the Western Ghauts commences in Khandesh, where it meets that of the Vindhya beyond the limits of the area under description; thence, pursuing a nearly south-by-east direction, interrupted by the singular gap of Paulghautcherry, it terminates a little above Cape Comorin, near the Amboli Pass, in a bluff granite peak about 2000 feet high. A low broken range extends from its

base to the southern extreme of the peninsula. The extreme ascertained elevation of the Western Ghats above the sea occurs in the Nilgherries,—a little above the gap of Paulghautcherry,—8760 feet. Towards the north they rise, in the Mahabuleshwar hills, to the altitude of about 5000 feet. The most striking feature in this great dislocation is the comparatively precipitous façade presented by its sea, or western side. To the east, or inland, it usually slopes away gradually, to the general level of the table lands.

Along part of the base of the western flank gushes a line of thermal springs, which have been traced from the north of Bombay southerly to Rajapore, and probably extend still further south, concealed in the forests that clothe the feet of the mountains. I have found springs of a thermal character at the western base of the Eastern Ghats, with a temperature from 88° to 89° Fahrenheit.

EASTERN GHATS.

The Eastern Ghats are supposed to rise in the vicinity of Balasore, in lat. 21° 30' N. ; and, passing a little to the west of Ganjam, pursue a southerly course to Naggery, where they appear to terminate in the bluff height called Naggery Nose, about fifty-six miles north-west from Madras. Their course is here broken apparently by another line of elevation, which, sweeping irregularly inland, crosses the peninsula in a south-westerly direction by Chittoor, Sautghur, and Salem, and joins the Western Ghats north of the gap of Paulghautcherry. The southerly direction of the first-mentioned elevation line is marked at intervals along the Coromandel coast by outliers and detached hills, and reappears in the almost contiguous island of Ceylon as a continuous mountain range. There is little doubt from this and other geological reasons, that Ceylon was raised above the ocean by forces similar to, and contemporaneous with, those that elevated the peninsula.

It is worthy of remark that, while the steeper declivities of the Western Ghats face generally towards the sea, those of this cross range, or rather break in the continuity of the elevation, have usually a southerly aspect.

Below, or south of this great break, which I shall call that of Salem, the Eastern Ghats, as just stated, lose the character of a chain, and reappear at intervals in detached hills, groups, and clusters, while the general level of the peninsula ceases to be sustained as a continuous table land. Some of these clusters rises to a considerable altitude: the Pulney Hills attain an elevation above the sea's surface of between 6000 and 7000 feet; isolated patches of table land not unfrequently

occur on their summits. The average elevation of the Western Ghauts may be roughly stated at 4000 feet, and that of the Eastern at 1500 feet.

Geographically speaking, these great chains are separate and distinct; but, in a geological point of view, after a careful and extended examination of the intervening table lands, I am inclined, until further evidence be adduced, to regard the Western Ghauts south of Malwan, the Eastern Ghauts and their table lands, as part of one magnificent elevation of plutonic rocks, by a succession of efforts, during a period which may be termed plutonic, breaking up the hypogene schists; and, in some instances, uplifting aqueous beds of a more recent origin.

The true general direction of this elevation is nearly N. 5° W. though the apparent directions of the lateral chains on its flanks are, as we have noticed, to the east and west of north respectively.

PHYSICAL ASPECT OF TABLE LANDS OF SOUTHERN INDIA.

The surface of the table lands between these chains, extending from the Salem break on the south, and comprising the elevated plains of Mysore, the Ceded Districts, the South Mahratta and Hyderabad countries, and the Dekhan, ably described by Colonel Sykes, though usually presenting vast plains, which to the eye often appear perfectly horizontal, has a general inclination easterly by south towards the Bay of Bengal, into which the principal rivers empty themselves. This gentle inclination, often assisted by cross lines of elevation, determines the great drainage lines of the country, throughout our area, east of the Western Ghauts, and beyond it to the northerly slopes of the Vindhya, whence another system of elevation and drainage commences. Every traveller, who has ascended the Ghauts, is struck by the singular appearance, in plutonic areas, of detached hills, and clusters of hills, starting up abruptly from the surface of the flat plains spread before him, with little or no tali, presenting a *coup d'œil* which has caused the not inapt comparison of a table with tea-cups here and there reversed on its surface. These hills are usually naked masses of gneiss or granite, and seldom rise above 500 feet from the level of the plain. Some few exceed 1200, and the highest not 1800 feet; many have been selected by the natives as the sites of the Droogs or hill-forts so celebrated in the annals of Southern India.

The mean elevation of the table land around Bangalore and Nundidroog above the sea is 3000 feet. Northerly towards Hyderabad it sinks to 1800 feet; and a little south of Bangalore it falls, by rather abrupt steps, to the level of the plains of Salem and Coimbatore, (viz. 1400 feet,) whence, to Cape Comorin, the mean height of the country

is about 400 feet. The average height of the low country between the Ghauts and the sea, on both the coasts of Coromandel and Malabar, may be roughly estimated at 200 feet, rising at the base of the mountains to 800 feet. Nothing can be more contrasted than the aspect of these coast tracts: while the former presents an open and comparatively bare, sandy plain, gently rising towards the interior, the monotony of which is diversified by a few detached hilly clusters, palm, cocoa-nut trees, and topes, planted by the hands of man; the latter is broken up by a succession of low irregular hilly spurs, separated by narrow marshy flats, covered with eternal forest, and often descending to the sea in precipitous cliffs.

Through these flats and ravines a number of mountain torrents stream, in the monsoon, from the Ghauts' steep sides; and, after a short but rapid course, rarely exceeding fifty miles, fall into the sea. North of Malwan, owing to the different geological character of the country, the physical aspect of the Western Coast undergoes a considerable change, being less clothed with forest, and its lowlands generally not so much elevated above the sea. According to Colonel Sykes' this part of the coast to Bombay, which is usually called the Konkan, presents a long strip of land from thirty to fifty miles in breadth lying between the Ghauts and the sea; the mean elevation of this strip is less than 100 feet, but it is bristled with isolated hills, or short ranges, some of which attain an elevation equalling that of the Ghauts. Numerous shoulders or salient angles are thrown out from the Ghauts on the Western or Konkan side, and by means of these the ascent to Dekhan is effected; with what difficulty, will be understood when I state that the military road of communication between Bombay and Poona up the Bou ghat rises nearly 600 feet in a mile.

RIVERS.

The large rivers of Southern India within our area, viz., the Godavery, Kistna, Toombuddra, Cauvery, and Pennaur, flow from the eastern slopes of the Western Ghauts, and, crossing the peninsula in an east-by-southerly direction, escape through singular fissures in the Eastern Ghauts to the plains of Coromandel, and the Bay of Bengal. The Godavery passes through the break of Papcondah; the Kistna and Toombuddra through that of Beywarah, and the Pennaur through those of Ganjicotta and Sidhout. The Cauvery alone, having descended from the table land southerly by the Salem break, turns

¹ Geology of the Dekhan, Transactions Geological Society, Second Series, vol. iv., pp. 409—432.

easterly and falls into the sea below the southern termination of the Eastern Ghauts as a continuous chain. The Paniani, and the mountain streams that rise west of the anticlinal ridge, or watershed of the Western Ghauts, run westerly into the Indian Ocean. These fissures, and cross valleys, run nearly at right angles with the elevation line, and offer striking illustrations of the correctness of Mr. Hopkins's theory of the origin of the cross valleys of the Weald, a district, part of which I had recent opportunities of observing, during a brief visit to Europe. The great Himálaya chain appears to present similar phenomena on a scale of greater magnitude.

The gap of Paulghautcherry, previously mentioned, is evidently a continuation of the Salem and Nilgherry break, near the southern base of whose lofty precipices it opens an easy commercial road of communication between the interior and the sea. It would almost seem, that the strata of crystalline schists had been here broken asunder, across their direction, and to their very foundations, by the unusual energy evinced by the upheaving forces in the neighbouring elevation of the highest peaks of the Western Ghaut chain, viz., those of the Nilgherries and Koondahs, and that the shattered sides of this great rift had been swept away, and its aspect modified, by the current of the retiring ocean, above whose waves the granitic and hypogene summits of the Ghauts then first emerged.

The gap is from sixteen to twenty miles broad, narrowing towards its eastern extremity, the surface tolerably flat; and the descent from the plains of Coimbatore and Salem to the Malabar Coast, so gradual as to be almost imperceptible. Its height about the centre, roughly approximated by means of the boiling point of water, I found to be about 970 feet above the sea's level. It is covered with a reddish soil, mostly sandy, imbedding angular, or slightly worn fragments of the granitic and hypogene rocks, from the detritus of which the soil itself is evidently the result. Bare bosses of these rocks, in many places, protrude from the soil. The rocks on both sides are precipitous, greatly modified in external form by that process of exfoliation and splitting into cuboids, to which granitic rocks, and frequently the crystalline schists in contact, are subject.

It has been stated as a well known fact¹, that ships navigating the Malabar Coast during the N.E. monsoon commonly experience a stronger gale in the neighbourhood of Paniani (a town on the coast nearly opposite the western embouchure of the pass) than elsewhere; and this break in the Ghauts appears to be the cause of this effect.

¹ Madras Almanac, 1840.

During the S.W. monsoon it exerts a considerable influence on the climate of Coimbatore; particularly on that of places immediately east of it, or in a line with its longitudinal axis, by admitting, as through a funnel, and concentrating the full force of the strong westerly winds on the tracts within its focus. Its influence on climate in this respect is felt even farther east than Trichinopoly. At places situate centrically like Bellary between the Ghauts, the force of the monsoons is but slightly felt, from the protection afforded by these great natural barriers.

The influence exerted by the geological features of the regions of India not only over the climate, but over the commerce, government, the moral, social, and physical character of its singular and widely varying population, is in itself a study fraught with the deepest interest, and affords an ample and rich field, hitherto almost untrodden, to the research of the philosopher, and man of inquiry.

It may not be irrelevant to remark, in order to show more clearly the relative geographical position (in a physical sense) of the tract under description, that the whole of the vast continent of India, embraced by the Ganges, the Indus, and the Ocean, may be classed under four great physical divisions, independent of the climatic zones of altitude peculiar to each.

The first is that of *Himálaya*, and its subordinate chains, characterized by a general line of elevation running nearly W. 26° N., and a drainage flowing southerly and easterly into the Bay of Bengal.

The second, that of *Vindhya*, or Central India, with its low plains traversed by the Palamow and Vindhyan ranges, whose general direction is W. 5° S., with a drainage running in a similar direction to the Indian Ocean. This system of elevation serves to determine the drainage of the Himalaya to the east, and that of the plains intervening between its own constituent ranges to the west, from their otherwise natural southerly course.

The third is that of the *Ghauts*, or Southern India, already described, with a line of elevation N. 5° W., and a drainage running easterly and southerly to the Bay of Bengal.

The fourth and last is that of the Indus, flanking those of *Himálaya* and *Vindhya*; the great lines of drainage run S. by W. into the Indian Ocean, from the southern slopes of the *Hindoo Kosh*, whose course appears to be westerly¹.

¹ A fifth might be added, viz., that of *Maláya*, or Ultra-Gangetic India, comprising the Malacca peninsula, part of Siam, and Birma. This immense line of elevation, extending from the foot of the Himalaya system to the verge of the Equator, has a direction almost parallel to that of Southern India, with which it

The above classification is susceptible of a number of subdivisions; many exceptions exist, chiefly arising from local physical causes, but the limits of this paper will not admit of my noticing them here.

I shall now proceed to attempt a sketch of the geology of Southern India, as far as hitherto known, commencing with the inferior stratified, or hypogene rocks, following the ascending order. The plutonic and trappean rocks I have found it convenient to describe in the concluding portion of this paper.

SUMMARY. PART I.

THE geology of Southern India will probably have little interest to the mere student of organic remains, from the extremely limited extent of its known fossiliferous strata; yet the bare extensive surfaces of the granitic, trappean, and hypogene rocks, afford, on a grand scale, exposés, not to be surpassed in any other portion of the globe, of the protean aspects under which these rocks present themselves. The very absence of those fossiliferous beds which so thickly encrust the surface of a great portion of Europe, and many other parts of the world, is in itself a subject of interesting research; and the geological anatomist of the earth's skeleton may, in the peninsula of India, advantageously study a huge and disjointed mass of the nether-formed rocks which constitute the framework of our planet, and which here present themselves almost divested of integument, weathering under the alternations of a vertical sun, and the deluging rains of the tropics. Commencing with these rocks, I shall ascend to those more recently formed, in regular succession.

may possibly be found identical (in epoch.) On its northern portions the drainage is determined southerly by the great westerly elevation of the *Himálaya*; and entering the longitudinal valleys of the *Maláya* system passes southerly along their course to the Indian Ocean. The anticlinal ridge of the chain that runs down the interior of the Malayan peninsula throws off its drainage to the east and west into the seas of China, India, and the Straits of Malacca. The granitic rocks that constitute a great portion of this ridge are remarkably distinguished, mineralogically, from those of Southern India by their highly stanniferous character.

HYPOGENE SERIES.

Extent.—Hypogene schists, penetrated and broken up by prodigious outbursts of plutonic and trappean rocks, occupy by far the greater portion of the superficies of Southern India. They constitute the great bulk of the Western Ghauts, from between the latitudes of 16° and 17° N. to Cape Comorin; and from the base of the Eastern Ghauts, from beyond the north limit of our area, to their deflection at Naggery, Lat. N. $13^{\circ} 20'$. They are partially capped and fringed, in the Western Ghauts, by laterite; and in the Eastern Ghauts, by sandstone, limestone, and laterite.

From Naggery to Cape Comorin, they form, with a few exceptions to be adverted to in due order, the basis of the plains of the Carnatic, Arcot, the Valley of Seringapatam, Salem, Trichinopoly, Coimbatore, Tanjore, Madura, Tinnevely, and Travancore; and, intimately associated with granite, the principal hills and ranges on the low lands south of the Salem break and valley of the Cauvery. North of this valley, and above the break, they form the basis of the table lands of Mysore, the Baramahal, Bellary district, part of Hyderabad, and the Southern Mahratta country; and present a groundwork on which will be sketched out, as accurately as the present imperfect state of information will permit, the circumscribed areas occupied by more recent aqueous strata. Toward the north-west flank of our area, almost in a line drawn diagonally across the peninsula from Nagpore by Bijapore to the western coast, the hypogene and plutonic rocks disappear, emerging only occasionally, under one of the largest continuous sheets of trap in the world, and which extends far beyond our limits to Central India.

Physical aspect of Hypogene area.—The inequalities and undulations observed in the table lands and plains of Southern India, though originating in the dislocations and flexures of the metamorphic strata at the periods of their upheaval, have been evidently modified by aqueous erosion and by the faster weathering of the softer members of the series,—such as mica and talcose schists,—the softer clay slates and shales; which crumbling and washed away, have left their harder brethren standing out in relief on the face of the country.

Where we see gneiss, hornblende schist, and quartzite, rising in parallel ridges separated by valleys, we generally find the valleys occupied by the softer members of the series, often deeply covered with debris from the ridges.

The following section was taken from some low ridges on the table land of Mysore near Chinrayapatam.



Where gneiss rises above the general level of the surrounding plain, its elevations may be distinguished from those of granite, which the hills of thick-bedded varieties of gneiss sometimes assimilate, by their greater continuity and uniformity of altitude; their tendency to a smooth dome-shaped outline, and greater freedom from precipices and disrupted masses. Near lines of plutonic disturbance, however, these distinguishing marks are less perceptible.

Elevations of mica and talcose schists obtain, generally, a less altitude than those of hornblende or gneiss; and have a more round-backed and smoother contour on the whole; yet the outline in detail is jagged, owing partly to these rocks weathering in larger, more angular, or less concentric fragments; often leaving abrupt steps, and small precipices. Hornblende and gneiss are seen rising in the Western Ghats, in the Nilgherries, to the height of 8000 feet above the sea's level. The former is recognised by its bold sharp ridges, often precipitous, but rarely presenting conical peaks.

Hills composed entirely of actinolite, or chlorite, schist are seldom met with: those of quartzite have long crest-like outlines, often running smoothly for some distance, but almost invariably breaking up into large, angular masses, sometimes cuboidal: the sides of the crests are usually precipitous. Hills of clay slate are distinguished by a smooth, wavy, outline, separated by gently sloping valleys. Outliers, or detached hills, of this rock are usually mammiform. But, as before remarked, all these normal crystalline rocks, when near lines or foci of plutonic disturbance, frequently undergo great changes in physiognomical aspect; and in lieu of the smoothly rounded hills of clay slate, and its gently sloping vales smiling with fertility, we behold it cleaved into sterile, rugged ravines, and rocky precipices.

Order of Stratification.—Gneiss is usually found lowest in the series: next to it mica and hornblende schist, actinolite, chlorite, talcose and argillaceous schist, and crystalline limestone, in due suc-

cession: but to this rule there are numerous exceptions. I have observed all these rocks, except crystalline limestone, resting on granite without the usually intervening gneiss. Why these beds, termed metamorphic from the supposition of their having been deposited from water, and crystallized by the influence of plutonic heat, should not have all been similarly altered is difficult to explain, unless it is supposed that their mineral composition differed originally, and that various degrees and durations of heat will produce different effects upon the crystallization and mineral arrangement of the mass acted upon.

Dip and Direction.—The strata are often violently contorted, or bent in waving flexures, particularly in the vicinity of plutonic rocks; and much irregularity occurs in the amount and direction of dip throughout the hypogene area. In the Western Ghauts it is usually easterly, and at angles varying from 10° to 90° . In the Udigherry portion of the Eastern Ghauts and in the plain at their eastern base I found the dip often westerly, and varying as above from 10° to 90° .

The dip in the plains south of the Salem dislocation, and in the gap of Paulghautcherry, is for the most part to the S.S.E. at angles from 30° to 80° . In the low lands at the west base of the Western Ghauts at Honawer, it was easterly at an angle of 30° ; a little further, S.S.W. At the summit of the Ghauts near the falls of Gair-sippa, the gneiss dipped at an angle of 35° to the N.E.

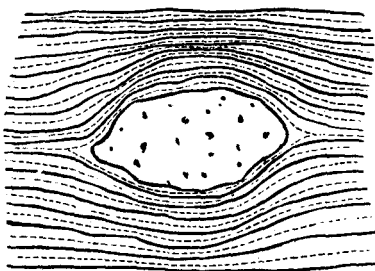
On the table lands the dip also varies much in intensity and direction: among the Kupputode hills, in the South Mahratta country, it was in one situation quaquaversal; and Benza observed the hornblende schists at the east and west bases of the Nilgherries dipping anticlinally from the axis of elevation; but they do not always dip from the plutonic rocks—in many instances the dip is towards them: a fact, indicating that the strata have been disturbed at some previous period, or that they may have suffered inversion; which is known to be the case in beds of more recent origin. While the dip of the two great lines of elevation, viz., the East and West Ghauts, is generally westerly, and easterly, or at right angles with the direction of the strata, that of the minor cross ranges is usually southerly. Numerous irregularities and exceptions, however, to this general rule occur, particularly near the northerly and southerly great synclinal line of dip on the table lands between the Eastern and Western Ghauts, and near localities where it is traversed by the cross lines of elevation. The intrusion of trap dykes has also caused much diversity in the dip. These irregularities will always prove obstacles in tracing out

with accuracy the synclinal dip line between the Eastern and Western Ghauts.

Joints and Cleavage.—The jointed structure is most observable in the thick-bedded variety of gneiss, the hornblende schist, and quartzite; in the two latter it is often so strong as to deceive some observers, who have taken the joint planes for the lines of stratification, which they cross usually at right angles, or nearly so. The planes of cleavage are most distinct in the chlorite and clay slates; they are sometimes parallel with the joints, but more frequently with the lines of stratification, which are often remarkably indistinct in the clay slates.

Lithologic Character.—Gneiss and hornblende schist are by far the most prevalent rocks of the series: to gneiss the other members may be termed subordinate. Near its contact with the granite it commonly assumes the character of, what has been styled by Boué, granitoidal gneiss, losing its stratified appearance, and not to be distinguished in hand specimens from granite. Spherical and oval masses of granite, resembling boulders, are sometimes observed impacted in the gneiss.

The following is a sketch of one of these bodies imbedded in the gneiss of the Western Ghauts, in the Paulghautcherry Pass near Vaniencolam.



These have certainly more the appearance of imbedded boulders of granite, than the concretions we see in the sandstones of Europe: while others again assimilate the globular forms produced by heat in regularly sheeted trap rocks. Veins of reddish compact felspar, felspar coloured green with actinolite, epidote or chlorite, with, and without, quartz; also of milky quartz with nests of iron ore, mica and hornblende, are very common in gneiss: also dykes and veins of granite. All these veins are of older date than the intrusion of the greenstone dykes which invariably sever them. Particular varieties of gneiss prevail in different districts. Protogenic gneiss, viz., gneiss where the mica is replaced by talc, is found in the western parts of

Mysore; albitic gneiss, in the Eastern Ghauts above Beswara. Garnets are universally distributed: but in the greatest abundance in the gneiss of the Eastern Ghauts. The gneiss of the Eastern Ghauts is also lithologically distinguished from that of the Western Ghauts by its less auriferous and more cupriferous character, and by its assuming, in many places north of the Kistna to Ganjam, so arenaceous a texture and colour as hardly to be distinguished from sandstone in hand specimens; and where capped by true sandstone, it is difficult to say where the gneiss ends or the sandstone begins. The mica and felspar are replaced by quartz and minute garnets, coloured and loosely agglutinated by peroxide of iron. The felspar is often aggregated in veins, decomposing into a white clay. It is a fact worth remarking, that the gneiss in contact with granite almost invariably assimilates the latter in mineral character. The grand characteristic of these rocks, however, on the Indian peninsula is their highly ferri-ferous nature, which remarkably distinguishes them from the stanniferous hypogenic and granite rocks of the sister peninsula of Malacca, which has an almost parallel direction and is separated only by the Bay of Bengal. In Southern India these rocks not only abound in nests and veins of rich magnetic and oxidulated iron ore, but in thick interstratified beds and mountain masses of these minerals, while not a grain of tin ore has hitherto been discovered.

Mica Schist.—Mica schist is found sparingly distributed over the whole of the hypogene area in thin beds. It is found in the greatest abundance and purity in the western parts of Mysore. I do not remember ever having seen in it a vein of granite, though abounding in those of quartz. Talcose, chloritic, and actinolitic schists are still more sparingly distributed: the first is seen in the western parts of Mysore; near Salem, in the valley of Cauvery; and in the Eastern Ghauts, in beds of some thickness; as also chlorite slate. Fine varieties of actinolitic schist occur in the Western Ghauts at the falls of Gairsippa; near Palliconda, and Suntghur in the Carnatic; and it is pretty generally distributed in thin beds over the Bellary districts, Mysore, and in the western and southern portions of the Nizam's territories.

Hornblende Schist ranks next to gneiss in extent and thickness of beds, and is seen washed by the sea at the bases of the Eastern and Western Ghauts, forming some of the loftiest peaks of the latter, and supporting large level tracts of table land. This rock varies from the compact structure of basalt to the crystalline texture of granite, and to that of porphyry, and may be seen from laminæ of a few lines in thickness, passing into beds forming mountain masses. The principal

constituent minerals of this rock, for which so many different names have been applied by geologists according to the preponderance of one or the other, its laminar, or thick-bedded structure, degree of crystallization, &c., are hornblende and felspar. Quartz, garnet, and mica are frequently mixed. Near the junction with granite I have observed, in some situations, the hornblende rock appear to pass, like gneiss, into granite by insensible gradations: the change in this instance is the more striking, as the hornblende rock not only loses its bedded structure, but, on account of its darker colour, the change in its mineral arrangement is more perceptible than in the gneiss: the hornblende and felspar gradually separating, assume the granular and crystalline structure of granite, the resemblance still increased by the appearance of a few scales of mica. The granite, in its turn, often becomes hornblendic. It must not be forgotten, however, that, in most instances, when these rocks come in contact, the line of demarcation is tolerably distinct. The occasional passage of this rock into granite will serve to distinguish it from the greenstone of the dykes in granite, and in the hypogene strata, with which it has been confounded; the latter rock, though sometimes slightly blended at the contact, I have never witnessed passing insensibly one into the other. The needle-striped crystals of augite observable in the basaltic greenstone of the dykes, its generally more compact and homogeneous structure, and greater freedom from quartz and felspar in a separate state, may serve as empiric distinctions between the two.

Large beds of compact felspar, generally of a pinkish hue, with a little quartz, and a few scales of mica, quartzite,—the Arkose of Brongniart,—and milk quartz, having a similar direction to that of gneiss, &c., occur forming low ranges of hills. Interstratified garnet rock is met with at the base of the Eastern Ghauts, in the Nilgherries, and at Senklidroog in Salem.

Hypogene limestone (marble) is of such rare occurrence as to have entirely escaped the notice of most geologists who have written on this part of India. Captain Macpherson¹ mentions a "primary limestone" laminated by argillaceous matter in the neighbourhood of Nundigamah near Bezwarah, in the Eastern Ghauts, but was unable to ascertain its exact situs. Calder² states its occurrence in the Tinnevely district near Courtallum; and I have seen it, in extremely thin layers, in the hornblende schist of Dummul, of the South Mahratta

¹ Asiatic Researches, Vol. XVIII., Part II., page 18.

² Ibid., Part II., page 8.

country, and in that of the Copper Mountain range at Bellary, and also in the garnitic gneiss of Senklidroog and Karpur (Salem district). The deficiency of this member of the metamorphic series, so largely developed in the Alps, is almost equally remarkable in the hypogene rocks of the Grampians, and in those of Norway and Sweden. It exists, doubtless, in Southern India in more localities than those just specified, but in such paucity as forcibly to exemplify the truth of Mr. Lyell's remark, viz., "that the quantity of calcareous matter in metamorphic strata, or, indeed, in the hypogene formations generally, is far less than in fossiliferous deposits." Why this should be so has been attempted to be explained by the theory of the non-existence of those mollusca and zoophytes by which shells and corals are secreted, at the period when the hypogene rocks were deposited. Others, again, are of opinion, that when these strata were broken up by the grand outbreak of plutonic rocks, the same heat which imparted to them their present highly crystalline texture, expelled from them the lime and carbonic acid. Neither of these theories, taken individually, appears to be satisfactory. It seems more reasonable to suppose that, during the earliest phases of the history of our planet, when the hypogene rocks were deposited, lime was far less abundant on its surface than at present; for although it has not been proved that lime-secreting molluscs and zoophytes did not exist in the ancient waters from which the metamorphic schists were deposited, yet it seems proved, from their scarcity in the lower rocks, that they must have existed in far less numbers than at subsequent periods.

The other, and principal source from which the lime on the earth's crust has been derived, is springs of water charged with carbonate of lime brought up from beneath its surface. If we assume that the greatest quantity of lime is brought up from calcareous rocks in the interior of the earth, when fused or heated, during periods of plutonic activity, as would seem to be the case by springs of water charged with this mineral abounding in volcanic districts, it will be readily admitted, that but little lime was deposited during the period of repose in which the hypogene strata were accumulating under the ocean; and that a large development of it took place, when by far the greater bulk of these beds were broken up and uplifted. At all events, there can be no question that the deposit of lime brought up from the earth's interior by springs, many still in operation, must be greater now, than when it commenced at a remote geological era.

Clay-slate.—Clay-slate does not occupy a large surface of the hypogene area. Its principal localities are in the Nellore and Gun-

toor copper district; around Darwar; in the Ceded Districts, near Bellary and Sondoor; in the south-west portions of the Nizam's country, at Idlapur and Cundagal. It is generally associated in conformable strata with beds of chlorite and hornblende schists, also of quartzite and siliceous schists. Blue roofing slate is rare. The siliceous schists of Sondoor, Darwar, Ceded Districts, &c., often pass into a striped jasper, and may be classed under M'Culloch's second division of schist, viz. :—

“F. Laminar, with alternate colours, and forming some varieties of the striped jasper of mineralogists. The colours are commonly shades of red, brown, yellow, and purplish black, and these kinds appear to be derived from the coloured shales.

“G. Containing imbedded crystals of quartz, and of a porphyritic aspect.”

This rock is usually seen cresting hills of chlorite, hornblende, or clay-slate, regularly interstratified. At other times the stratification is obscure; the structure, usually laminar, sometimes puts on the aspect of a breccia that has the appearance of the laminar variety having been broken up, and re-cemented *in situ* by a dark brown ferruginous paste. The rock is often highly ferruginous, and composed of alternate layers of magnetic iron ore with polarity, and grey, or brownish-grey chert. Basanite occurs associated with the hornblende, chlorite, and clay-slates.

It would be endless here to enumerate the various aspects under which the hypogene rocks present themselves dependent on mineralogical differences. The numerous divisions into which M'Culloch has petrologically classed them may be all observed in an area of a few miles' extent. Their mineral character has, however, been minutely described in my more detailed geological notes published in the Journals of the Bengal and Madras Asiatic Societies.

Imbedded Minerals in the Hypogene Rocks: Earthy Minerals—Silica.—Fine crystals of quartz are found at Vellum, near Tanjore. Chert is pretty generally distributed, also the common garnet; the latter occurs in the greatest abundance in the Eastern Ghauts, the Copper Districts of Nellore and Guntoor, Salem, the Nilgherries, and in the Western Ghauts below Goa. Mines of the precious garnet, almandine, have been excavated by the natives at Gharibpett near Palunshah in the Nizam's territories. Pyrope is said to be found in the central parts of the Peninsula: green garnet occurs in the gneiss of Senklidroog, in the Salem District¹; dodecahedral garnet, assim-

¹ Benza, Madras Journal of Literature and Science, Vol. IV., pages 266, 267.

lating essonite or cinnamon stone, in the hornblende schist of the Nilgherries¹; and black garnet, and tremolite in the granitoid gneiss of Peroor and Wurrallconda (Mysore). Epidote and actinolite are found usually in quartz and felspar veins. Hypersthene is occasionally seen in the hornblende schist of the Ceded Districts. Indianite occurs sparingly with corundum, fibrolite, and garnet in gneiss and hornblende schist in the valley of the Cauvery.

Earthy Minerals: Alumina—Corundum.—Bournon considered indianite and fibrolite to be the matrix of corundum in Southern India; and Phillips states, on what authority is not mentioned, that its gangue in the Carnatic is a coarse-grained white marble. I have always found it, both in Mysore and Salem, in talc, mica, or hornblende schist, associated with iron ore, asbestos, and sometimes indianite and fibrolite. It occurs imbedded in the rock in grains and crystals. Viralimodos and Sholasigamany are its principal localities in the valley of the Cauvery; Golashully and Kulkairy in Mysore, where it also occurs at Mundurim², near Seringapatam, Tippiaty, Beygoor, Bannerkota, Baugoopilly, and other places. It is also said to be found in the hypogene schists of Nellore and Guntoor. The spinel ruby (dodecahedral corundum), and sapphire (the corindon hyalin of Haüy), are occasionally found with the common corundum in the Salem district, and in the valley of the Cauvery. Emery, or granular corundum, is found at Bombardipádu³, about twenty-four miles northerly from Tripaty in North Arcot, in hornblende rock, in pieces varying from the size of a pea to that of a hen's egg, or even larger. Common corundum is also found where the Godavery escapes though the Eastern Ghauts, east of Papconda, from the Nizam's territories to the plains of Rajahmundry and the sea. Beryl occurs at Paddioor in Coimbatore; and, according to the natives, at Vaniambadi, at the north base of the Nilgherries.

Fibrolite occurs but rarely with indianite and corundum, as has been before alluded to, in speaking of the last two minerals. Kyanite I found associated with adularia, asbestiform tremolite, and magnetic iron ore, at Adipuram; in the Nellore district, in gneiss: it occurs in the same rock near Gharibpett⁴, in the Nizam's territories; also in Mysore⁵, and in the maritime districts of the Godavery and Kistna⁶, with tremolite, pearl spar, bitter spar, almandine and staurolite. The

¹ Macgregor, Madras Quarterly Medical Journal, July, 1842, page 284.

² Clarke, Madras Journal, January, 1839, page 121.

³ Hayne's Tracts, page 110.

⁴ Voysey.

⁵ Clarke, Madras Journal of Literature and Science for January, 1839, p. 120.

⁶ Macpherson, Asiatic Researches, Vol. XVIII., page 120.

last-mentioned mineral occurs in the hypogene and plutonic rocks north of Ryacota, in the Baramahal, associated with hornblende, felspar, and epidote¹.

Earthy Minerals: Magnesia.—Steatite occurs in the talcose schists in the western parts of Mysore; as also potstone, in beds of considerable size, and veins, and more or less dispersed over the whole hypogene area; occasionally associated with nephrite.

Alkalino-Earthy Minerals: Potash.—Mica is found universally diffused. In some parts of the Western Ghauts, and on the table lands to the east, this mineral and talc are found in plates large enough for windows, and lanterns; for which purpose they are used, as also for ornamental devices, and for painting on, by the natives of India. Chlorite is rarely found uncombined with felspar, silice, or hornblende. Nacrite, or scaly talc, is here and there met with. Adu-laria is found in the gneiss at Adipuram, in the Nellore district, and other places.

Alkalino-Earthy Minerals: Soda.—Albite, or cleavandite, occurs pretty abundantly in the gneiss of the Eastern Ghauts above Bezvara, north of the Kistna, at Paddoor in Coimbatore, and occasionally throughout the gneiss districts of Southern India: as also tourmaline, or schorl, both black and green.

Acidiferous Earthy Minerals: Alumina and Lime.—Sulphate and sub-sulphate of alumina are occasionally found in thin incrustations and efflorescences between the layers of the soft ferruginous slates into which the hornblende and mica schists pass; for instance, in the Copper Mountain range near Bellary, where I have also observed calcareous spar in nests in the gneiss and hornblende schist. General Cullen has found calcareous spar in the gneiss of Travancore. This mineral is of rare occurrence in the hypogene rocks of Southern India. Bitter spar is said to occur² in the maritime districts of the Kistna and Godavery.

Acidiferous Earthy Minerals: Magnesia.—Magnesite, an almost pure carbonate of magnesia, occurs in beds, veins, and nests in the hornblende and talcose schists near Salem, associated with rocks analogous to serpentine, or chromiferous ophiolite, asbestos, chert, a silicate of magnesia, nephrite, and chromate of iron: also at Yedichicolum, and other places on the banks of the Cauvery; and in the vicinity of Hoonsoor in Mysore. In geological situs, and age, the magnesite of Southern India assimilates the older magnesites of Styria, Moravia, Baltimore, and Turin.

¹ Hayne's Tracts, page 345.

Macpherson, Asiatic Researches, Vol. XVIII., p. 120.

Metalliferous Minerals: Iron.—Iron pyrites, or sulphuret of iron, is distributed in small proportions in the hypogene rocks; but the oxides, both magnetic and hæmatitic, exist in extraordinary abundance, forming masses and large interstratified beds in mountain chains. In gneiss these ores frequently replace hornblende and mica; alternating with quartz in regular layers. Magnetic iron ore with polarity is found at Pakanandoo, in the Salem district, in beautiful octohedral crystals. It occurs in the massive state on the Baba Booden hills in Mysore, those of Kittoor and Darwar in the Southern Mahratta country; in large masses among the hills of Sondoor near Hospett, and in many other localities.

Micaceous and specular iron ore are less common. A dark magnetic iron sand is usually found, in the beds of streams having their origin among hypogene rocks, associated with gold dust; and sometime with menaccanite.

Titanium.—Iron ore slightly titaniferous is found over the whole hypogene area. Menaccanite I found among the iron sand, and gold dust in the bed of the Doni rivulet among the Kupputgode hills, and in some of the rivulets of the Ceded Districts.

Manganese.—The black oxide of manganese, associated with iron ore, is found in considerable quantities among the Kupputgode hills, and more sparingly in those of the Ceded Districts, Mysore, and the Nilgherries.

Chrome.—Chromate of iron occurs associated with the magnesite of Salem, and probably exists in other magnesite localities.

Copper.—Ores of copper, principally the green carbonate and sulphuret, occur in strings, nests, nodules, and short broken veins in the gneiss, mica, and hornblende schists of the Nellore and Gunttoor districts. The carbonate is also found among the Kupputgode hills, in the Copper Mountain near Bellary; and in various localities in the Eastern Ghauts. The rarity of a regularly continuous lode of ore in the rocks of India is a remarkable peculiarity, and has hitherto discouraged the exertions of miners. However, our knowledge is confined to veins near the surface: and I do not consider that up to the present a fair trial has been made of their mineral resources.

Silver.—Ores of silver are said to occur in Madura, and also in Mysore¹. I found a single fragment of the grey carbonate in the auriferous sands of the Doni rivulet in the Kupputgode hills. The rocks in all these localities are hypogene and plutonic. In the Doni rivulet the sand contained magnetic iron sand, menaccanite, carbonate

¹ Clarke, *Madras Journal of Literature and Science* for January, 1839, p. 120.

of copper, and a grain or two of a white metal, soluble only in nitromuriatic acid,—probably platinum. Two bits of metallic silver and copper were also found in the sand here, which from not being *in situ*, and the possibility of their being adventitious, cannot be safely pronounced as native.

Antimony.—This mineral is said by Dr. Clarke¹ to occur in the Baba Booden hills of Mysore. What is generally sold as surmeh, or antimony, in the bazaars of Southern India, and used largely as a collyrium by the natives to improve the brilliancy of the eye, I have found to be a micaceous iron ore. Galena, or sulphuret of lead, is said to be also substituted.

Combustible Minerals: Graphite.—Graphite I found in thin shales in the gneiss of the south-west part of the Nizam's dominions at Nundapur.

Many minerals common in the hypogene series of Europe have not yet been noticed in this class of rocks in Southern India; such as fluor spar, barytes, strontianite, apatite, chialtolite, pyenite, andalusite, antomolite, and a number of other minerals less frequent.

Zircon is said to occur in the alluvium at Ellora, and cats'-eye in that of the Kistna, and of the rivers in Malabar; and umber in the Nilgherries. I have little doubt that the labours of future mineralogists will add greatly to this list of minerals associated with the hypogene formation of Southern India.

In concluding this summary of the metamorphic rocks of Southern India, I cannot refrain from remarking how forcibly they recall to mind the remark of the illustrious Humboldt, who, in concluding his survey of the plutonic and hypogene series of South America, says: "When we pass to another hemisphere, we see new forms of animals and plants, and even new constellations in the heavens; but in the rocks we still recognise our old acquaintances; the same granite, the same gneiss, the same micaceous schist, quartz rocks, &c."

PART II.

DIAMOND SANDSTONE, AND LIMESTONE.

RESTING immediately on the hypogene and plutonic rocks are found beds of limestone, sandstone, and sandstone-conglomerate (the latter often imbedding diamonds)—argillaceous, arenaceous, and siliceous

¹ Clarke, Madras Journal of Literature and Science for January, 1839, p. 120.

schists, which, from their being usually associated, sometimes alternating, and their frequent conformability of strata, it has been thought convenient, until the discovery of distinguishing fossils, to describe under one head.

Geographical extent and position.—Next to the hypogene schists, just described, and the associated plutonic rocks, these limestone and sandstone beds occupy, perhaps, the greater portion of our area north of a line drawn from Pulicat to Mangalore on the south, and the southern edge of the great overlying trap formation on the north. In the south of India, from Cape Comorin to the Salem Break, they have not hitherto been seen; and, what is remarkable, they appear almost wholly confined to the elevated table lands, and to the Eastern Ghauts, which they cap at intervals from Naggery to beyond the northern limit into Cuttack. Below the escarpment of the Western Ghauts the sandstone has only been observed at Atchera¹, on the Malabar coast.

Dipping at a considerable angle to the north-west, the limestone has not hitherto been seen either on the maritime plains below the Eastern Ghauts, or in those of the Western Ghauts. On the tablelands these works are most frequently observed, exposed in the vicinity of the great drainage lines of the country—for instance, those of the Godavery, Bhima, Kistna and Gutpurba, Malpurba, and Pennaur. They occur in irregularly-shaped patches, separated usually by broad and apparently denuded zones of the subjacent hypogene and plutonic rocks.

Physical aspect.—The tracts occupied by the limestone and sandstone beds present a diversified aspect, sometimes flat and monotonous, and at others, near lines of plutonic disturbance, bare, rugged, and picturesque. The limestone in some situations has evidently been denuded of the usually superjacent sandstone, dislocated, and elevated several hundreds of feet above the general level of the surrounding country in regular ranges, and often in highly-inclined strata, as in the tract between Banaganpilly and Gooty. Caps of sandstone, though in such cases often wanting, are sometimes seen still covering the limestone peaks. The outline of these limestone ranges usually presents long, flattish-topped ridges, whose sides and summits are not unfrequently covered with detached angular blocks of the rock, with a grey, weathered, and scabrous exterior, resembling that of the mountain limestones of Europe.

The sandstone, where undisturbed by plutonic intrusion, occurs in

¹ Malcolmson, Geological Transactions, Vol. V., page 367, Second Series, Part III.

low, flat, wall-like ranges, rising at an almost similar level, rarely exceeding 500 feet from the surface of the surrounding country, supporting table lands of some extent, and evidently once continuous. It is often intersected by deep fissures, extending from the summit of the rocks down to the base. These sometimes run through and divide entire hilly chains, in a direction at right angles to their course, and not unfrequently afford outlets to the streams that cross the Peninsula from west to east on their passage to the Bay of Bengal. The direction of the fissures is sometimes zig-zag, as in the remarkable gap of Ganjicotta on the table land of the Ceded Districts, through which the Pennaur flows, washing the bases of the precipitous and picturesque cliffs that form its sides. In some instances these great cracks in the sandstone have been widened and altered by the force of the streams that find a vent through them.

When disturbed by plutonic force, the sandstone exhibits a striking contrast in its outline to the tame horizontal aspect it assumes at distance from the axes of disturbance. It rises in bold relief against the sky in lofty rugged cross, or hog-backed and crested hills, with precipitous mural ridges, which, rarely running at the same level for any distance, are interrupted by portions of the same ridge thrown up at various angles with the horizon in steep and often inaccessible cliffs. These features are more strikingly seen in the ranges east of Gooty, on the edge of the granitic rocks, and in the Eastern Ghauts in the vicinity of Naggery, Udigherry, and in some parts of Goomsur. When it crests the hypogene rocks, the lower part of the elevation is often composed of the latter to the height of about 200 to 400 feet, the slope of which has usually an inclination of from 15° to 20° , while that of the cap of sandstone presents a steep or precipitous declivity varying from 45° to 90° , giving a decided character to the aspect and configuration of the mountains and ranges thus formed.

The hills of arenaceous schists are to be recognised from the more massive sandstones by their undulating, round-backed summits, and their buttressed and dimpled flanks; while those of the softer slates and shales affect the mammiform outline.

Both limestone and sandstone beds there is little doubt were formerly of greater extent than now, and owe much of their present discontinuity and scattered positions to the agency of plutonic disturbance, and subsequent denudation. The tracts of country intervening between their areas are usually occupied by granitic and hypogene rocks. The superincumbent beds, broken up by the granite rising to the surface, have been more easily carried away by aqueous

currents, than in undisturbed situations, where we find their continuity greater. To admit this, it will be necessary to adopt the theory of the granite's rising above the surface in a solid, or a nearly solid, state. It is a fact, that in granitic tracts the denudation has been most complete.

I shall now proceed to notice, in detail, the extent, &c., of the various detached portions, or patches, of the limestone and sandstone strata.

Cuddapah Beds.—The Cuddapah beds appear to be the most extensive, occupying an area of about 9000 square miles, comprised between the 13th and the 17th degrees of north latitude. They extend east and west from the Eastern Ghauts over the table land of the Ceded Districts, to the village of Yaripilly, about nine miles east of the fortress of Gooty, and to Peddapa. On the north they stretch from the left bank of the Kistna, near Waripilly, covering the eastern and central portions of the Eastern Ghauts to Naggery, the adjacent table lands of Cuddapah, Kurnool, Tripetty, and part of North Arcot, to the north frontier of Mysore, near Rayachooty. It meets the hypogene and plutonic rocks of Hyderabad near Myapoor, a village on the left bank of the Kistna, about nineteen miles northerly from the city of Kurnool.

Godavery Beds.—A number of small outlying patches stud the plains between the Kistna and the Godavery; and the sandstone is seen at intervals capping the Eastern Ghauts, and forming low ranges stretching into Cuttack beyond our limits. Near the diamond mines of Condapilly, on the north bank of the Kistna, it appears to touch the Cuddapah beds, which are seen in the channel of the Kistna at Amráwati. Further inland, on the north-east extremity of the tract under description, another patch extends in a south-eastern direction on the banks of the Godavery, commencing to the north-west of its confluence with the Banigunga, and traceable to the hot springs of Budrachelum, on the south-east¹. Others occur at intervals on the banks of the Godavery at various distances to the alluvial plains of Rajahmundry near its embouchure.

South Mahratta Country Beds.—Separated by a zone of outcropping hypogene and plutonic rocks, about a degree and half in breadth, from the Cuddapah beds, and immediately to the westward of them, lie those of the South Mahratta country, extending north and south from the vicinity of Chimlugh, near the confluence of the Kistna and the Gutpurba, to Gujunderghur on the south, and from Moodgul

¹ Malcolmson, Geological Transactions, Vol. V., Second Series, Part III, pp. 567, &c.

on the east, to the subordinate chains of the Western Ghats at Gokauk, and thence stretching down southerly towards Belgaum. The hill-forts of Pedda and Chich Nurgood, and of Nowlgoond, stand on outliers a little below the southern limit of this patch. The course of the Gutpurba forms an irregular boundary to the north, with the great overlying trap of the Dekhan.

Hydrabad Beds.—Smaller isolated patches are observed in the Southern Mahratta country, between it and Hydrabad, viz., at Mudibhal, and Talicota, on the banks of the Bhima, between the city of Gulberga and Firozabad; and also in the vicinity of Digaye, between Muktul and Gulberga.

The sandstone again¹ crops out in the Hydrabad country near Sarapúr, between Hunnumkoondah and Pakkal, to which it continues penetrated by granite.

Beds of limestone occur at Kotah, about ten miles up the Pundeeth river above its confluence with the Godavery.

Identity.—The identity of these scattered beds is proved by their relative geological position with respect to other rocks, their imbedded pebbles, and striking mineralogical resemblance.

Order of Stratification.—The limestone occupies, with few exceptions, the lowest position in the sections afforded by the great lines of drainage of these tracts, and in places where the superincumbent strata have been stripped off.

Next in order of superposition come calcareous shales, mingled with much argillaceous matter, then argillaceous shales and slates, sandstone, siliceous and arenaceous schists, quartz rock and sandstone conglomerates.

In one or two situations I have observed the limestone, where elevated into chains of hills, alternating with sandstone; for instance, between Banaganpilly and Pycut Puspoolah; and near Ryelcherroo in the Cuddapah tract; and also a little south of Kulladghi in the Southern Mahratta tract.

Direction and Dip.—The direction of these beds usually conforms to that of the hypogene schists on which they rest. They have, with the latter, been broken through, penetrated, tilted up, and altered by plutonic rocks. The disturbance is most apparent on the edges of the beds. At a distance from the lines, or *foci* of plutonic action, the beds are found but slightly inclined, and their dip following the easterly and southerly inclination of the great table lands. The Cuddapah strata have been raised at their eastern limits by the elevation of the

¹ Dr. Walker, Journal of Asiatic Society of Bengal, 1841, No. 30, p. 471.

Eastern Ghauts with the subjacent hypogene schists, to the average elevation of about 2000 feet above the sea's level; dipping about 40° westerly. They have been similarly lifted by plutonic rocks at their western edge, between Ryelcherroo and Gooty, where the dip is 42° easterly. Intermediate between these axes of elevation the strata are but little inclined. In the tongue of land separating the Toombuddra from the Kistna, the dip of the limestone appears to conform to the undulations of the plain; and is in some mammiform elevations, quâquâversal. On the south bank of the Gutpurba, near its confluence with the Kistna, large masses of the light bluish-grey limestone have been thrown on their edges, and the strata inclined at various angles to the horizon. At Kurnool, the ditch of the fort affords a beautiful section, illustrating the little extent to which disturbance is sometimes carried by plutonic forces. The beds of limestone in the vicinity have but a very slight dip, which in the short space of 500 yards, passes into highly inclined, waving, curved, vertical, and anticlinal, having been broken through by a wedge of hypogene rock (hornblende schist) resting on granite.

Dip of the Sandstone Beds.—The dip of the sandstone when resting on the limestone is usually not so great as that of the latter, or, in other words, unconformable. It may be hence inferred that an interval took place between the deposition of the limestone and sandstone strata, during which the former were disturbed and again tilted up after the deposition of the latter. To strengthen this supposition of two epochs of geological disturbance, it may be added that pebbles of chert and jasper, evidently derived from veins in the limestone, are frequently found in the sandstone conglomerates. The sandstone sometimes rests horizontally on the granite and hypogene schists; but in general it conforms almost to the dip of the latter, as seen in many places in the Eastern Ghauts, north of the Kistna, and in Goomsur, where the dip is generally between 60° and 80° , and inclined to every point of the compass.

Cleavage and Joints.—Joints and planes of cleavage are often strikingly developed in the structure of the more schistose and laminar members of the limestone and sandstone rocks. At Nundaloor, in the Cuddapah district, where the strata have an easterly dip of 12° , the cleavage planes formed an angle of 40° with those of deposition, dipping in an almost similar direction, and preserving far greater regularity and uniformity of dip even over extensive tracts. The lines of deposition are here distinctly marked by alternate parallel light and dark-coloured bands. The joints are at right angles, or nearly so, with the planes of stratification, and often filled or lined

with calcareous incrustations. Near Kulladghi, the calcareous slates associated with the limestone sometimes possess a true transverse cleavage, dividing the rock into rhomboids capable of indefinite subdivision into similar forms, at angles of from 30° to 40° with the direction of the strata. The joints here intersect the cleavage at right angles. The true surfaces of deposition may be usually distinguished from the smooth rectilinear planes of cleavage, by their peculiar dimpled aspect. This characteristic is, however, often more or less obscure.

Ripple Marks.—On the exposed surfaces of the sandstone cliffs south of Cuddapah, at Ganjicotta in the Ceded Districts, Gokauk in the Southern Mahratta country, among the ranges between the Kistna and Bagulcota, and various other localities, I have observed distinct ripple marks. Their longitudinal axes, though extremely various, have on the large scale a tendency to an E.N.E. direction, showing that the current which caused them flowed generally in a W.N.W. or in an E.S.E. direction. The marks are not confined to strips or zones of the sandstones, like those of ancient beaches, but extend in every direction over considerable spaces, resembling those on sand constantly under water.

Fissures and Caves.—I have already alluded to the fissures which often cleave the sandstone masses from summit to base. These when numerous and crossing each other at right angles, impart a tessellated appearance to the surfaces of the flat-topped hills. The pebbled surfaces of the conglomerates thus divided are often remarkably level, and reminded me of the artificial pebbled floors found among many of the Roman ruins in Italy. In other situations the fissured surfaces resembled those produced by contraction in drying, in the mud of a tank or river, or in the *Regur*, or black cotton soil. In the sandstone their origin may have been similar, during the consolidation of the rock by plutonic heat. Vertical fissures are also seen in the limestone, though by no means to the same extent: they vary from a few lines in width to many yards. Caverns, so common in the limestone formation of Europe, are rarely seen: a few occur in the Cuddapah beds; some of which, as well as the fissures, I have searched in vain for organic remains. They usually contain incrustations of carbonate of lime, stalactite, kankar, detritus, and angular debris of the rocks forming their sides. Both caverns and fissures are frequently the outlets of springs. The sides of the vaults, though often smooth, do not exhibit the polished or grooved surfaces of attrition; nor can we expect to find such in tracts where the strata are undisturbed.

Parallel furrows and grooves, apparently caused by the action of pebbles moved along by water, are occasionally observed on the surface: particularly on the summit of some limestone cliffs between Banaganpilly and Peapilly, in the Ceded Districts. Rock basins above the present drainage level of the country are rare.

PART III.

DIAMOND SANDSTONE, AND LIMESTONE.

Lithologic Character of the Limestone.—The limestone passes from a dark blue, or nearly black rock with a smooth, but somewhat earthy, conchoidal fracture, into one of a more compact texture and of a light buff, or cream colour, adapted for lithographic purposes: for instance, some of the varieties near Bagulcota, and Talicota in the Southern Mahratta country; near Kurnool and Ryelcherroo in the Ceded Districts; and Datchopilly in the Nizam's territories. The specimens of these lithographic limestones that have been subjected to actual experiment, though found occasionally to answer, have proved inferior to those of Germany; being often penetrated by minute threads of siliceous spar, and not of a sufficiently homogeneous texture. It must be remarked, at the same time, that these localities have not been explored and quarried with adequate care or labour for better specimens, which, it is probable, the lower beds may yield. In structure the limestone is both thick-bedded, and laminar; in colour it is generally of a light bluish grey, though, sometimes, as just observed, nearly black, passing into a variety of beautiful and lively shades of green, yellow, pink, and white; sometimes irregularly disposed, but more frequently in alternating bands, coinciding with the lines of stratification. The green varieties are often spotted with a darker green, or bluish black, assimilating in colour some varieties of serpentine. This latter mineral sometimes occurs in thin strings and nodules in the limestone, and evidently imparts to it much of its colouring matter. These nodules in the vicinity of Kurnool and Ryelcherroo, are usually of a light or siskin green colour, translucent and sectile; streak nearly white. Before the blowpipe they become opaque, redden slightly, and fuse partially on their edges into a white enamel. The variety of limestone imbedding them is often magnesian, and contains asbestos; although the general character of the beds is siliceous and argillaceous, as is evident from the following analysis of an average specimen

of the Cuddapah dark blue limestone made for me by my friend Mr. Macleod, Inspector-General of Hospitals, Madras.

Silex	-	-	-	12	5
Alumina	-	-	-	2	5
Oxide of iron	-	-	-	1	3
Carbonate of lime	-	-	-	33	3
Loss	-	-	-	0	4
				<hr/>	
				50	0

The chief object of this analysis was to ascertain the origin of the dark colour of this limestone; since, from its whitening before the blowpipe, I had long thought it could not be ascribable to protoxide of iron: the analysis has proved the truth of the conjecture. Mr. Macleod is of opinion that it owes its colour to volatile matter; "extractive." The limestone, in the vicinity of basaltic, plutonic, and hypogene rocks, is usually siliceous, and presents veins of chert, red and brown jasper; sometimes intermingled with films and nests of a mammillary chert, resembling calcadony; and calc spar, as in the vicinity of Kurnool, and Yaripilly east of Gooty. The cherts are usually of a greyish white, translucent, and sometimes of a faint roseate hue; while others resemble carnelian both in colour and texture. In veins and layers, it splits by microscopic fissures into parallelopipedal fragments. The red jaspers are often striped like the limestone with red and green. The limestone frequently graduates insensibly into these cherts and jaspers. A soft reddish and purplish laminar variety of the limestone prevails in the western parts of Kurnool and Cuddapah; and more or less in all the localities where this formation extends, passing by insensible gradations into the ordinary blue limestone of the country. The transition, however, is sometimes so abrupt, as almost to excite the idea of their being a distinct formation: but as yet, this conclusion cannot be arrived at in the absence of organic evidence. These red slaty and shaly beds are frequently interlaminated with thin light green chloritic flakes, which are also seen in the white marbly varieties of the limestones of Baguleota in the Southern Mahratta country. In the dark varieties thin argillaceous lamellæ occur; which, in decomposition, turn of a light brown hue and become distinctly visible, alternating with the dark blue limestone.

In the vicinity of Baguleota, Kulladghi, and Kurnool, the limestone acquires so crystalline a structure as to resemble the finer marbles. At Talicota, beautiful dendritic appearances occur inscribed on the successive surfaces of the laminæ, like characters on the leaves of a book, with features so strongly resembling those of vegetation as

to induce Dr. Wight the botanist to believe they were organic, though probably the result of metallic infiltration.

The following is the note he sent me on the subject; and, if these appearances be really nothing more than the result of metallic infiltration, it will serve, at least, to show how closely they sometimes mimic the productions of the vegetable kingdom.

"The arborescent appearance in the slate I think an organic remain. At least, I find, when under a high magnifying power, that the black lines can, with the point of a needle, be picked off without touching the stone, as if the carbonaceous matter of the plant was still there. I feel uncertain, however, whether to call the original a *moss* or a *fungus*, but think the latter."

At Chillumcoor, in the Ceded Districts, the limestone is associated with a greyish breccia, having a coarse granular and crystalline structure, resembling that of granite, and imbedding small angular fragments of siliceous slate, and iron pyrites. The line of junction with the ordinary blue limestone could not be traced owing to the thickness of the superincumbent soil.

There are also some beds of a curious rock in the Southern Mahratta country south of Darwar, which, from their insulated position, circumscribed limits, and petrological character it would be premature to give a permanent place to in the formation under description. These beds constitute a hill near the village of Hurti with a mammi-form shape, having its surface covered with detached, angular, and rugged masses of a similar rock, which appears to have been subjected to the action of violent disruptive forces. It is of a massive character, rarely laminar, veined with a white opaque quartz, and imbeds crystals of iron pyrites. It is composed of minute angular fragments of a dark glistening quartz, and crystals of pale flesh-coloured felspar, cemented together by a greenish, granular, subcrystalline paste, composed chiefly of carbonate of lime. It is very likely to be mistaken, from the colour, hardness, and granular texture, for a variety of massive siliceous, chlorite rock; and, in some varieties, resembles diallage and serpentine; but on the application of a lens, and, indeed, by the naked eye, its true aggregate character may be distinctly recognised. The application of dilute nitric acid to the rock in substance excites but a feeble effervescence; but from the powder, the extrication of carbonic acid gas is abundantly evident. Some varieties of a dull green hue, are traversed with reddish brown delineations. Before the blowpipe, *per se*, it phosphoresces slightly, and exhibits on the edges points of black shining enamel. The compact varieties are susceptible of a high polish, and are used as an

ornamental building stone, which often retains the pyrites bespangling in gold-coloured spots the smooth surface. The minute scales of mica, the crystals of reddish felspar, and dark coloured quartz, together with the general dull green hue of the rock, indicate its detrital origin from the micaceous and chloritic schists with which it is associated. No section presented itself showing the dip of its beds. The crystals of pyrites, not weathering so rapidly as the embedding limestone, frequently stand out from its surface. This is the case with the veins of jasper and chert in the ordinary limestone of Cuddapah, the Southern Mahratta country, &c., exhibiting curious reticulations in relief on their exterior.

Associated Minerals.—The most prominent mineral characteristic of the limestone is the iron pyrites, abounding in nests and cubic crystals; and which, on atmospheric exposure, particularly where subject to moisture, acquire a liver-brown hue. Nests and strings of a poor hæmatitic iron ore are also pretty generally distributed; the former more particularly in the dark blue and green varieties; the latter is sometimes seen filling a succession of small spheroidal and tubular cavities in the substance of the rocks, which are not unfrequently empty; and have possibly originated in bubbles of inclosed air, or gaseous extrication, while the rock was yet in the state of a soft mud.

Galena is found in the limestone near Jungumrazpilly, Bussapur, Mahanandi, and other localities in the Cuddapah district; usually in brown jaspideous calcareous and white quartz veins, associated with iron ore and sulphate of barytes, a mineral hitherto unnoticed by writers on the geology of Southern India, and which occurs in the Nundi Cunnama Pass, over the Eastern Ghauts. Between the layers of the laminar, and more frequently in the argillaceous varieties, thin incrustations of muriate of soda are often found: and I have observed that, where this saline development is greatest, the rock is less solid, has an earthy fracture, and appears to have undergone a chemical change. Selenite is rare: a specimen of this mineral, labelled "Tiagar, southern division of Arcot," occurs in the Museum of the Madras Branch Royal Asiatic Society.

Coal has been discovered by Mr. Walker¹ in the limestone on the north limit of our area at Kotah, about ten miles up the Pundeetah river, above its confluence with the Godavery; where it is described as occurring as a vein in a layer of shale and bituminous shale, in the argillaceous limestone associated with the sandstone, and dipping at a low angle towards the north-east.

¹ Journal of Asiatic Society of Bengal, No. 112, 1841, pp. 341, &c.

Organic Remains.—The almost total absence of fossils in this limestone, in Southern India, is a remarkable feature, and renders it impossible to assign it, for the present, a place corresponding with any of the classed formations of Europe or America.

In some of the chert veins in the limestone of Nannoor, in Kurnool, I recently discovered myriads of microscopic, spherical, and oval bodies, resembling at first sight the grains in oolite; but they are larger, and have a more organic appearance, resembling somewhat that of Bohemia. Their section, however, usually gives two or more concentric circles, with a point or nucleus in the centre, which have sometimes a distinctly chambered structure, like that of nummulites. These foraminifera exhibit no traces of carbonate of lime, being entirely silicified. In decomposition they fall out, leaving the surface of the stone so perforated with cavities, as to give it the appearance of coral. Their colour is usually white and opaque: the opacity is evidently caused by disintegration, but in others, translucent, like white carnelian. Those embedded in the red jasper-like chert frequently retain this appearance: some are entirely charged with the red colouring matter, while others have only the outer circles tinged by it.

Lithologic Character of the Sandstone.—The sandstone and its associated beds, lithologically speaking, are not very dissimilar to the Devonian sandstones of England, the finer chloritic slates of which, with their dendritic delineations, find resemblances in those of Chittiyaripilly, between Cuddapah and Gooty, in the Budwail, and Cummum Divisions of the Eastern Ghauts, and in the vicinity of Kulladghi, alternating with hard quartzose slates, tilestones, and sandstones. Assimilations to the millstone grit are seen in the coarse white and red sandstones of Badami and Mudibhal in the Southern Mahratta country. In many localities, for instance Banaganpilly, Rylcherroo, near Bagulcota, and the Juggernaut range of Kurnool, we find breccias and conglomerates passing into red sandstone and quartz rock.

The sandstone-capping portion of the Eastern Ghauts, from Naggery to the Mahanuddi, rarely passes into a breccia, and is seldom associated with the limestone on the more elevated portions of the Ghaut chain. Here it often assimilates the weathered gneiss on which it rests. It frequently passes into red and green argillaceous and siliceous slates, and laminated marls. Beautifully variegated sandstones, exhibiting waving and contorted bands, occur in the vicinity of Sidhout, Cuddapah district.

The sandstone conglomerate of Southern India is most remarkable

for being the matrix of the diamond; and it is in absence of organic and other data to class it with any known formation, that it has been deemed convenient, from this almost peculiar mineral feature, to apply to it this temporary distinctive prefix. The diamond occurs both in the sandstone and its interstratified breccias and conglomerates, the pebbles in which are principally quartz, chert, flinty slate, basanite, jasper, and jaspideous clay impregnated with iron, with a few fragments of trap, and the hypogene schists. The pebbles of quartz greatly predominate; and it is worthy of note, that not a single bit of true granite has hitherto been found in these conglomerates. Those of chert, jasper, and indurated clay have evidently been derived principally from the subjacent limestone, and the rest from the hypogene rocks. Fossil chert from the limestone is often found embedded in the diamond breccias of Banaganpilly and of Ramulacota in Kurnool. As the diamond has never been discovered in these subjacent rocks, it cannot be said to exist as a transported crystal or fragment in the sandstone. The pebbles from the hypogene and limestone rocks are both rounded and angular, varying in relative proportions in different localities, and are found from the size of a duck-shot to that of a man's head. They are usually cemented together by an arenaceous paste, more or less fine and compact, mixed with argillaceous matter and oxide of iron. These conglomerates usually rest on the limestone, particularly the beds where the diamond has been found in greatest abundance. In many localities the limestone is entirely wanting, and the conglomerates and sandstone rest immediately on the hypogene strata. Granite, or basaltic dykes are invariably found intruding into diamond areas, of which as a detailed account has already been given, I will not dwell on them here. It may be noticed, *passim*, that in all alluvia in which the diamond is found, pebbles of this formation invariably occur. The most noted diamond localities are in the Cuddapah District, near Condapetta, Lamdoor, Penchetchapadoo, and Ovalumpully, at Banaganpilly, and in Kurnool at Bamulacotta, Devanur, Tandrapaud, and near the Nundi Cunnama Pass, near Gazoopilly; at Munimudgoo, and Wudjra Caroor near Gooty; at Malavilly, a village about sixteen miles W.S.W. from Ellore; at Ganipartata¹, or Partial, Alkur, Burthyenpada, Pertala, Wustapilly, and Codavetty Kalu; at Kattakindapalle, near Bombartipadu, about twenty-four miles northerly from Tripetty. Old diamond pits are also said to exist about forty-six miles west from Ongola, and about twenty miles north from Nellore. Large diamonds have been found from time to time in the bed of the Kistna, below the Moorcondah ferry in Kurnool.

¹ Hayne's Tracts, pp. 92 and 110.

Most of the localities just enumerated were formerly within the ancient kingdom of Golconda, but are now under the British Government and the Nizam of Hyderabad. The diamond also occurs in the alluvia of the sandstone districts of the Mahanuddi, the Bramini and Ehee rivers, particularly the latter. There are diamond mines at Wyragurh, ninety miles S.W. of Nagpoor, formerly celebrated, but now nearly deserted.

Muriate of soda and sulphate of alumina occur frequently in thin seams and layers in the purple, reddish, and brownish shales, interstratified with the sandstone of the hills of Gokauk; and I found veins of manganese in the sandstone between the falls of the Gutpurba and Kulladghi.

Iron ores, chiefly magnetic and hæmatitic (specular and micaceous more rarely) are pretty generally distributed in veins with quartz and in nodules; iron pyrites occur less frequently in veins of white quartz.

Cavities filled with fine crystals of quartz, and sometimes embedded in calc spar, occur in the Juggernaut range of Kurnool. In these crystalline nests I observed a few laminæ of a mineral of a bright grass green colour, with a lustre and appearance resembling those of uranite. Galena occurs in the quartz veins of the Nulla Mulla chain and occasional detached strings and thin patches of carbonate of copper.

Anthracite has recently been found in the Goond country in the sandstone of Dantimnapilly, about twenty miles north-west from Jungaum, which is sixty-five miles west from Chinnore. The bed has an extreme breadth of three feet, and length 200 feet. Traces of coal are also said to exist in the diamond sandstone north-west of Nagpoor, and it occurs in great abundance in similar rocks in the valley of the Nerbudda, a little further north.

The great intrusion of basalt into diamond areas has already been noticed, and it has usually been accompanied by evidence of heat, viz., induration and silicification of the limestone, fissures, and numerous thermal springs rising up through them, impregnated with carbonic acid. It is possible that this subterranean heat, during its periods of intensity, by acting on the limestone which has been shown to contain volatile vegetable matter, in addition to carbonic acid, drove off a portion of these in a gaseous form, with the superincumbent sandstone, and thus caused its diamondization, if I may be permitted so to express myself, by a process somewhat similar to that of the dolomization of limestone. The atoms of carbon set at liberty from their old combinations of lime, oxygen, and hydrogen, and having little affinity for the silica of their new matrix, gradually aggregated

under the influence of certain laws in the pores of the sandstone, and assumed a crystalline form.

Organic Remains.—Although, as already stated, there is a certain degree of mineral resemblance between the sandstone beds of South India and those of the Devonian group, yet the singular ichthyolites, molluscs, and corallines that distinguished the latter are totally wanting in the former—that is, as far as has hitherto been ascertained. The sandstones supporting the coal measures at Chirra Punji, resting upon plutonic rocks, hypogene schists, and supposed to be identical with the diamond sandstones of Punna in Bundelcund, of Cuddapah, Kurnool, Banaganpilly, and Nagpore, are said to abound in teredines, and to imbed fossil stems and fruits of *Mimosæ*, while in its associated limestone, bivalved and univalved shells, with coralloids hitherto unclassified, are found, and a single gryphite¹; this limestone, however, from its superior position to the sandstone, is probably of more recent origin than that just described.

A few impressions of stems and leaves of plants, one of which resembles a fossil *Glossopteris Danæoides* of the Burdwan coal-fields figured by Professor Royle, have been discovered by Lieutenant Monro in the Nagpore sandstone. There are two other impressions in Lieutenant Monro's specimens, bearing some resemblance, Mr. Malcolmson thinks, to the large bony scales of the sauroid fishes of the old red sandstone. However, they were so indistinct, that it would not be prudent to indulge in any speculation, until further discoveries be made. One of those impressions, which I carefully examined, bore resemblance to that of the reticulated skeleton of a leaf.

In the sandstone hill of Won, Mr. Malcolmson discovered a fossil of a deep black colour, and having a compact structure, which he conceives to be a portion of a hollow compressed vegetable; its centre is filled with sandstone. The carboniferous sandstones of Damuda, it is well known, contain fossil remains of the *Vertebraria Indica*, R.; of *Sphenophyllum* (?) *speciosum*, R.; of *Glossopteris Browniana*, Ad. Brongniart; *Pustularia Calderiana*; *Precopteris Lindleyana*, &c.

Age.—With regard to the age of the diamond sandstone and limestone, geologists are of conflicting opinions. Christie referred the latter to the transition period, and the former to the old red sandstone, without further evidence than mineral character, and their having been disturbed, with the hypogene schists, by plutonic rocks. Major Franklin² has referred the limestone to the lias, and the sandstone to

¹ Conybeare's Report to British Association, 1832.

² Geological Transactions, Second Series, Vol. III., Part I.

the new red. Mr. Malcolmson¹ has already refuted the opinion of the latter, and states his conviction that they belong to the more ancient secondary, or even transition rocks. Major Franklin's theory appears to have been principally founded on the saliferous seams occurring in the sandstone; but in Southern India, as Mr. Malcolmson justly observes, salt occurs in all the formations, from granite to alluvium, and the blue limestone, classed as lias, almost invariably underlies the sandstone classed as the new red. A large sandstone track in Russia, long supposed identical with the new red, on account of its interstratified gypseous and saliferous beds, has recently been proved by MM. Murchison and Verneuil² to belong to the old red, from its imbedded ichthyolites. It is a well-known fact, that the old red in the north of Scotland is saliferous: salt springs occur in the English coal measures, in the lias of Switzerland, in the tertiary limestones of Egypt and Greece, and in the old transition slates of America.

The frequent horizontal position of the diamond sandstone and limestone strata must not be regarded as a proof of recent origin. Granite, it is well known, has tilted up, and disturbed rocks of a period more modern than the chalk; while, on the other hand, the distinguished geologists first quoted found the older silurian rocks, covering a considerable portion of Russia, in perfectly horizontal stratification. Until the further discovery of organic remains enables the geologist to see his way more clearly, it would be advisable to refrain from any hasty and premature classification.

With respect to their age, relatively to other Indian rocks, it has been clearly shown, from superposition, unconformability of stratification, and imbedded pebbles, that they are posterior to the oldest hypogene schists, and anterior to the latest outbreaks of granite and basaltic greenstone, which have penetrated and altered their structure. A few pebbles of an older greenstone occasionally occur imbedded. I have already stated my opinion of an interval having taken place between the deposition of the limestone and the sandstone sufficient for the consolidation of the former, from the fact of a slight unconformability of dip, and of the latter's containing imbedded pebbles of a fossiliferous chert evidently derived from the limestone.

¹ Geological Transactions, Second Series, Vol. V., pp. 568, 569.

² Ibid. Ibid. Vol. V., Report of Buckland's Anniversary Speech, 1841.