Mean Places of the Comparison Stars for 1888·0.

Star.	α	δ	Authorities.
	h. m. s.	° ′ ″	
1	8 42 30·10	+12 57 35·0	Lalande, 17336; Glasgow Cat. 1870, 2247.
2	8 42 35·87	+13 0 33·5	Lalande, 17339.
3	9 7 20·67	+10 46 5·8	Lalande, 18179; Glasgow Cat, 1870, 2377.
4	9 11 41·40	+ 9 50 8·0	Star = 9 mag. Approximate Position.
5	9 32 37·01	+ 5 9 18·9	Lalande, 18940; Greenw. Cat 1850, 680; Glasgow Cat. 1870 2501; Bruxelles Obs. 1873, 1517; Cape Obs. 1881, 285.
6	9 36 9·24	+ 5 29 7·1	Lalande, 19045.
7	9 48 57·12	+ 4 33 7·1	Lalande, 19398.
8	9 50 37·20	+ 4 18 55·0	Star = 9 mag. Approximate Position.
9	9 57 7 44	+ 2 1 34·8	Lalande, 19622; Lamont (1), 2779.
10	10 4 21·47	+ 1 59 53·1	Lamont (1), 2834.
11	10 52 50·70	− 6 27 31·0	Star = 9 mag. Approximate Position.
12	10 57 22·43	− 7 47 13·3	Lalande, 21196; Lamont (3), 1017; Schjellerup, 4022.
13	11 42 59·82	−13 43 12·6	Radcliffe Obs. 1881, 266.
14	11 50 37·00	−14 53 0 0	Star = 8½ mag. Approximate Position.
15	11 51 31·00	−14 50 0·0	Star = 8½ mag. Approximate Position.

THE DESERT SANDSTONE.

By the Rev. J. E. Tenison-Woods, F.G.S., F.L.S., &c.

[With Plates.]

[*Read before the Royal Society of N.S.W., November 7, 1888.*]

All round the Australian coast, proceeding northwards, say from the latitude of Brisbane there occurs at intervals, and in patches of different sizes, a peculiar formation which goes by the name of Desert Sandstone. It varies much in colour and in character, though mostly a bright or a livid red, yet it is often white, yellow, and of various intermediate shades, or mottled. Usually it is composed of sand consisting of small grains more or less firmly cemented together. There is generally a somewhat rounded appearance in the grains, though they are not abraded in the characteristic manner of eolian sands. Yet it is not entirely composed of sand; in North Australia 50 feet and more of the upper surface is magnesite or carbonate of magnesia, and there are other admixtures in places, though usually the rock is composed of spherical grains of sand cemented together or hardened into quartzite. There are certain constant features in the formation which entitle it to the name of Desert Sandstone, namely:—(1) It usually gives rise to a desert country of a very profitless character, with a scanty vegetation, yet not wholly destitute of fair sized trees and poor grasses. (2) It is utterly destitute of fossils, unless in certain cases impressions of leaves, seed-vessels, and fragments of silicified wood. An exception to this is mentioned by Mr. Taylor. I may state, however, that I searched in vain in the neighbourhood of the locality named, and my impressions are that it would be more likely that the fossils belonged to the underlying Cretaceous formation. (3) It is of a broken precipitous character, forming tablelands with precipitous faces, and round, flat-topped hills. (4) Wherever met with it bears marks of being much denuded. Water seems easily to have broken it up and denuded it, cutting it down into astounding precipices and forming country of the roughest description, utterly impassable for man or beast. (5) Its generally uniform height is another feature ; 500 to 600 feet is the highest elevation in North Australia, but in North-Western Australia Mr. Frank Gregory speaks of the same formation attaining 1000 feet high. The Desert Sandstone is found in detached hills and plateaux of varying extent. (6) In close proximity to it there are nearly always recent volcanic formations.

So peculiar a formation was very early a puzzling geological problem to those who made a study of the geology and physical geography of Australia. Mr. Daintree imagined that, at one time, the strata to which he was the first to give the name of "Desert Sandstone," extended over the whole Continent, and his opinion has been more or less followed by subsequent geologists and explorers in their writings and maps. It is certain that the formation reappears very often on the coast and throughout the interior in the form of detached outliers with a certain uniform aspect, so that it may be easily believed that such outliers were once connected together. My own observations have made me notice further that these outliers of Desert Sandstone are always in the neighbourhood of rivers and creeks, and seem equally connected with the ancient volcanic emanations which form portions of the dividing ranges. The following is Mr. Daintree's description :—

*"On the eastern branches of the upper Flinders River and elsewhere fine sections are exposed of lava, resting on horizontal beds of coarse grit and conglomerate, which lie in turn unconformably on olive-coloured and grey shales with inter-stratified bands and nodules of argillaceous limestone, containing fossils of cretaceous affinities. I have called this upper conglomerate series "Desert Sandstone," from the sandy barren character of its disintegrated soil, which makes the term particularly applicable. Only a few rolled fragments of coniferous wood have been found imbedded in it, proving nothing as to its

* Daintree, "Notes on the Geology of the Colony of Queensland, with an appendix containing descriptions of the fossils," from the "Quarterly Journal of the Geological Society" for August, 1872, p. 275.

age ; and all that can be asserted is that its horizon is above and unconformable to the Cretaceous series of the Flinders.

" *Without doubt it is the most recent, widely spread stratified deposit developed in Queensland.* The denudation of the Desert Sandstone since it became dry land has been excessive ; but as will be seen by the geological map (pl. ix.), there still remains a large tract *in situ*, whilst outliers and isolated ridges are to be met with in the most unexpected localities. A view of a cliff section of Desert Sandstone with outlier, is represented in the accompanying wood-cut (Fig. 3).

"All the available evidence tends to show that this Desert Sandstone did at one time cover nearly, if not quite, the whole of Australia, with the probable exception of the south-eastern corner of the Continent from the Cordillera to the ocean. The journals of the two Messrs. Gregory in their expedition on the north-west and north, and Goyder's description of the new settlement of Port Darwin, all bear evidence to the continuity of this so-called "Desert Sandstone" over all the extended areas investigated by them, where denudation has been resisted by local peculiarity of structure, or other special causes. Frank Gregory, in his description of the geological peculiarities of that portion of the Nichol Bay country that came under his observation during his exploring expedition of 1861, observes that 'it consists of a series of terraces rising inland for nearly 200 miles, more or less broken up by volcanic hills towards the coast.

" 'The first belt averages from 10 to 40 miles in width from the sea, and is a nearly level plain, slightly ascending to the southward, with an elevation of from 40 to 100 feet, the soil being generally either light loam or strong clay, according as it is the result of the granite rocks that occasionally protrude above its surface, or of volcanic rocks of black scoria that frequently interrupt the general level.

" 'Proceeding inland for the next 50 or 60 miles is a granite country that has been originally *capped with horizontal sandstones*, and has an elevation of about 1000 feet. This range terminates to the southward in level plains of good soil, the produce of the next series or more elevated country ; whilst towards the northern edges the granites and sandstones have undergone great changes, through the action of numerous trap-dykes, that have greatly disturbed the surface, producing metamorphic rocks, some resembling jasper, and others highly cellular and scoriaceous.'

"In about Lat. 22° on the meridian of Nichol Bay, he came upon another and more elevated range, trending away to the S.E., having an altitude of 2,500 feet above the sea.

"This, unlike the last section, has a southern escarpment of 500 or 600 feet, and an average breadth of eight or ten miles ; it consists of *horizontal sandstones and conglomerates,* which have undergone comparatively little change."

In Mr. A. Gregory's report on the results of his expedition up the Victoria River in 1855, he described a sandstone which Mr. Daintree identifies with his "Desert Sandstone." He says the specimens from the Victoria River agreed exactly with those from the Desert Sandstone of Queensland, and were undistinguishable one from another, "while the same sandy soil, the same hostile Spinifex* *(Triodia),* the same fatal poison plant† mark its presence from Perth to Cape York. In Queensland the upper beds are ferruginous, white and mottled sandy clays, the lower being coarse alternating grits and conglomerates; the extreme observed thickness has not exceeded 400 feet. A characteristic view of the Upper Desert Sandstone beds is shown in Betts' Creek.

"Whether these are marine, lacustrine, or estuarine deposits, there is hardly sufficient evidence to show; the enclosed drift-wood as before observed giving no clue.

"A single shell *(Tellina)* found in a bed of horizontal limestone at the head of the Gregory on the Barkly Tableland, and forwarded to me by the Rev. W. B. Clarke, of Sydney, would, if belonging to this series as it probably does, give reason to believe that the lacustrine condition may be eliminated." (Daintree, op. cit., p. 277.)

It is now ascertained that the limestones on the Barkly Tableland do not belong to the Desert Sandstone formation at all, but to the great Cretaceous formation of Central Australia.

In Mr. Daintree's essay a section is given of the upper valley of the Victoria River. This section shows: (1) Desert Sandstone, in massive tableland and flat-top outliers covering (2) basaltic or trap rocks, which sometimes lie above the sandstone through an

* The species commonly called Spinifex in Australia, has been confused by some strange mistake with a grass which bears that name, but so entirely different from the Australian desert grass that it is as well to point out what that difference is. The true Spinifex are spreading or creeping hard branching grasses growing in the loosest sand by the sea-shore only, forming large tufts with diœcious spikelets, the leaves being sometimes smooth and sometimes covered with a silky pubescence. Besides three Australian species which are entirely marine, there is a fourth very closely allied to one of the Australian species, widely spread along the sandy sea-shores of tropical Asia. *Triodia* on the contrary is entirely a desert prickly grass, with leaves as sharp and as stout almost as needles. There are six species, supposed to be distinct from one another, in Australia, the two commonest being *T. pungens* and *T. irritans.* Besides the Australian members of the genus there is a common European *Triodia* and a few African species.

† The poison plant is *Gastrolobium grandiflorum,* F. v. M., not confined unfortunately to the Desert Sandstone.

overflow ; (3) hard sandstones and grey and blue slates, which from their lithological character Mr. Daintree supposed might be classed as Devonian. These beds were highly inclined, and were supposed to be the underlying basis of all that part of the country.

My own explorations in the valley of the Victoria River confirm generally the correctness of Mr. Gregory's ideal section as far as its leading features are concerned, with the exception of some alterations in the details of the so-called Devonian rocks.

Mr. Jack in his Handbook of Queensland Geology* devotes Chapter ix. of that work to the Desert Sandstone, from which I make the following quotation :—"This remarkable formation must at one time have covered at least three-fourths of the colony of Queensland, as well as a great part of South and Western Australia. The waters in which it was deposited, had for their eastern shores the cordillera of the palæozoic rocks, which look down upon the Pacific. The deposit filled up the inequalities of the denuded surface of the rocks of the "Rolling Downs ;" while the Mackinlay and other ranges lifted their peaks as islands above the waters.

"The base of the Desert Sandstone on the western side of the Cordillera rests unconformably on the "Rolling Downs" formation, at an average elevation of about 1,800 feet above the sea level. In the south-western part of the Colony its elevation is probably not more than 1000 feet. In the York Peninsula it steals gradually downward, till it reaches the sea at Temple Bay, and covers the Peninsula from the Pacific to the Gulf of Carpentaria. In the east, important fragments of the Desert Sandstone rest, at a considerable elevation on the Bowen River coalfield, and on the auriferous rocks of Cania and Croombit. At Maryborough and Moreton Bay, sandstones which have been referred to the Desert Sandstone come down to the sea level. The formation has suffered extremely little disturbance. It is almost always found in horizontal beds, which form table-lands, with terraced edges. It consists mainly of siliceous sandstone and conglomerates. Among the sandstones thin beds of coal occur to the north of Cooktown. A thick bed of coal or oil-shale has recently been discovered on Bullock Creek, near the Northern Railway. The sandstones are mainly white, but red beds are largely developed in the York Peninsula. The latter form fair pastoral country ; but the greater part of the formation justifies the name of "Desert Sandstone" given to it by Daintree. It grows, as a rule,

*Colonial and Indian Exhibition, London, 1886. Queensland, its Resources and Institutions. Essays prepared by the authority of the Executive Commissioners in Queensland. Handbook of Queensland Geology, by Robt. L. Jack, F.G.S., F.R.G.S., Government Geological Surveyor, Brisbane, 1886.

worthless grasses, mainly Spinifex, and is thickly covered with rather stunted timber.

"Opals form the chief commercial product of this formation. They occur in nodules of ferruginous siliceous sandstone and siliceous ironstone. Although the majority do not exactly meet the definition of "precious opal" insisted on by jewellers, they are not less beautiful. A change in popular fancy, or the eradication of prejudice, is all that is required to make the Queensland opals as valuable as the most appreciated gems from Hungary. Among their chief sources are the Opal Range, the Winton, the Mayne River, the Canaway Range, Bulgroo, Nickavilla, and Listowel Downs. A fine collection is to be displayed by Mr. Bond at the Exhibition.

"The Desert Sandstone attains a thickness of 300 to 400 feet on the west slopes of the Coast Range. In the west of the colony however it dwindles to 50 or 60 feet. The Desert Sandstone affords a most impressive instance of denudation. The most casual observer, standing on the edges of one of its table-lands, cannot fail to be struck with the obvious former connection of the terrace-edged tablelands which meet the eye on all sides. This formation, geologically so new, is left only in isolated fragments, and does not cover in Queensland one-twentieth part of the area over which it once extended.

"The Desert Sandstone has yielded little but plant remains, chiefly fragments of silicified wood. Mr. Norman Taylor, late of the Geological Survey of Victoria, who accompanied Hann's Exploring Expedition, however, found in it at Battle Camp, near Cooktown, some fossils which Mr. R. Etheridge, Senr., described as 'a *Hinnites* like *H. velatrix*, and an *Ostrea* like *O. sowerbyi*, Eth.' Mr. Etheridge, however, thought that the fossils were drifted specimens lying on the surface; which Mr. Taylor assures me was not the case. In confirmation of Mr. Taylor I have the unquestionable testimony of Mr. A. C. MacMillan, that he himself had seen fossils in the locality referred to by the former gentleman. In any case, however, the fossils are insufficient by themselves to determine the age of the deposits.

"In his paper on the Geology of Queensland, the late Mr. R. Daintree first referred in 1872 to a series of rocks occurring at Maryborough, and containing fossils which, in the appendix to Daintree's paper, Mr. Etheridge, Senr., named as follows:—*Cyprina expansa*, Eth.; *Trigonia nasuta*, Eth.; *Crenulata gibbosa*, Eth.; shell resembling *Lucina (Codallia) percrassa*, Stol.; *Culcullœa robusta*, Eth.; *C. costata*, Eth.; *Nucula quadrata*, Eth.; *N. gigantea*, Eth.; *Tellina mariœburiensis*, Eth.; *T.* sp.; *Avicula alata*, Eth.; *Natica lineata*, Eth.; *Panopœa sulcata*, Eth.

"Mr. Etheridge placed the Maryborough beds (which lie in the Burrum River Coalfield) below the Hughenden and Marathon beds. There is, however, no stratigraphical evidence whatever in support of this, and it is obvious from the number of new species, that the co-relation of the Maryborough beds with any European horizon rests on very insecure grounds.

"Mr. Gregory* says that the Maryborough beds merge upwards into the Desert Sandstone, 'which appears as a thin covering to the older rocks along the sea-coast from the Burnett River to the Logan River.' If we could be sure of the identity of the 'thin covering' with Desert Sandstone, the relations of the Maryborough beds would be clearer; but the point is a doubtful one. I am inclined to regard the 'thin covering' as a newer deposit than the Desert Sandstone—possibly post-tertiary. But the solution of the difficulty must await the production of further evidence.

"I have in the meantime coloured the Maryborough beds, provisionally, as Desert Sandstones, but the arrangement is merely a temporary convenience.

"Leaving the Maryborough beds out of the question, the only direct evidence bearing on the age of the Desert Sandstone is that it lies unconformably on the "Rolling Downs" formation. It may be the equivalent of the Upper Cretaceous.

"In the arid western interior, the tablelands of Desert Sandstone serve one useful purpose. They are 'sponges' which absorb the rainfall, and let it out in springs at their junction with the underlying more argillaceous rocks of the 'Rolling Downs.' Some of these springs were still active, at the end of 1885, after three years of drought."

From the time of Leichhardt, North Australia was generally regarded as a plateau of Desert Sandstone, with a precipitous face on its northern edge. Sometimes these cliffs on the edges of the table-land abutted on the ocean, and sometimes a low flat land very gradually rising from the sea led up to the plateau, varying in width from 1 to 100 miles. Where the Sandstone abuts upon the sea-coast, it gives rise to a precipitous series of gorges like the Sydney Harbour, and its character at a distance is like the Blue Mountains. Leichhardt in exploring the Alligator River to Port Essington, had much difficulty in finding a practicable place where he could descend from the plateau. By some mistake in transcribing his notes, he has been quoted as saying that the height of this plateau varied between 1,800 and 800 feet, but it is stated that an attentive examination of the original MS. journal shews that the height given is 300 feet only. Stuart

* Geological Features of the South-Eastern Districts of Queensland. Brisbane, 1879. By authority.

appears also to have experienced considerable difficulty in descending from the plateau on to the alluvial margin of the north coast, though in his case there were many rocky gorges at hand. He says in his journal of 10th July, lat. 13° 24′:—"At half-past one crossed the table-land, *breadth thirteen miles.* The view was beautiful. Standing on the edge of a precipice, underneath, lower down, a deep creek thickly wooded. * * * * We had to search for a place to descend, and had great difficulty in doing so, but at last accomplished it without accident. The course of the table-land is about N.N.W. and S.S.E., and the cliffs appear to be from 250 to 300 feet high. We were now without doubt upon the Adelaide River." Other instances of the character of the edge of the table-land need not be given, for it would appear to be very much alike in the various places where its limits have been been crossed by Gregory, Burke, Landsborough, Walker, and McKinlay. The southern edges of the plateau have sometimes the same precipitous faces as the northern.

Having made an attentive examination of much of the coast line between Carpentaria and the Victoria River, I am able to speak positively as to the nature of the formations which are met with. The physical structure of this part of the Australian Continent is best described in the words of my report to the South Australian Government in September, 1886, as follows :—

"Before proceeding to give details of the geology of the Territory, it will be necessary to correct an erroneous idea which has prevailed as to the physical structure of this part of the continent. That idea has been that the plains, after rising by an easy slope from the sea southward, reach points at varying distances where they are covered by a rampart of sandstone, about 600 feet in height. This rampart is supposed to be the edge of the great plateau of the interior or continental Australia. In other places the table-land is supposed to be 800 feet in height above the plains, and 1,800 feet above the sea. Latterly this plateau has been called by the name of the Desert Sandstone, and is supposed to cover most of the older formations, and to cut out as it were all the older and mineral deposits. Whether it does so or not in the far interior I cannot say, though I am inclined to think not. Where I have been there is no such thing as a continuous table-land. Patches of broken table-land occur frequently at the sources of rivers and creeks, but they are only patches, often no more than ridges ; if they are more than four or five miles in width they descend as an inclined plane to the valley of the next large watercourse, where the older formations generally crop out ; their height varies between 120 and 300 feet ; once only have I seen a plateau of 370 feet in height. At its northern, which is always the broken edge, it was less than half that elevation. Leichhardt is said to have found on his descent from a plateau, precipices 800 feet high, but this is now known to be an error in transcribing his notes.

"The name of Desert Sandstone is unfortunately chosen for these table-hills or flat-topped ridges. Sandstone there is in abundance, besides ferruginous sandstones and sandstone conglomerates, but they are not always in the cliffs, or only form a portion of them. Nearly all the cliffs are capped with compact magnesite or carbonate of magnesia, from 10 to 40 feet in thickness, sometimes ferruginous, or quite pure and white. The cliffs are made up of various formations, and it is incorrect to call them Desert Sandstone. Here are the proofs:—At Yam Creek, about two miles south from the telegraph station, the line passes through a gorge, bordered on each side by precipitous cliffs, varying in height from 130 to 200 feet. The bottom of the valley is 335 feet above the low water level of the sea. At one place where I ascended the cliffs they were 130 feet high, of this 90 feet was granite, 10 feet waterworn quartz conglomerate, ferruginous magnesian sandstone 16 feet, pure white magnesite 14 feet. Two miles further the cliffs were 140 feet high; of this 80 feet was granite, and 50 feet a highly ferruginous sandstone horizontally stratified. At the head of the Mary the cliffs were 200 feet high, 30 feet of this was a fine-grained white sandstone, formed of wind-blown sand, the grains under the microscope being rounded and abraded like the sands of the Sahara; above this was 170 feet of pure white magnesite. The valley was composed of palæozoic slates and felsites.* Other instances will be given in the body of this report.

"At the gorge at Yam Creek the table-land is a mere ridge. At M'Minn's Bluff (270 feet above the plain) it is an outlier, broken up into detached hills; it is the same at Mount Shoobridge. At the head of the Mary the cliffs are about 200 feet high, then there is an inclined plane, rising 100 feet higher in six miles; then for four or five miles an inclined plane descends for 40 feet a mile, until Kekwick's Springs, on a tributary of the Katherine, is reached. Again, on the heads of the Katherine, a sandstone table-land was ascended to a height of 250 feet, but it was a mere ridge, with a valley 50 feet deep on the east side, with large springs of fresh water, giving rise to a creek. Crossing, this led to an inclined plane of four miles, falling about 25 feet to a mile; this brought us to a gully, the head of Maude Creek, where we were in about three miles almost on the level of the Katherine, and in auriferous country again.

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* A compact mixture of quartz and felspar without any traces of crystallization.

"It will appear, therefore, that as far as I have seen, the Desert Sandstone so called, is confined to numerous small patches of a newer formation of moderate thickness, which does not cover the older rocks to any large extent. Yet this character would not be suspected from its aspect as seen from a distance. I do not wonder in the least at earlier explorers having been led into error with regard to it. When one ascends to the summit of any moderate elevation, the sloping base, white cliffs, and flat summits of these hills are conspicuous objects, and there extend from these, level plains of apparently unlimited extent. But none of the hills are high enough to command an extensive view: if they did, other hills would be seen cropping out. The mistakes which have occurred have been for want of careful measurements, or giving descriptions from distant views rather than from actual exploration and a close examination of the nature of the rocks. I have also had the advantage of the 125 miles of levels taken for railway purposes.

"It must be also borne in mind that the magnesian and sandstone formation never rises to the height reached by the palæozoic and metalliferous rocks. Thus Mount Wells (mica slate, with tin and copper veins) is about 900 feet above the level of the sea; Springhill—gold mine, 800 feet; the Union, 700 feet; Jensen's, 800 feet, and so on. None of these heights are ever attained by the flat-topped table-land. So far, therefore, from much of the auriferous formation being covered by it, from its nature and elevation that formation is far more likely to crop out above it.

"From what has been said, it appears that the term Desert Sandstone is a misnomer. Whether the formation is the same as that which was described under that name by Mr. Daintree, in Queensland, is not certain. There are here three kinds of rock:—(1) A red sandstone, composed almost entirely of rounded grains of sand and ferric oxide; the appearance of these grains and the stratification of the rock show a desert origin, such as blown sands present. (2) Magnesite and silicate, and ferro-silicate of magnesia; this rock is pure white and yellow, or mottled fiery red. These rocks I believe to be derived from the decomposition of fine volcanic ash, containing much olivine, or otherwise rich in magnesia. South of the Edith River there is a large volcanic area, with high basaltic hills and much vesicular lava, all rich in olivine. When these volcanoes were in activity (in Miocene times ?), the fine dust from the ashes covered a large area; thus we find these flat-topped cliffs of magnesite lying on granite rocks and on slates (Mount Shoobridge). (3) The third formation included under the name of Desert Sandstone, is a fluviatile conglomerate; it is only found on the banks of streams;

it is an extremely hard sandstone, horizontally stratified and cross-bedded, with the finer laminations marked by black specular iron; it contains much rounded and water-worn quartz gravel, from the size of a small pebble to that of a man's head. This formation is much broken into immense boulders and rocks of most fantastic shapes. It is very hard, but being full of cracks and fissures weathers easily, and gives rise to a surprisingly rough country, almost inaccessible to explorers. It is composed of sandbanks and river boulders, which have hardened since the rivers cut through them. Like the banks of the rivers of the present day, they rise occasionally 100 to 300 feet above the bed, and extend two or three miles on either side. Mount Douglas is an instance of this formation, and in the ranges on the upper Katherine River it is developed to a large extent.

"The above description of the table-lands and other formations will help much to understand the physical structure of the Northern Territory, which is as follows:—

"The coast is very low and flat, and rises by a gentle incline at the rate of about five feet a mile. But there are low ridges of quartzite, slate, and sandstone, rising almost from the sea level to a height of 50 feet or more, gradually increasing to 100. They run north and south, that is, generally speaking, with a general trend to the eastward, as they are traced to the south. From these ridges, small creeks and tributaries take their rise, and descend towards the main valleys, in which there are permanent waters.

"The following heights and distances will give a better idea than any description:—

	Distance from Palmerston.	Height above sea.
The Elizabeth ...	25 miles 15 chains ...	52·56 feet
The Berry	35 „ 70 „ ...	76·84 „
The Darwin ...	43 „ 45 „ ...	93 „
The Finniss ...	45 „ 5 „ ...	184 „
The Stapleton ...	69 „ 64 „ ...	239·50 „
Peters Creek ...	74 „ 40 „ ...	188 „
The Adelaide ...	76 „ 58 „ ...	183 „
Burrell's Creek ...	80 „ 12 „ ...	177·50 „
Calder's Creek ...	88 „ 36 „ ...	199 „
Bridge Creek ...	94 „ 59 „ ...	322·50 „
The Howley ...	99 „ ...	250·50 „
Yam Creek ...	111 „ 69 „ ...	328 „
The Margaret ...	114 „ ...	340 „
Foelsche's Creek ...	122 „ 66 „ ...	318 „
The McKinlay ...	124 „ 68 „ ...	304 „
Snadden's Creek ...	131 „ 10 „ ...	404·50 „
Lady Alice Creek...	135 „ ...	484 „
Pine Creek... ...	145 „ 79 „ ...	657 „

"The distances are by the railway line, and the heights above low water sea level at the railway crossings of the various streams.

"It will be seen that the heights begin to increase rapidly from the 95th mile, and continue to Pine Creek, so that the average rise, which is about five feet per mile, is less than three feet per mile for the first 100 miles, and more than six feet per mile for the next 50 miles. This is owing to the commencement of ranges which are connected with most of the mineral country in the Territory. These ranges are a series of parallel ridges having a south-south-easterly trend, and rising to a height of from 200 to 600 feet above the plains, though the latter height is exceptional. This mountainous area is about 20 miles in width, from east to west, and 40 miles in length from north to south; in it are contained the sources of most of the small tributaries of the Adelaide and Mary, which are rivers with a north and south direction. The Adelaide may be said to take its rise in the midst of this chain, and the Mary to the eastward and southward.

"The ridges and ranges are separated in their northern portions by somewhat wide alluvial flats or valleys, but to the south-east the ranges are closer together, higher and more abrupt, besides being exceedingly stony and barren. Thus the country south-east from Mt. Wells, as far as the Mary River, is exceedingly rugged, and many of the ranges and valleys almost inaccessible. The most closely metalled road would not be more deeply and thickly covered with stones than the valleys and ranges. Several long and high spurs (500 feet above the plain) are continued to the eastward into the valley of the Mary River, but at about 100 miles from Southport the ranges decline to the level of the plain.

"At the sources of the Mary, the river takes its rise amid flat-topped cliffs of the most picturesque description. The view along the stony white gorges has few parallels in Australia. The valley of the river is hemmed in by straight cliffs of castellated outlines some 150 or 200 feet high. There is often a slope or talus at the bottom, but they are only accessible in a few places, and the valley is for the most part fertile and shaded by fine graceful palm trees; springs bubble out from the shady thickets at the foot of the cliffs, giving rise to streams many feet wide, and deep from their sources. The valley is strewn to a bewildering extent with huge boulders and masses of rock, which have fallen down from above, because the magnesite is very brittle, with a foundation of loose and friable sandstone. Thus no very long time would be required for the springs to crumble and break away the edge of the table-land, or scoop away the valleys as we see them now.

"The springs, therefore, I believe to be the origin of the cliffs and gorges at the heads, not only of the Mary but of the West and South Alligator Rivers, and many besides. The magnesite and sandstone strata are very permeable to water. The heavy rainfall of the wet season easily drains through the strata, and bubbles out at the base, where it has weathered and broken it away into abrupt, precipitous, and fortress-like hills."

Beyond the Mary to the eastward there is table-land of a very broken character, forming scenery which has few parallels I think on the face of the earth. To use the words of my journal at the time of my visit—

"There was no high hill near us, but from the summit of the steep slope above the camp a fine view was to be obtained. A fine view and a strange one; indeed I doubt if there be another like it in the world. All around there is such a sight of cliffs and gorges, isolated hills and flat-topped hills, hills like lighthouses, hills like fortresses and bastions, and city gates, and ruined palaces—in short, like anything and everything except the common-place and monotonous. And then there were such combinations of colour—white cliffs, red cliffs, blue cliffs, striped cliffs; in fact, I am afraid to go on for fear of overtaxing the confidence of my readers. I could have gazed and wondered at the scene for a long time, and still found plenty to wonder at and ponder over, for it is a prospect about which one could imagine anything. It seemed to me so lifelike and so deathlike, so real and so imaginary, that I knew not what to compare it to. One could hardly believe that such startling shapes, so like the work of man, could be entirely a freak of nature, and then the utter absence of anything like human life about it suggested all sorts of associations. It looked very barren, too, but this it certainly was not, as we found on a nearer inspection. One thing this view from afar impressed on us was the difficulty we should find in crossing such a country. The gorges seemed as difficult to descend into as Sindbad's Valley of Diamonds, and once in them the problem was to get out again. It seemed like expecting horses to be able to climb up a wall. However, it was not so bad as it looked."

I now proceed to deal with the formations of Desert Sandstone. They may be arranged as follows:—

1. Magnesian sandstones, magnesite or carbonate of magnesia and ferruginous magnesites from 40 to 50 feet. This stratum is not always present.

2. True siliceous sandstones, quartzites, and loose sand-beds scarcely indurated into a rock mass.

3. Fluviatile drifts of a very broken character 500 to 600 feet thick at greatest thickness, mostly connected with the present fluviatile drainage of the country, but forming valleys of much greater width.

Before dealing in detail with these different formations, it is important to point out a fact which has a significant bearing on their origin. If a geological map of any portion of the interior is consulted, it will be observed that in many instances where recent volcani rocks are marked, they are seen to be associated with what is called the Desert Sandstone. Sometimes, as at Dubbo, Wellington, Warburton, Sofala, &c., it is called Hawkesbury Sandstone, but the connection with the volcanic rocks is indisputable. The position that these sandstones always occupy with reference to the points of ejection of the recent volcanic rocks, shows that they are dependent upon them, and they are sometimes intercalated with them as I shall show hereafter. The high lands of New England, which contain large manifestations of recent volcanic rocks, are rich in these sandstones too, which the late Mr. Lamont, one of the able assistants of Mr. Wilkinson in the geological survey, early recognised as ash-beds. In the interior on the Lachlan, Darling, and the back country between both, there are many instances of Desert Sandstone occurring as detached outliers, but always so near recent volcanic rocks that they cannot be otherwise than connected with them. Particular instances of this will be given further on, but it is important to note the facts themselves at this stage of the paper.

I will now proceed to give detailed descriptions of the various formations in the Desert Sandstone which I have enumerated above.

Magnesite deposits—I venture to suggest that we have in these strata remains of a volcanic origin which have accumulated during a long period of volcanic activity. The beds seem to have occupied a wider area than they do now. They vary in thickness from 10 feet to 500 or even more, though the thickest deposits measured by me did not exceed 40 feet. They are now formed into a compact and various coloured stone, consolidated no doubt by chemical action and decomposition as well as pressure.

If my suggestion as to the volcanic orgin of these magnesite beds be accepted, we have not very far to seek for volcanic points of ejection, from which they may have proceeded. Geological readers need scarcely be reminded of the great mass of trap-rocks which encircles the edge of the continent of Australia, with perhaps the exception of the south-west side. Western Victoria seems one of the recent foci of activity, the latest disturbances having occurred at no great distance from the mouth of the river Murray. Very recent outbursts have also occurred about the middle of the east coast, in the latitude of Moreton Bay, where volcanic emanations and existing shells are mingled together on the coast. It is difficult to form an opinion as to the relative ages of the volcanic rocks and the so-called Desert Sandstones, for both as yet have been imperfectly surveyed. There are many areas of volcanic rock, such as basalts, diorites, and other igneous or trap formations in the Northern Territory; but if we regard the magnesite as an ash deposit, it is not easy to say as yet to what portion of the volcanic history they owe their origin.

The uppermost magnesite strata form a rock which is very much decomposed. They are seldom uniform for any great extent either in colour or material; pure white, cream-colour, mottled, and various shades of purple and red prevailing in ever varying tints. There are few marks of stratification, but long divisional lines which indicate protracted periods of rest in their accumulation. If we accept the volcanic origin we may suppose that the craters or trap rocks connected with such deposits must have been very rich in magnesia, the most probable source of which would be olivine. About ten miles north of the Katherine River there is an area of volcanic rocks, the limits of which I was not able to examine. In the bed of a creek near which I had formed my camp there was an appearance of trap rocks, amongst which there was a basalt very rich in olivine. It cannot be said exactly, however, from whence the magnesite proceeded. It may be due to some such rock as suggested. The deposit is too extensive to have been derived from freshwater action on the underlying rocks which are rich in mica, and probably other magnesian minerals. A marine origin is of course out of the question.

The volcanic deposits which are found on the Katherine River are not the only ones in Arnheim's Land. A large area occurs to the west of Port Darwin, and a very large volcanic district is found at the head of the Victoria and of the Fitzmaurice Rivers. The rocks here exposed are of modern character and probably belong to several distinct periods, certainly to two, of which there is constant evidence in the continent of Australia. I have mentioned a significant fact connected with the strata as far as my observations extend; namely, that wherever they are developed trap-rocks are associated with them. If it will be borne in mind that I am not extending these observations beyond the limits of my own experience, I might add that the converse of this proposition is true, that is wherever there are volcanic rocks there are extensive accumulations of volcanic sand; though what I am presuming to be ash deposits are not always presented in the form of magnesite.

It is not easily understood why these magnesite deposits have been preserved so extensively in North Australia, and are to be seen, rather rarely, in connection with the Tertiary trap rocks elsewhere. Circumstances, we may presume, have combined for their preservation in a way which I shall try to explain hereafter. Yet it may also be inferred that the absence from other places may be more apparent than real. An attentive examination has not been made, or these ash remains would possibly have been much more extensively recognised. It must be borne in mind that Mr. Jack the Government Geologist of Queensland, and myself have been the only geologists who have paid attention to the matter, and attributed to these strata their true character. I may say, however with some confidence, that though few ash beds have been recorded as occurring on the south of the Australian continent, unless in seams that are quite insignificant, it is only because the true nature of such formations has not been understood. In the "Notes on the Physical Geography, Geology and Mineralogy of Victoria"* (p. 74) Messrs. Selwyn and Ulrich, report many important deposits of magnesite, thus :—" *Magnesite (Carbonate of Magnesia)*—This mineral is tolerably abundant in the 'kaolin' deposit of Bulla Bulla, near Keilor, at Heathcote, and generally in the Tertiary clays near Geelong, Bacchus Marsh, Western Port, &c. ; also in the surface soil along the banks of the Loddon River, near Newstead, forming nodules of all shapes and sizes, from that of a pea to several inches cubic. According to analysis these nodules are however, not composed of pure carbonate of magnesia, but contain small variable proportions of carbonate of lime, carbonate of iron, and clayey matter. A peculiar occurrence of very pure magnesia is observable at the Hard Hills, near the junction of Jim Crow Creek and the Loddon River. It appears like an annular outcrop of a bed of nearly one foot in thickness round the base of a small hillock, composed of older Pliocene gold drift, but extends barely a few inches beneath the surface. This outcrop consists of an aggregation of nodules of all sizes, from several inches diameter to even fine roundish grains, like oolitic sand. Some of the nodules are extremely hard and homogeneous, but the generality consist of roundish particles of pea-size, with obscure rhombohedral planes, sometimes closely, but in most cases very loosely adhering together. The origin of the mineral appears to be due to the action of the carbonic acid of the atmosphere on a seam of white soapy clay which contains a large percentage of silicate, and perhaps hydrate of magnesia, and would crop out now where the *magnesite* appears. Where the atmosphere could have no access to the clay, there is a total absence of *magnesite*, whilst on the other hand, in places where the clay has been exposed to its influence, even in the most recent times—for instance in the drift heaps from several shafts on the hillock—the small white grains appear in profusion like white sand artificially strewn over the surface."

* Intercolonial Exhibition Essays, Melbourne, 1866.

I have very little doubt that in many of the places here enumerated, the magnesite is derived from volcanic ash, probably in a decomposed condition. The deposit observed at Hard Hills on the Loddon River belongs to the great volcanic outbreak, which has covered the country with basalt more or less uninterruptedly all over Western Victoria, and which includes a large number of extinct volcanoes.

Prof. Liversidge in his "Minerals of New South Wales,"* thus speaks of magnesite (p. 165):—It is found in New England in various places, and upon the diamond fields at Bingera, co. Murchison (where the mineral has a peculiar reticulated surface and mammilated form) and near Mudgee. When impure it is of a grey or grey-brown colour, but when pure it is a dazzling white, compact, tough, and breaks with a flat conchoidal fracture. . . . Other localities are Kempsey; Mooby Gully, Lachlan River; Scone co. Brisbane; Louisa Creek and Lewis Ponds Creek, co. Wellington; Barabba, co. Darling; Tumut; Gulgong; and Warrell Creek, Nambuccra River.

We might include also to some extent serpentines as well as magnesites, though I have not met with any such deposits of an extensive character that seemed attributable to volcanic ash.

One of the main sources of the magnesium salts would be doubtless from volcanic rocks, and particularly basalts containing olivine. By many of the older mineralogists only those volcanic rocks which contained olivine were regarded as true basalts: at any rate basalts containing large quantities of olivine are extremely common. Thus Messrs. Selwyn and Ulrich, in the work already referred to, state under the head of olivine or chrysolite (op. cit. p. 66) that "this mineral is so common in the newer basalts (except where the latter appear as true 'dolerites') as to deserve to be regarded as an essential constituent of the rock. It generally appears disseminated in small angular grains of light apple to blackish-green colour; but at many places, especially in the neighbourhood of basaltic craters and points of eruption (Mount Franklin, the Anakies, Gisborne Hill, the Warrion Hills, &c.) it occurs in irregularly shaped, or sometimes sphæroidal masses, of both fine and coarsely granulated texture, and from one to five, in some instances (Anakies) to even twelve and eighteen inches in diameter. Crystals have not been observed as yet. An analysis by Mr. Daintree of light green olivine from the Anakies yielded:—

Silica	42·60
Protoxide of iron...	7·36
Magnesia	50·00
	99·96

* London, Trübner & Co., Ludgate Hill, 1888.

According to all appearances this mineral easily decomposes through atmospheric influence, assuming at first chatoyant colours, then turning to reddish-brown, and ultimately, beneath a thin coating of hydrous oxide of iron, changing to a brownish-red mica ('Rubellane')."

Prof. Liversidge (op. cit. p. 117) gives many localities for the occurrence of olivine, besides many magnesian products which may be supposed to have been derived from the decomposition of chrysolite in basalt; but it is not necessary to cite the passage. It may be mentioned however that at the railway cutting along the Main Range, about 100 miles west of Brisbane, both tunnels and cuttings are made through ash deposits derived from a large extinct volcano on the edge of the Darling Downs. Over the ash-bed there is a distinct overflow of basalt which is conspicuously full of olivine, the masses being sometimes of large size. The section is very instructive, for the ash-beds are partly decomposed and in some respects remind one of the Nepean Sandstones near Sydney, New South Wales. At the junction of the lava stream, the ash-beds are conspicuously discoloured from the action of the heated basalt, forming long lines of red, pink, and other colours, like the effect of burning in a kiln.

Though the ancient character of the ash-beds of North Australia may be inferred from their chemical metamorphism, yet they are the newest deposits that are to be found in this region. They lie on the top of all other formations which they cover, as already stated, to a varied depth. The following description of some of the beds exposed is taken from different portions of my report.

McMinn's Bluff.—The road from Pine Creek by the side of the telegraph line passes along a valley formed by a flat sandstone table-land on the west side and a low slate range on the east side. The table-land forming the western boundary of the valley is at its southern end a long narrow range, covered with a stratum of stone, which stands out like a rampart some 30 or 40 feet thick, giving a castellated appearance to the flat-topped hills. As the range is followed north it is broken into three or four small outliers of white and red colours. They look like ramparts and fortresses, and are of very picturesque appearance. They all have a steep incline for about two-thirds of their height, and then become rugged for some distance, and then suddenly precipitous for 30 or 40 feet to their flat-topped summits. One of these hills is of fiery red on the top, and it is joined by a low saddle to another outlier, which is capped with picturesque cliffs which are white.

The section of these hills is as follows:—Granite, 90 feet at least, it may be more, but the line of junction is concealed by weathered masses of rock, which have fallen down from the cliffs. Then follows 100 to 150 feet of coarse red sandstone. Then 30 to 40 feet of magnesian silicate, making a total at the highest of about 270 feet above the plain.

The coarse red sandstone lies in horizontal strata. It consists of large quartz grains imbedded in a reddish-brown cement. Its materials have no apparent connection with any rock visible in the valley now.

The upper stratum is a compact rock with small vesicles. It is either creamy-white, yellow, or mottled a deep red-brown, with streaks and veins of lighter colour. There is a concretionary character about its decomposition, which makes it break up into a number of small red rounded pebbles like pea iron ore. But this is not always visible, only where there is much iron oxide. In other places it is a pure white, and consists of a magnesian silicate. The mottled character of the upper stratum is very remarkable, varying through all the shades of livid red, purple, yellow and brown, more in the shape of rounded clouds than anything like crystallisation. No doubt it is the effect of the action of water upon the iron ores contained in the ash deposits.

The Shackle Gorge.—The section visible near the old telegraph station at Yam Creek, proceeding from above downwards into the valley is as follows :—

Magnesite	14 feet.
Sandstone, purple and red stains ...	16 ,,
Waterworn conglomerate ...	10 ,,
Granite	90 ,,
	130

In this section the magnesite is of the usual mottled and pisolitic character. The sandstone is derived from granite sand of a fine character, the grains being angular and not at all rounded as if by eolian action. The granite is pink with very coarse felspar of orthoclase and muscovite mica. It apparently belongs to the great fundamental granite bed which crops out through all North Australia.

Douglas Springs.—This section is taken from the sources of the Mary River in the narrow gorges of much broken tableland in which that river takes its rise.

Magnesite	130 feet.
White sandstone	20 ,,
Red sandstone	50 ,,
	200

There is no appearance of the granite formation either here or for some considerable distance southward. The magnesite is of the usual character and variously coloured, many cliffs being entirely white, without any red mottling. The sandstone is friable and under the microscope shows an eolian character, which is like a true aerial sandstone. The grains have been photographed as seen by an inch objective, and have been figured at plate xxii., fig. 4. It is seen that they have a perfectly transparent appearance, being rounded almost as much as the sands of the Sahara. For comparison the grains of the ordinary sandstone are figured at plate xxiii., fig. 8. This is a seam of small thickness as appears from the above figures. The red sandstone underneath it is of a somewhat less rounded character.

From the above sections it appears that the plateaux are only to a certain extent formed of sandstone. It may be asserted from all I have seen of the formation, that the greater portion of this tableland is granite, and that as the magnesian beds are traced northward they thin out or disappear.

False-bedded Siliceous Sandstones.—But if the general character of the magnesite rocks suggests their origin it is not so easy to deal with the sandstones which underlie them. These need hardly be described. They are brown, reddish, purple-red, and yellow sandstones with thick more or less horizontal layers and false bedding between. To those who are familiar with the Sydney sandstone, no other description will be necessary than to say that they are similar in stratification and the mode of occurrence.

The great mass of the Desert Sandstone formation is of this character, and in many places there is no appearance whatever of magnesite strata. The only variation that I can trace amongst this sandstone is that some of it has the grains rounded as if by some aerial attrition, while in other portions they are fine and angular, containing small irregular fragments of white quartz and felspar, not more than an inch in diameter, and mostly less than half that size. Sometimes these are crowded together so as to give a conglomerated appearance, or rather that of coarse angular gravel; but there are wide areas also with nothing but finely grained sandstone varying only in its many colours.

These sandstones have been a great problem to every geologist who has studied Australian rocks. The Desert Sandstone was very perplexing to Mr. Daintree, just as the Hawkesbury Sandstone was to the eminent Chas. Darwin. It is now nearly eight years since I wrote a paper on a similar matter, and I suggested that these were sands that had been blown about loosely and accumulated in the form of dunes. It will be observed that there is nothing contrary to this idea in what I am now suggesting. The grains from whatever source they came, whether volcanic, granitic or metamorphic, may have been blown about and probably were blown about in the upper strata ere they were consolidated into stone. It may be observed also that these sand ashbeds are not always hardened into a stone. Every intermediate stage may be met with in the interior and on the coast, from loose drifting sand of a true eolian character to hardened stone like the Sydney sandstone. At Double Island Point, about 100 miles north of Cape Moreton in Queensland, there is a sand formation some three or four miles on the south side of Wide Bay. The southern boundary of the bay is formed by two somewhat conical hills of scoriaceous rock separated by a long interval of low land from a mass of volcanic rock. All this may have been part of the ancient crater; but it is now covered with green vegetation and light timber. On the west side there is an extensive development of sand cliffs quite precipitous on the seaward side, varying between 100 and 200 feet high. I have already referred to this curious formation in the paper above mentioned on the Hawkesbury Sandstone, (read before this Society May 10th, 1882) in which I deal with it simply as a formation of blown sand without entering into the question of its origin. No one will dispute that the sands in this case are the ash-beds from the volcano extending to no great distance, but being a patch of such thick beds that there would be no way of accounting for them but for the ancient crater which is close by. The cliffs have curious undulating layers of varying thickness forming sinuous lines with laminæ of sand, false-bedded and dipping at every angle up to 30 degrees. The layers no doubt mark different periods of activity. They are of various colours, giving the cliffs a ribboned appearance, white, yellow, or ochreous-red. On the surface there is a dense growth of tea-tree, with a few patches where the sand forms shifting dunes of rounded outline and great height.

In various geological essays of mine, I have referred to a formation on the south coast of Australia, especially between Port Philip and the river Murray, but always in connection with recent volcanic emanations. It is described as a rock of dark brown colour in patches of rough and compact character ; at times it forms sea cliffs of considerable height. At a distance, one would imagine the rock to be divided into large strata, some 14 or 15 feet thick, with false-bedded lamination between. The material of the rocks is sandstone, but the surface consists of fragments of shells and marine remains with grains of sand and sponge spiculæ intermingled. At one time I regarded this as composed of hardened eolian calcareous sand ; but a more careful microscopic examination has shown it to be an ash-bed, though sometimes it is many miles distant from recent volcanic rocks. Instances may be seen all along the coast, but fine examples near the extinct crater of Cape Grant, at Warrnambool &c. The rocks around Guichen Bay are all tufaceous, in fact there are few parts of the coast which do not show traces of the former activity of Mounts

Muirhead, Graham, Leake, Gambier, and others too numerous to mention, which occur a little way inland.

The vast accumulations of sandstone in the interior without any fossils, diversified with cañons, gorges, precipices, plateaux, and table-topped hills, indicate such an origin as I am suggesting, if we can only satisfy ourselves that the material of which this sand is composed is such as may have been derived from volcanic sources. The evidence that appears to me to bear upon the matter I will now place before my readers.

In my recent travels through Java, my attention was specially directed to the origin of the sandstones met with in that very volcanic island. The first thing that took my attention on landing in Java was the sand upon the beach, which was black and as unmistakably volcanic as anything could well be. No one could misunderstand its character, which spoke plainly of subterranean fires; just, in fact, like very recent volcanic ejectamenta on the latest extinct craters of South Australia. What this deposit would become in a few years time was plainly evident in the older beds. Close by Banjuwangi is the large active volcano of Rawun over 10,000 feet in height, and with a crater of more than five miles wide. As one ascends its torn and rugged sides the huge crevasses and terribly precipitous gullies of 1,000 feet and more reveal immense masses of beds deposited by ancient eruptions. In colour, in consistency, in material, and in stratification they very strongly reminded me of the Desert Sandstone; but I should be far from considering this resemblance as a sufficient proof of their identity. There is not a grain of sand cast forth from the bosom of the earth that is not stamped with marks innumerable to show the nature of its origin. As truly as every coin minted bears a stamp to mark the place of its coinage, so each tiny grain of dust bears its impress unmistakably. It is almost proverbial to say that grains of sand are as like one another as things can well be. But direct the tube of the microscope upon them and what a number of differences are revealed. The volcanic grain with its freshly molten certificate of character, its glassy inclusions, its gas-cavities, and its optical properties, has entirely peculiar qualities of its own which no other grain of sand in the wide world can pretend to. It is true, however, that if it has lain exposed to chemical influences from remote antiquity, its genealogy may be so obscured that only the most experienced eye could trace it, and there are very many sandstones, whose origin, volcanic or no, cannot be decided. But for modern volcanic sands no such thing is possible. The finest volcanic dust (indeed the finer the better) of anything like modern geological times is one of the easiest things to detect, and few could be mistaken in it.

In my paper on the Hawkesbury Sandstone, sands and their characters became a special subject of investigation. Thus my attention was specially directed to the subject and thenceforth I have collected sands and sandstones all through the various colonies. What with these and the aid of friends, thousands of specimens have passed through my hands and have received what attentive examination I could give them from the microscope. Afterwards when travelling through the volcanic regions of the East, I have collected numbers of specimens as well, besides observing the manner in which the ash deposits accumulated and how the different epochs of eruption were represented by strata. I have now before me while I am writing, many specimens, not only from the hundreds of craters in Java, both active and extinct, but sand from the active craters of the Moluccas, the Philippines, Celebes, the Linschoten Islands and Japan. The list of Javanese craters alone would be a long one.

All these sources of volcanic material however distant and different in their extent, have produced volcanic sands which are one in character; though one mineral may have been present or absent, or more or less abundant in particular cases, yet the general result is the same.

It may be necessary moreover to state that sand is one of the commonest and most frequent of volcanic emanations; but sand just like sandstone may mean many different things. Sand is a term applied to finely divided particles of various different minerals; such as quartz, felspar, the various compounds of silica with quartz, alumina, magnesia, iron &c. Even when restricted to the siliceous sands alone, the term has still a wide multiplicity of applications. If the fine sand of a granite country for instance is placed under the microscope, the quartz presents a peculiar aspect which a very little experience enables one to recognise as belonging to that rock. It has a characteristic ruggedness about it with cavities and included crystals always of some size. There are sure to be crystals of different kinds of felspar, with mica and perhaps hornblende. But if the sand be recent, or in fact an ash, the quartz bears quite a different appearance. It has vitreous inclusions, though these are not always numerous, but innumerable gas-cavities; and nearly every fragment has microliths or crystallites, which are microscopic portions of very many minerals in different stages of development from an amorphous state to a complete crystal. The oddest as well as the most beautifully fantastic forms may be seen even in minute broken pieces of stone. They frequently present crystal faces, and from this the nature of many of them can be made out, and generally this is the case with the great majority; but some defy all attempts to reduce them to a geometrical form. Thus there are threads and beads, hooks and symmetrical arrangements of dots and feathered fragments. Petrologists, without attempting to say what these may be, have made some sort of a classification by arranging them under the heads of microliths, crystalloids, trichites, and globulites. Microliths are imperfectly developed crystals, often possessing optical characters which enable their nature to be determined. In sections of certain volcanic rocks, streams of microliths with their longest axis in one direction may be seen sweeping in curves round the larger crystals and fragments. Crystalloids manifest a higher development, being bounded by curved or straight lines, and sometimes stellate and cruciform varieties; often too in the form of true crystals which can be recognised. Trichites are like hairs or fibres, more or less straight, curved, or bent in all kinds of angles and twists, twirling in the most fantastic modes round larger granules. Trichites often are lines of granules like beads in rows or in pairs. Finally the name globulites is reserved for those amorphous and roughly spherical bodies which cannot be identified with any of the other categories; though these shapeless masses are symmetrical often in their mode of grouping, and are also arranged in streams in the viscid lavas.

Now when volcanic sands are very fresh, we find all the above inclusions well represented and unmistakably present; but I regret to add that it does not take a very long time to destroy them. Chemical interchange goes on, oxidation and crystallisation accompanied with the weathering action of water, so as to obliterate most of the former characters. I wish I were able to say after having spent so much time in the microscopic examination of sands, that I have discovered any definite mark or character by which the history of the mere quartzose residuum could be determined, that is to say the nature of its former genesis; but I repeat to my regret that such evidence is not always very visible. It is true that even when the stone is apparently an aggregation of pure siliceous grains, there are always some foreign minerals left which may help to determine its origin; but it must be admitted that the evidence is not always of a conclusive or satisfactory kind. Without wishing to rely upon such facts for more than they may be worth I will here notice some that have fallen under my observation, which may help to throw a light upon the origin of these Desert Sandstones.

First of all is the shape of the grains which are rounded, and this apparently not from attrition. Eolian sands usually are rounded; but they are also often opaque. Some of the sands are rounded and egg-shaped and have a decidedly molten look about them, such as I have seen in volcanic glass; but this is not a universal character. Some of the Desert Sandstone has angular grains though roughly spherical in shape. Partial crystallisation has taken place amongst the grains in many instances, and this prevents the former figure from being now discernible.

The included fragments can sometimes be recognised, and if I am not mistaken, small fragments of augite, labradorite and other volcanic crystals, are amongst them. If this were beyond question it would go far towards proving a volcanic origin for the sands. Fragments of biotite, olivine, and other crystals associated usually with igneous rocks have been apparently present, but in so small a quantity and in such a fragmentary way that the evidence is not conclusive.

Finally there are the cavities in the quartz grains which seem to me after having examined many specimens, to have something peculiar and characteristic about them. Those who have not had much experience in the microscopic examination of quartzose sands can scarcely form any idea of the extent to which the grains are full of cavities. There is no such thing as solidity in this mineral; it is honeycombed to such an extent with minute bubbles, that no fragment however small is free from them. They assume the most fantastic shapes, not always rounded or oval like bubbles generally, but compressed, flattened, twisted and spread out in every conceivable form. Sometimes a succession of parallel lines of cavities in one direction is crossed at varying angles by similar lines, so as to give a clouded appearance to the grain. High magnifying powers are required for the perception of a large proportion, and each increase in the power of the objective brings into view cavities whose existence was not previously suspected. There does not seem to be much difference in this respect, between the quartz of granites, volcanic sands, and crystals that have been formed by slow infiltration without heat or pressure. At Mount Bramble near Springsure, in Queensland, there is an extinct crater on the volcanic tableland, the lava of which is covered with an infiltration of hyalite, no doubt a slow result of weathering; yet the quartz is as full of cavities as the quartz grains from the ash deposit of Mount Bromo, in Java. In the sandstone from the Victoria River, which is an aggregation of purely siliceous grains, in fact a quartzite, there is little else besides these cavities visible in the transparent particles; though even here small grains of magnetite and other minerals are present, including particles of brown augite, which are being converted into grass green mineral, probably viridite. The sands of this rock did not afford me a sufficient number of examples to enable me to speak positively; but from what I have seen I think that the volcanic cavity is more obliterated in this rock than in any other of the same character.

It is not however impossible to recognize recent volcanic particles of quartz by certain frothy aggregations of bubbles, which are unmistakably indicative not only of former melting, but boiling. Sometimes this gives rise to a ribboned structure as if the bubbles had been drawn out by flowing. There are also roughly parallel lines twisted and undulating like the grain of woody fibre; and finally a glass structure like Pele's-hair.*

Without entering further into the detail of the appearances presented by the sand grains when they are either granitic, metamorphic or volcanic, I may sum up by saying that it is perfectly possible to distinguish between them when they are recent, nor is the evidence entirely lost until completely changed by metamorphic action.

After having examined a considerable number of specimens of the Desert Sandstone taken from different places, I incline to the conclusion that they are all volcanic sands; that is to say, speaking now of microscopic appearances only. The reasons for coming to this conclusion are generally the numerous inclusions of foreign matter in the quartz, their nature, and finally the peculiar character of the cavities. I do not pretend that the evidence is perfectly convincing, and I admit that the inclusions and the minerals are scanty in comparison with what I have been able to gather on recent crater walls. However, it would be difficult to reconcile the appearances in the grains of the Desert Sandstone with any other than a volcanic genesis. Moreover when we add the evidence afforded by the magnesite beds, the peculiar aggregation of these sands, and finally their unfossilliferous character, the conclusions as to their igneous origin become strengthened.

The weight of evidence becomes however, very great indeed when we notice, what I have already called attention to, that throughout Australia these sands and sandstones are always found associated with recent volcanic rocks.

It may appear somewhat unnecessary to bring so many proofs forward on a matter so obvious; but the lithological character of these sandstones has caused them to be erroneously identified with Mesozoic strata, and even Carboniferous and Devonian. The government geologists will no doubt rectify some of these errors; but in the mean time Mr. Clarke's map, founded alone on specimens forwarded to that gentleman, retains them. That lamented geologist gave what he considered to be the best inference in the time at his disposal. I could not record any difference of opinion between myself and this painstaking observer, who was justly considered as the father of Australian geology, without recording my sense of the difficulties under which he laboured and the immense credit due for the work he effected. Mistakes in the early history of any science are what must be expected: steps have been retraced and new systems adopted over and over again

* A filamentary variety of obsidian produced by the action of the wind upon the viscid lava projected into the air by the escape of steam from the surface of the lava lake in the crater of Kilauea, Hawaii. Pele is the name of a goddess supposed to inhabit this crater.

in geology in Europe, therefore we must not be surprised or disappointed at the same thing happening here. It is the Desert Sandstone which is being dealt with now, but it will be obvious to any one who has paid even a slight attention to the subject that this is applicable to some portions of the Hawkesbury Sandstone as well. A considerable thickness of the upper strata is composed of tufa or Tertiary ash-beds. This is especially applicable to some of the Sydney sands and sandstone and the strata on the Nepean River.

It will be remarked also that the form of these ash-deposits is nearly always crescentic with reference to the volcanic rocks, and that the thickest portion of the beds and the greatest extent is exactly in keeping with what we might expect as the effect of prevailing winds. Many instances of this can be seen on all geological maps where a survey has been made.

For those who are not familiar with volcanic phenomena it would be hard to realise that a mass of sandstone is nothing more or less than an accumulation of volcanic ashes. The word ash does not represent ashes in the ordinary acceptation of the term. We must remember what a volcano is. We speak of smoke and flame, ashes and cinders in connection with volcanic eruptions; but there is no such thing as smoke, as the word is usually understood, and no such thing as flame, unless sulphurous fumes can be called such. The smoke is steam intermingled with quantities of finely divided stone fresh from the melting cauldron, but blown into the finest particles by incessant explosion. The flame is the reflection on the clouds of steam of the incandescent molten rock rising from the depths of the earth. The ejectamenta comprise what are termed dust, ashes, sand, lapilli, pumice, and scoria, with fragments of stone; but the latter category includes them all, the difference being only that of size. The ashes therefore consist of small fragments of lava comprising minerals of the nature of felspar, augite, olivine, biotite, magnetite &c. Many of these are opaque or coloured, and traces of their crystalline form are very frequently visible. It is evident that these minerals must be abundant or scarce, or one prevailing over another according to the nature of the rock from which they are derived; but it is astonishing how one peculiar kind of mineral will prevail over a wide area.

Generally speaking ashes may be classified according to the rock formation of the volcano. Most readers are aware of the great divisions that are made between the acid or basic lavas as they are called. These fall into five great groups of rocks viz.: the rhyolites or acid lavas, the basalts or basic lavas and the intermediate lavas known as trachytes, andesites, and phonolites. The basic lavas contain a larger proportion of oxide of iron and other heavy oxides, and hence have a higher specific gravity. They are of much darker colour, while fresh lavas of acid composition are usually nearly white. Trachyte, andesite, and phonolite ashes are of various tints of grey. But no ash keeps its colour long: the quantity of iron is too great and the minerals too unstable for the ordinary weathering not to affect them. Moisture soon produces yellow, red, and purple-brown shades. But the mineral character is not lost; and this mainly consists of silica, no matter what the chemical nature of the ejectamenta is. The acid lavas contain from 60 to 80 per cent. of silica, the basic from 45 to 55, and the intermediate from 55 to 65. Thus silica forms the great mass of the deposit, no matter under what category the lavas are placed.

I am able to give an illustration from actual experience of how these sand-beds are deposited. I happened to be on more than one occasion in the neighbourhood of volcanoes during a period of active eruption; and what I saw in connection with the deposition of ashes helped me much to understand how such formations as the Desert Sandstone have arisen.

I was in Java about the time of the eruption of Krakatoa, in 1883, and visited some portions of the kingdom of Sunda in its neighbourhood. In this case the volcano was in activity from the 20th of May casting forth ashes in great quantity. There was a kind of lull again until the 16th of June, when a fresh eruption broke out. Thenceforth there was more or less a continued scattering of ashes over a wide area. The molten mass below the earth's crust was being acted upon by pressure and gradually approaching the surface upon which the sea-water was producing a violent convulsion. Everybody knows what the result was in the catastrophe of the 27th of August. The whole kingdom of Anjer wherever I visited was covered with a coating of light grey ash, something like snow, a foot deep and more, 130 miles from the volcano. The whole of the intermediate country was covered of course in thicker deposits nearer to the volcano, except where the tidal wave had washed it away. It was incredible what destruction was caused by the ash alone. In one village trees were torn down and great limbs stripped off, as though they had been shrubs. The cocoa-nut trees were mere bare poles. The ash, though apparently so light and insignificant was really very heavy and in a very short time would accumulate in sufficient thickness to bear down even the strong resistance of the stout cocoa-nut palm. Houses were crushed in, roads were obliterated, and the sand silted up in many places so as to cover and conceal fences and hedges. At a tea plantation (Parakansala) where I was on a visit, 100 miles or so to the east of Krakatoa, at about 3,000 feet above the level of the sea, the tea plants were curiously covered over with this ash deposit, and the effect at a distance was to resemble a flock of sheep feeding on a snow covered plain. The ash was grey, but where exposed to the bleaching effect of the sun's rays, had become white. The composition of the ash was according to Prof. Liversidge, as follows :—

	I.	II.	III.
Loss on ignition ...	2·17	2·74	2·12
Silica	63·30	65·04	68·06
Alumina	14·52	14·63	15·03
Iron sesquioxide ...	} 5·82	{ 4·47	·28
Iron monoxide ...		{ 2·82	3·66
Manganese	·23	trace	trace
Lime	4·00	3·34	2·71
Magnesia	1·66	1·20	·81
Soda	5·14	4·23	4·25
Potash	1·43	·97	3·41
Titanic acid	1·08	...	·38
	99·35	99·44	100·71

No. I. by Sauer, No. II. by Renard, No. III. by K. Oebbeke. *Journ. Chem. Soc.*, 1884, p. 974.

Professor Judd dealing with the nature of the materials ejected points out that the compact lavas poured forth from Krakatoa at the close of the eruption, contained as much as 70 per cent. of silica, the dust derived from which of course would be nearly a pure sand. The lavas were porphyritic pitchstone and obsidian. The heavier lava dust, which fell in Java, and was examined by numerous geologists contained almost every variety of felspar crystals.* The minute ejecta, consisting of pumice as well as finer dust, carried by the unusual violence of the explosions into the higher atmospheric regions, where it remained suspended for very long periods, was thus drifted to enormous distances from the scene of the eruption, showing how volcanic material even from one point of ejection may be spread over immense areas. The whole of this material from the rapid rate at which it cooled, was a volcanic glass of high specific gravity and slight friability. The most characteristic substance in these dusts was rhombic pyroxene or augite.†

The above analyses show ash derived from a lava of the intermediate character and such deposits are usually grey when

* Professor Judd considers this to be without precedent amongst volcanic products. See Report of the Krakatoa Committee of the Royal Society, London, 1888.

† As an instance of the extent and distance to which this augitic dust was carried I may mention that when making a series of soundings between the Philippines and Moluccas in 1886, there was always an admixture of fresh pyroxene crystals amongst nearly every specimen of the sea bottom. On the north coast of Australia it was especially abundant.

fresh ; but after some time they become brown, as every one can see wherever sections of ash-beds are exposed, and there are few parts of the island without them. On the sides of the extinct craters the crevasses and gullies cut by the rains form gorges, which have been a subject of comment and admiration to every traveller. The precipices and escarpments in these ash-beds form a wild scenery of the grandest kind. The gorges however are in some cases cut down in the loose and friable ash for hundreds of feet and more, exposing in this way different coloured beds of black, white, brown, or yellow, according to the age of the formation. I have seen gorges of 1,000 feet deep at the very least. Perhaps the whole of this is the result of a single eruption.

As an illustration of the manner in which ash-deposits will accumulate and form mountain ranges I may take Java as an instance, about which so many erroneous impressions prevail. In a work entitled "The Eastern Archipelago,"* one of the popular scientific series that convey to the public the most astounding information under the name of useful knowledge, it is stated that "throughout its entire length Java is traversed by two chains of mountains, which occasionally unite, but more frequently run at some distance from each other and send spurs and branches of the most various outline down to the shore." This is an impression as prevalent as it is incorrect. There is no mountain range extending the length of the island, in fact the last hundred miles of the eastern end is formed by four craters making a rough quadrilateral. To the west of Surabaya there is an extensive mountain range which has not any extinct crater for 100 miles or more. It is deeply scored by valleys of erosion, showing that it is built up of fine ash sands in places, or by a accumulation of coarse material when the volcanic period was indeed one of nature's periods of fury. In other parts of the island too, there are detached hills of volcanic material, which have evidently never been a crater or an outflow of lava. They are accumulations of ashes which mark former eruptions, and their resemblance at times in shape and material to the Desert Sandstone is very striking. As a rule they are about 4,000 feet high, though their surface is very ragged and irregular, owing to the wearing down by rainfall which here averages nearly 100 inches per annum.

Professor Liversidge in his "Minerals of New South Wales,"† mentions the occurrence at New Ireland of a pale brown calcareous mudstone, looking at first sight much like a sandstone containing much volcanic ash. He also mentions a sandstone which must have had a similar origin, since the dark thin parallel planes of

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* London : T. Nelson & Sons, 1880.

† London, Trübner & Co., 1888, p. 254.

stratification formed dark bands from the presence of small hornblende or augite crystals.

The following passages from Russell's Geological History of a part of North-Western Nevada,* so aptly illustrate the views taken in the foregoing pages that no apology is necessary for introducing them here. "*Pumiceous dust.*—In describing the section of upper lacustral clays observed in the Humboldt, Truckee, and Walker River cañons, strata of fine siliceous material varying in thickness from a fraction of an inch to five or six feet, were noted at a number of localities ; it is now our intention to describe these abnormal deposits more fully.

"In all the exposures of this material the same characteristics were observed. The beds are composed of a white, unconsolidated, dust-like, siliceous substance, homogenous in composition, and having all the appearance of pure diatomaceous earth. When examined under the microscope however, it is found to be composed of small angular glassy flakes, of a uniform character, transparent and without colour, but sometimes traversed by elongated cavities. When examined with polarized light it is seen to be almost wholly composed of glass with scarcely a trace of crystal or foreign matter. On comparison with volcanic dust that fell in Norway in 1875, derived from an eruption in Iceland, with the dust erupted in Java in 1864 and the similar material ejected in such quantities from Krakatoa in 1883, it is found to have the same physical characteristics ; but it is much more homogeneous, and, unlike the greater part of the recent dust examined, is composed of colourless instead of brown or smoky glass. In the accompanying figures, which we copy from Mr. J. S. Diller's instructive article on the volcanic sand which fell at Unalaska, October 20th 1883, the microscopic appearance of volcanic dust, from various localities and of widely different geologic age, is shown with accuracy. The peculiar concave edges and acute points of the shards of glass render it evident that they were formed by the violent explosion of the vesicles produced by the steam generated in the viscid magma from which the glass was formed, and were not produced by the mere attrition of the fragments during the process of eruption. It is noteworthy that the dust erupted from Krakatoa but yesterday is undistinguishable in its main characteristics from the material of a similar origin which fell in the waters of Lake Lahontan during the Quaternary, or from the dust thrown out by some unknown and long extinct volcano in the vicinity of the Atlantic coast, which fell near the site of Boston during pre-Carboniferous or possibly in pre-Cambrian time. The volcanic phenomena of to-day are governed by the same laws as obtained

* U.S. Geological Survey.—Monographs, xi., p. 146, Washington, 1885.

at the dawn of geologic history. . . . . . More extended operations in the field revealed that beds like those described above are not confined to the Lahontan basin, but are found as superficial deposits above the Lahontan beach at many localities and at points far distant from the old lake margins. Accumulations of the same nature occur in the Mono Lake basin, interstratified with lacustral deposits, and were also found in the cañons about Bodie at a considerable elevation above the level of the Quaternary lake that formerly occupied Mono Valley. About Mono Lake these deposits are frequently of a coarser texture than those found farther northward, and, at times graduate into strata which reveal to the eye the fact that they are composed of angular flakes of obsidian.

"The Mono Craters form a range of some 10 or 12 miles long, which extends south-eastward from the southern shore of Mono Lake, and in two instances attains an elevation of nearly 3,000 feet above the lake. A few coulées of dense black obsidian have flowed from them, but the great mass of the cones is formed of the pumiceous obsidian which occurs both as lava-flows and ejected fragments, the latter forming a light lapilli which gives a soft grey colour to the outer slopes of the craters. Fragmental material of the same nature has been widely scattered over the mountains and on the ancient moraines that occur in the Mono Lake basin, while fine dust, unquestionably derived from the same source may be traced to a still greater distance.

"From the evidence given above we conclude that the strata of fine siliceous dust-like material occurring in the Lahontan sections, as well as the similar beds found about Mono Lake and scattered as superficial deposits over the neighbouring mountains, are all accumulations of volcanic dust which was probably erupted from the Mono Craters. The greatest distance from the supposed place of eruption at which these deposits have been observed is about 200 miles."*

In the same region we have ash deposits like those of Sydney, taking the form of loose sand dunes which the author thus describes: "The first acquaintance the explorer in the Great Basin usually makes with the material forming these deposits is when it is in motion, and fills the air with clouds of dust, sand, and gravel, which are blinding and irritating, especially on account of the

* I have to observe, with reference to this quotation, that the description here given of the volcanic dust from Krakatoa does not quite tally with the specimens gathered by me. These were not wholly composed of glass, and, small as they were, they were full of traces of crystal and foreign matter, especially microliths of triclinic felspar and pyroxene. I am not however contending that the Desert Sandstone is composed of volcanic dust, but volcanic sand derived from ashes with which of course dust is intermingled.

alkaline particles which saturate the atmosphere at such times. Dust-storms are common on the deserts during the arid season, and impart to the atmosphere a peculiar haziness that lasts for days and perhaps weeks after the storms have subsided. Whirl-winds supply a characteristic feature in the atmospheric phenomena of the Far West especially during calm weather, and frequently form dust columns of two or three thousand feet, even more in height, which may many times be seen moving here and there over the valleys. The loose material thus swept about at the caprice of the winds tends to accumulate on certain areas, and forms dunes or drifts which at times cover many square miles of surface. During its journey across the country the material which finds a resting place in the dunes becomes assorted with reference to size and weight, so that the resulting sand drifts are usually homogeneous in their composition, but are characterised by extreme irregularity of structure when seen in section. In the Lahontan basin the sub-aërial deposits are usually composed of fine sharp quartz sand ; but in some instances small drifts are principally formed of the cases of ostracoid crustaceans."

Without following the author into all the details, some further peculiarities of these eolian sands may be inserted here. A few miles further north there is a belt of drifting sand about 40 miles long by 10 wide. The drifts are fully 75 feet thick and the whole vast field of sand is slowly travelling eastward. The sand is of a light creamy-yellow colour and forms beautifully curved ridges and waves. Another area is south of the Carson desert. This train of sand dunes is 20 miles long and four or five wide. In a sheltered recess of Alkali Valley the sand drifted by eddying wind currents has formed a mountain 200 to 300 feet above the plain. This great sand hill changes its outline from year to year while the winds modify the rounded domes and gracefully curving crests of creamy yellow sand. This tract is also slowly travelling eastward across mountains and deserts, unaffected by the topography of the country. The sands find temporary resting places on the terraces in the black basalt on the shores of Lake Lahontan, "bringing out the horizontal lines in strong relief and accentuating the minor sculpturing of the cliffs." (op. cit. p. 155.)

I have given this quotation rather fully, to show how the volcanic character of these sands does not prevent them from being, in particular cases, eolian. In my former paper on the Hawkesbury Sandstone I laid stress upon this mode of formation, but as a rule the ash sands do not always remain loose and drifting. Probably their consolidation depended upon the amount of water that was discharged from the volcano which sent them forth.

The colour of the volcanic sands is another thing to which attention may be drawn. The creamy yellow sands around Sydney will suggest comparisons with those of America. When consolidated and affected by oxidation the sands become brown and red with bands of limonite.

It is nothing new in geology to identify an extensive rock formation with ash deposits. The ancient city of Rome itself affords an apt illustration of this, which bears so high an interest from its scientific and its antiquarian character that it is well worth the space it will occupy by a reference to it. Everybody has heard of the Seven Hills of Rome, on which the city is seated at the eastern side of the valley of the Tiber. Four of the hills namely the Quirinal, Viminal, Cœlian, and Aventine belong to the rising ground or plateau forming the valley. Two of them, the Palatine and Capitoline are detached. The Palatine, 170 feet high, appears to have had precipitous edges. The Capitoline, though only 150 to 160 feet in height, is from its abrupt face and well-marked outline, a conspicuous instance of a relic of ash-beds spared from the weathering of rain and rivers. For the rising ground on the eastern side, an elevated flat which reaches its culminating point in the Esquiline, 218 feet above the river, is composed of volcanic ashes once spread in a continuous sheet all along the valley. The ashes are now consolidated into a volcanic sandstone or tufa, hard enough to be used as building stone, but also easily excavated into the extensive subterranean cemeteries of the Catacombs. This great deposit of ashes came from some recent craters at no great distance from the city. Seventeen miles or so on the north-west are the Ciminian Hills, with Lake Bracciano, an enormous crater, now filled with water instead of fire. Thirteen miles to the south-east are the Alban Hills, with the relics of another extinct crater at Lake Albano. The Janiculum Hill which is on the west side of the Tiber has but little ash on its north side, but is composed of marine beds with shells such as now exist in the Mediterranean, though many are extinct. On the flanks of the Aventine Hill there is a still later deposit of freshwater travertin or recent limestone, showing that the river reached 140 feet higher than it does at present, before the ash-beds were cut down, and the Mistress of the World had spread herself out on the sides of the valley. She played her part and innumerable ruins tell of her former splendours. But the ash-beds lie beneath all, telling of a phase in her history such as once was shared by Australia.

It may be mentioned also as an illustration of these ash accumulations, that I saw the result of a very recent eruption at the volcano of Taal, near Manila in the Philippines. I descended into the crater in March, 1885, when all was quiet; but returning in 1886 I found a singular scene of devastation. An eruption had commenced in the preceding September, and the fall of ashes and liquid mud had caused widespread destruction for leagues around. The crater, it may be mentioned, is on an island which was at the time of my first visit partly covered with vegetation. But after the eruption, all this was devastated, and the forest entirely burnt and destroyed. For this I must refer readers to my account of the Volcano of Taal in the Proceedings of the Linnean Society of New South Wales, Vol. ii., (2nd series) 1887, p. 685.

The whole of the country round Manila for many leagues is covered with a fine-grained deposit somewhat different in mineral character from that of Rome, but evidently a volcanic sandstone or tufa derived from ash. Of this the buildings and walls of the city are constructed, for it forms a moderately compact sandstone like that of Rome. It is very much altered in places both in colour and its state of oxidation, yet a good many of the thickest beds have accumulated since the Spaniards conquered the islands, or about 320 years. Not many reliable records of the eruptions have been kept; but leaves of plants are found in the strata which are not indigenous, but beyond a doubt had been introduced by Europeans.

When we are dealing with a completely extinct volcanic region as in Australia, it is of course impossible to make a general surmise as to the periods covered by such eruptions as those which spread the Desert Sandstone over so much of the north and the interior of Australia. They may have been not only lengthened, but also separated by long intervals of rest; quite sufficient for the surface to have become loosely blown about by the winds, and giving rise to those round-grained sandstones found in the Mary River. The little change that has been effected in active volcanoes during the historic epoch, makes one think that what we call the volcanic part of our Tertiary era, represents a long duration of time. But in any case we might expect great deposits of ash ejectamenta of which the Desert Sandstone represents but a portion. I may mention in conclusion that whatever differences there may be between the sandstones of say Manila or Java and Australia when they are long exposed to weathering influences, there are always traces of a good deal besides pure siliceous sands. As a rule, recent volcanic sands and ashes are darkened by masses of small opaque fragments of black scoriæ, sometimes magnetite, pumice and what may be black fragments of dolerite. The abundance of these cindery opaque particles in recent volcanic ash is very striking, giving it a black igneous appearance which is unmistakable. Such appearances do not certainly belong to the Desert Sandstone, but there are traces of it. At any rate the differences in the appearances presented by the sands of recent volcanoes and that of the Desert Sandstone can be accounted for by chemical metamorphism from weathering, to which the latter has been exposed.

I have taken it for granted here that the Desert Sandstone in North Australia is of Tertiary age. This assumption depends upon the fact of its strong resemblance to a similar formation in Queensland which rests upon Cretaceous rocks. It is worth while however, to warn observers that the nature of such formations, that is simple sandstones without fossils, is to resemble each other as closely as possible, no matter to what age they belong. It is quite possible that sandstones of the middle or lower Mesozoic might be mistaken for those of Queensland, and therefore I do not assert positively that those we have been treating of are Tertiary, much less to claim for them any place in the Tertiary system. Yet it must be added that the recent character of the basalts and dolerites cannot be doubted, and all geologists have regarded them as Pliocene. The Mesozoic volcanic products on the other hand are diorites or greenstones of very uniform character throughout Australia and Tasmania.

It is unnecessary to describe all the localities where I have collected sands as I have given details of the microscopic appearances presented. It has already been stated that the volcanic rocks form more or less a ring round the northern, eastern, and part of the southern sides of the Australian continent. My observations have convinced me that the volcanic period has altered the physical features of the eastern side of the continent in a remarkable manner. Wherever recent lavas occur they now form the watershed between the rivers flowing into the Pacific Ocean and those flowing westward into the interior. Before this volcanic period the Divide on the eastern side was mostly granitic, and even now forms a much higher portion of the mountain range. The trap-rocks always give rise to rivers, some of which are amongst the most important on the north and east coast, such as the Flinders, the Victoria, the Leichhardt, the Roper, the Daly, the Mitchell, &c., &c. There arises also another set of rivers of smaller dimensions having their sources in the springs at the edge of the Desert Sandstone.

It can be proved however, that there has been formerly a very gradual slope from the ocean towards the centre of the continent, and that what is called the plateau is a local accumulation of limited extent. Yet some of the extinct craters are so far inland that it would be hard to restrict the boundaries of the ash and lava strata. They may be found in patches right through the continent. To suppose that they once occupied a very much larger area, or covered the whole country seems from the nature of the case to be an exaggerated view. Volcanic sands may have been carried to great distances, but until observation has shown that they covered the whole continent, we are hardly justified in supposing it. The frequent recurrence of the sandstones in widely separated regions, especially when their origin was unknown has naturally suggested one immense formation.

Fluviatile Conglomerates.—These consist of a coarse, slightly reddish, excessively hard quartzite, with numerous fine blackish lines of specular iron. They enclose many rounded waterworn quartz pebbles of various colours, sizes, and shapes, but all smoothed by fluviatile action. These pebbles are white for the most part, and generally sparingly scattered through the strata; but there are sometimes thick beds of conglomerate with fragments of slate and numerous veins of segregated quartz of small size. There are two kinds of stratification, namely, large divisional lines from one foot to six feet and more apart, and cross stratification or false bedding. Two peculiarities of this formation will now be mentioned:—1. The curious dip of the beds. 2. Its broken and fragmentary character.

1. The formation dips away to the east along the existing streams at an angle of about 30 degrees; that is to say the large partings of the beds seem to have this dip; but in this matter I much regret that I had not an opportunity of making more extensive observations, because sometimes I was inclined to think that the beds have been truly upheaved to a high angle independent of the false bedding or cross stratification. In other instances there was not the same evidence of tilting.

Mount Douglas will afford an illustration of what I am describing. It is a conspicuous hill lying to the eastward of the telegraph line about 100 miles south of Port Darwin. It forms the extreme end of ranges of meridional hills of a very broken character, though not exceeding 500 feet in height. Mount Douglas itself is a castellated hill, quite abrupt on its south-western end, and showing in section about 400 or 500 feet of the fluviatile conglomerates I am now describing. The strata dip away from the river McKinlay at an angle of 30 degrees or more; and though the general appearance would lead one to believe that this dip is due to a tilting of the beds, a more careful examination induces me to think that this angle may represent the direction of the current wherein the conglomerates were formed. There is nothing in the neighbourhood to correspond with this inclination of the beds, which are certainly the newest and uppermost rocks to be seen hereabouts. At the Margaret River I noticed the same dip of a similar conglomerate with similar appearances to those met with at Mount Douglas, though the direction of the dip was different. At Kekwick's Springs, on the tableland beyond the head of the Mary, an outcrop of the same kind of conglomerate was observed with the same high inclination in the general dip of the beds. This outcrop was very small and there was no detached tableland near it. At the head of the Katherine River about 12 miles north-east of the telegraph station, the river flows through a narrow gorge of sandstone conglomerate, which, in the few places that I was able to examine, dipped away from the stream in the manner described in the other localities. On the summit of all these sandstone tablelands the strata seemed to be horizontal; but this was difficult to ascertain satisfactorily owing to the amount of false bedding. I noticed the same curious dip in the McAdam Range on the side of the Victoria River and the same has been referred to by Gregory, Wickham and Stokes; but I was not able to examine the locality closely. We were but three Europeans in a small steam launch, and the blacks are particularly numerous and hostile, so that to land anywhere was to risk unnecessarily a personal encounter.

This then is the character of the fluviatile sandstones and it is an unvarying one wherever I have met the formation. The uniform dip, the hard flaggy nature of the deposit, and the included waterworn conglomerate mark it unmistakably. I have never met with it far from any river, but it is not always present. On the Victoria River it is never absent; but sometimes the range or plateau recedes five or six miles away from the channel as in the case of the McAdam Range. On the Katherine River there are long stretches of country in which it flows through a uniform sandy valley, and then succeeds another kind of channel which is bounded by broken tablelands of this fluviatile sandstone, either abutting on the stream or enclosed in valleys five or six miles in width. The broken detached character of these plateaux gives rise to a perfectly impassable country, with rugged rocky scenery of grand and wild character. In all cases the stone is composed in the same manner as already described with the usual waterworn conglomerate.

Now are we to attribute this singular formation to trap-rocks and ash, or what is its nature? The difference from the Desert Sandstone is the perfectly smooth and rounded conglomerate which it contains, and more or less through the whole of it; that is waterworn quartz gravel or a conglomerate of boulders eight or ten inches in diameter. The quartz is usually, but not always, milk-white. It is certain that we have here evidence of the long sustained action of running water rubbing down the very hardest materials and perfectly rounding them. Moreover the quartz does not belong to the sandstone formation, but rather to the palæozoic slates upon which it lies.

On the whole the most probable interpretation of this formation is that the conglomerate has been derived from a river channel through the palæozoic rocks which contain an abundance of quartz reefs. The sand has been an ash deposit partly filling up the channel and mingling with the conglomerate or covering it over.

At the Yam Creek section, I would remind readers that there is ten feet of large waterworn conglomerate, without any of the characteristic sand. This has been clearly derived from the granite before there was any admixture of other material. Generally speaking the conglomerate increases towards the base of the formation to the exclusion of the sandstone.

But the curious fact observed in connection with these fluviatile deposits is their great disproportion to the streams now connected with them. At Yam Creek the valley is a mile and more in width and the present small trickling stream is 90 feet below the bed of conglomerate. Its waters increased tenfold would be utterly inadequate to produce the erosion of 90 feet through granite and a valley of such width. The same argument may be used towards all the rivers in North Australia; they seem so much smaller than the deposits connected with them and the erosion effected that one is forced to the conclusion that the rivers, though strangely enough occupying the same valleys, have become reduced in an extraordinary manner compared to what they were formerly.

The erosion here referred to is different in its effects in the different streams. Thus the valley of the Victoria River is bordered on its whole course as far as I have seen by the fluviatile conglomerate into which the waters of the stream are daily making inroads. In the Daly River the same thing is taking place. In the Katherine River which is the main branch of the upper Daly, the river, as I have said, flows in some places through a wide and rugged tract of sandstone conglomerate; through other tracts in a deep sandy valley; and again, on the north side of a wide plain and at the foot of a very gradual slope of Desert Sandstone. From these considerations I think that the fluviatile sandstones are never more than local deposits of limited extent. If the sandstone once covered the whole of the country as Mr. Daintree supposes, these rivers would cut through valleys of the formation. Instead of this we have constant instances of the stream on one side winding round a sandy slope, which is evidently the thinning out of the deposit, while on the other side there is a wide plain of the older formations without any evidence of their having formerly been covered with an ash deposit.

There is no very great difference between the conglomerates connected with the fluviatile sandstone and what are called the "drifts" of Victoria and other colonies. Mr. Selwyn divides these into two formations, the newer drifts, and those which he considers upper and middle gravels, boulders, and water-worn conglomerates. The first are Pliocene or what Mr. Selwyn considered to be Pliocene, and are auriferous; the second he calls Miocene, and have never been found to contain gold. In some instances the oldest auriferous formation is made up of successive layers of volcanic and sedimentary material that gradually fill up the old valleys. The older waterworn gravels have been met with in the several localities from sea-level to an elevation of 4,000 feet; but some of these may not have owed their origin to fluviatile action. Hardly any other mode of accumulation will satisfy the requirements of the drifts of North Australia.

It is very singular that we should find such constant and unvarying evidence of the greater height at which the rivers flowed, when we should be led to expect immense subsidences in the volcanic tract. After such outpourings of lava and such an enormous transfer of material to the surface in the form of ash, one would expect to meet the same evidences of subsidence which we find in all volcanic regions. There is certainly no evidence whatever of any upheaval. Possibly it may be explained by supposing that the most of the river valleys were filled up in part by the volcanic ash deposit, until gradually the rivers cut down the loose material to its former level.

It seems to me probable that the continent, before the volcanic period, was higher above the sea than it is now. The period itself may have been connected with the destruction of the ancient land fauna of Australia, which does not apparently overlap the existing fauna, at least as far as the terrestrial mammalia are concerned. In Queensland the evidence about the Darling Downs and main range is that violent and sustained volcanic disturbance was followed by floods which swept into heaps fragments of the remains which volcanic action had destroyed. The deposit at King's Creek is an extremely abundant collection of broken bones, mingled together with indescribable confusion, on a few square yards of ground. In this there are gigantic marsupials—kangaroos, wombats, and opossums, with water-birds, large crocodiles, gigantic lizards and turtles.

With regard to the age of some of the later volcanic phenomena, we have very clear evidence in Moreton Bay that it belongs to the most recent period. There is satisfactory evidence afforded in a lava or ash stream which runs into the sea at Cleveland. It has flowed over shells and corals which differ in no way from the existing marine fauna. There is a basaltic flow at Lytton a few miles further inland which appears as old as most of the volcanic formations of the higher table-lands. The Glasshouse Mountains on the north side of the bay, of which figures are here given (see plates xix. and xx.) are apparently no older.

The volcanic emanations of Mount Gambier, Mount Shanck, and Tower Hill belong also to the recent period, and are connected with the existing fauna.

Altogether the evidence afforded by the volcanic rocks throughout Australia is that there were at least two distinct periods of eruption. The first or oldest, extends nearly all round the continent, and at least 300 miles into the interior. The south-west part of the Australian land seems to have escaped this volcanic disturbance, which however extended to Tasmania. There is a second period commencing towards the Pliocene epoch, continued into the most recent post-Pliocene times. These conclusions are entirely in accordance with those arrived at by Mr. Selwyn and his officers in the Victorian geological survey. They are also fully confirmed by Messrs. Daintree and Jack's observations in Queensland.

Mr. Selwyn's observations are thus stated *:—" The mineral and lithological characters of the volcanic products of the two periods present marked similarities and differences. An irregular concentric concretionary, or polygonal jointed structure, is eminently characteristic of the older, so much so that, though it affords any quantity of excellent road-making or railway-ballasting material, no building-stone is ever procured from it. The columnar structure is also not uncommon in both the older and the newer formations. Interbedded with the harder layers are strata of a very soft, unctuous, amygdaloidal clay or 'wacke,' bluish-grey, brown, yellow, brick-red, or pure white, Sometimes the section exposed consists almost wholly of such clay, traversed by ferruginous veins, and enclosing hard lumps or balls of dense-black basalt." The solid layers are mostly a dense, dark, crystalline basalt, composed chiefly of augite, labradorite, olivine and specular iron. Though some are cellular they are far more solid and dense than the recent Pliocene lavas, which present a much greater variety of texture, the most common and characteristic being the well-known Melbourne bluestone. It is a true dolerite or variable mixture of augite, labradorite, iron and carbonate of lime, vesicular and coarsely crystalline and compact, and not unlike a hard calcareous or metamorphic sandstone of blue, grey, or almost black colour. Olivine, specular iron, and hyalite are associated but not as component parts of the stone. In some districts it is associated with beds of regularly stratified ashes. These are so soft when first quarried as to be easily sawn into blocks which harden considerably after exposure. Obsidian is found, but no true trachyte.

The analysis of the older basalts shows a considerable proportion of iron and magnesia, the iron being as high as 31 per cent. in some lavas, and the magnesia 18. In the newer volcanic basalts a similar character is prevalent in some of the dolerites.

Mr. Daintree says in the essay on the geology of Queensland, from which we have already quoted, that " volcanic action seems

* Notes on the Physical Geography, Geology, and Mineralogy of Victoria, p. 29, by A. Selwyn, &c., Melbourne, 1866.

to have played the most important part in determining the elevation and present physical outline of north-eastern Australia. The main outbursts of lava have taken place along the dividing range, and these are generally due to the Pliocene disturbance. "The southern areas namely, Peak and Darling Downs &c. are older agreeing with the Lower Volcanic of Victoria."

The rock masses of both periods are basic in character and may with rare exceptions be all grouped as dolerites. Mr. Allport says: "This dolerite contains triclinic felspar, augite, magnetite, pseudomorphs after olivine. The felspar prisms are clear and transparent and exhibit well the striæ and bands of colour when examined in polarized light. The augite occurs in small brown crystals and grains; it frequently contains black magnetite and is sometimes slightly altered. The olivine has been completely altered to iron oxide, and appears in the sections as bright red grains and crystals. Pseudomorphs of quite similar character occur in the dolerites and basalts of the coast of Antrim."

Mr. Daintree speaks of an interstratified bed in the Upper Volcanic of a *highly siliceous rock in which one half the mass was composed of quartz crystals arranged in a quartzose matrix.*

In two places the Desert Sandstone is seen resting on the older Volcanic, namely at Agate Creek, a tributary of the Gilbert River, and near Morinish station.

These two volcanic periods formed a time when a fire-belt fissure undoubtedly existed round nearly the whole of the continent of Australia. On the south side there has been elevation of the land to the extent of 600 feet, about the period of volcanic activity. There are no such signs of elevation in any other part of the continent; no Tertiary marine fossils are found except on the south side. The volcanic evidences are not confined to the mainland: a few island craters exist at some short distance from the coast-line; such as Mount Prudhon, and probably several other islets between Keppel Bay and Whitsunday Passage. There are also flat-topped islands of Desert Sandstone amongst the numerous groups in the same locality. Altogether the evidence on East Australia is in favour of subsidence. On North Australia the shallow sea and other evidence would seem to indicate a stationary period. I do not speculate further on the geological history of those times, for the absence of facts would make such guess-work practically useless. The elevation of the Great Australian Bight is, however, a fact we can point to with certainty that it must considerably have altered the outline of the continent. This with the volcanic period and the formation of the Desert Sandstone are grand events in the physical history of our continent, succeeding the great Cretaceous sea which once invaded the north-eastern part. The fire-belt fissure seems to have been an isolated outburst on the earth's surface of very long ago, and perhaps the great oriental fissure which extends from Sumatra to the Philippines is its substitute. Had it not been for this fiery epoch all Australia would be utterly barren and fruitless, so we owe to its energy something more than the stony arid plateaux of Desert Sandstone.

Microscopic Appearance of Sands.—I now proceed to give the result of microscopic examination of the sand grains showing how far they afford evidence of their volcanic character.

Sandstone from Mary River, North Australia.—Grains all perfectly transparent, with no opaque particles, but in shape singularly rounded; all the rugged angles smoothed off; most of the particles spherical and some completely egg-shaped. Foreign inclusions not many; sometimes stained by oxidation a brownish-red (pseudomorphs after olivine?) more rarely grass-green (viridite?) Cavities not numerous, but sometimes arranged thickly in lines of trichites or rows of bubbles. Polariscope—about one-fifth of the grains are dark, with crossed nicols. The rest polarize brilliantly, rarely showing mineral inclusions of felspar. The number of glassy particles in this sand with occasional crystals of hornblende and other minerals, certainly suggest a volcanic origin. The rounded outline is due more probably to melting than attrition.

Port Darwin Jail Road.—Grains angular, none rounded, mostly transparent, but a few opaque, all more or less reddened by oxidation. Foreign inclusions somewhat numerous, cavities very numerous, sometimes taking the form of lines of trichites. Polariscope—about a third glassy, refusing to polarize or only feebly, the rest brilliantly, with the characteristic appearances of chrysolite, augite and felspar crystals broken and fragmentary. The large proportion of volcanic glass and included microliths give it certainly a volcanic appearance.

Fanny Bay, Beach Sand.—This sand is largely intermixed with marine remains, notably foraminifera (*Quinqueloculina*, *Rotalia*, *Planorbulina*, *Globigerina*, *Textularia*, &c.) echini spines, fragments of shells, corals, bryozoa, *Gorgonia* spicules and the usual tropical marine exuviæ, with opaque granules of magnetite, ferric oxides and a few crystals of chrysolite, transparent grains of quartz with included cavities and microliths. Polariscope—the few grains of quartz polarize freely and show inclusions of felspar, augite, chrysolite, and other volcanic minerals, all more or less changed. Some perfectly formed crystals of chrysolite and few glassy fragments. The matrix of volcanic minerals with marine exuviæ is very marked in this sand, but probably some of these may have drifted from the active craters of the Moluccas and the islands to the northward. The transparent sand-grains though few in number are somewhat like those of the Mary River.

It is not necessary to add further details about the microscopic character of grains of sand derived from the Desert Sandstone in other different places, since they are all of the most uniform character, showing few opaque particles, a fair proportion of volcanic glass, very transparent quartz grains with foreign inclusions principally of chrysolite, but often with small fragments of augite partly converted into hornblende, various kinds of felspars and gas-cavities.

For comparison, I insert a few notes on volcanic sands and ashes.

Ash from Krakatoa.—This ash, aggregated into small rounded grains like sago, caused by moisture of some kind, possibly the steam connected with the volcano. Particles when spread out very finely divided and more than half quite transparent, the included fragments of magnetite and other sphærulites very numerous; also gas cavities; some of the grains having the appearance of glassy froth of minute bubbles, in others the cavities forming rough parallel lines like the irregular grain of woody fibre; glassy fragments with the cavities drawn out into a long ribboned structure with occasionally aggregated crystals of augite, biotite, chrysolite, and labradorite. About half the fragments do not polarize.

Taal Volcano, Luzon, Philippines.—Most of the larger particles opaque, quartz and felspar whitish and transparent, full of brown and black sphærulites of magnetite and other minerals; gas cavities not so numerous as the included minerals, but all very much mingled as if frothy. Polariscope—only a very few fragments polarize belonging to the finest dust, the glassy particles however are frequently opaque.

Sand Sea, Bromo, Java.—More than half the particles opaque, transparent particles polarizing brilliantly with few exceptions, some of the fragments showing crystals of labradorite and other felspars besides olivine and augite. Cavities and sphærulites numerous, making most of the transparent grains frothy looking. Some of the opaque grains with crystalline faces. The actual crater of Bromo is a hill composed of the finest possible dust which is incessantly discharged with a loud series of explosions. These follow each other so closely as to make a roaring noise, that can be heard from a long distance. The dust thus discharged is a brownish powder, about half the particles of which are glassy and refuse to polarize. There are a few dark, opaque granules, the rest being transparent with comparatively few included microliths. Augite, olivine, and twin felspar crystals and microliths of felspar very numerous.

As a rule, it may be generally stated that the volcanic sands are darker and contain a very much larger proportion of opaque fragments than the grains of the Desert Sandstone. In polarizing also the fragments of crystals are much more numerous and unmistakable. There is much more volcanic glass, and the gas cavities have a decidedly more frothy look. Microscopic investigation shows decided differences between the sands of the Desert Sandstone and fresh volcanic sands; but these differences are such as can be accounted for by metamorphic action or local peculiarities, and the resemblances are such as to show the probability of a common origin. Moreover the discharge of pure creamy yellow sands as ashes from certain volcanoes is an undoubted fact of experience.

Conclusion.—The following conclusions are the result of the present inquiry into the nature of the Desert Sandstone:

1. What is regarded as belonging to this formation is found in detached plateaux through all tropical Australia.
2. It is characterised on its upper surface by magnesites, but the great mass of the formation is sandstone of a red, white, yellow, or brown colour.
3. Fluviatile sandstones are found near all the rivers, and only near them. They are distinguished by waterworn quartz pebbles and boulders which gradually increase towards the base into a waterworn conglomerate.
4. The fluviatile sandstones dip at an angle of thirty degrees throughout Arnhem's Land and along the Victoria River.
5. These sandstones are of a very broken character, rendering the country in places absolutely impassable. This is especially the case on the upper portion of the Daly or Katherine River.
6. The whole of these formations, except the conglomerate are probably derived from volcanic ashes. A microscopic examination of the sand grains would seem to bear out this conclusion.
7. The geological age of these sandstones is uncertain, but probably belongs to the two great volcanic periods of Tertiary age, the latter of which extends into the existing period. The lowest beds lie upon the Cretaceous formation.
8. The old idea of the broken edge of a great continental plateau is due to this formation, which, however, exists only in patches.
9. The surface of the Desert Sandstone is not entirely sterile, as it supports a poor vegetation of eucalypts, porcupine and coarse grasses; but as a rule the country is of a worthless character.

Specific gravity of Desert Sandstone.—The following table of the specific gravity of specimens of sandstone collected by me was kindly made at my request by Prof. A. Liversidge, F.R.S., using Joly's spring balance.

1. Red sandstone, base of Desert Sandstone, Gorge and Yam Creek, 2·60.
2. Sandstone, Victoria River, 2·51.

3. Desert Sandstone, Adelaide River, 2·59.
4. Gorge of the Katherine, 2·54.
5. Coarse friable sandstone from head of Mary River, North Australia, and under 40 feet of magnesite, 2·57.
6. Desert Sandstone, McMinn's Bluff, 2·51.
7. Desert Sandstone, McMinn's Bluff, 2·36 – 2·37.
8. Limestone, Tableland, Katherine River, 2·69.

The specific gravity of the magnesite was about 2·90, but at present I have no specimen to confirm this.

Explanation of Plates.

Plate xix., fig. 1.—Prismatic basalt, Glasshouse Mountain, Moreton Bay, Queensland.

Plate xx., fig. 2.—Core of prismatic basalt, Glasshouse Mountain, Queensland.

Plate xxi., fig. 3.—Various specimens of volcanic dust.

Plate xxii., fig. 4.—Desert Sandstone, Mary River, North Australia, × 70 diam.

Plate xxii., fig. 5.—Ash from Bromo crater, Java, (active volcano) × 70 diam.

Plate xxii., fig. 6.—Sahara Desert Sand × 300 diam.

Plate xxiii., fig. 7.—Hyalite from lava, Mount Bramble, Springsure, Queensland.

Plate xxiii., fig. 8.—Desert Sandstone, Yam Creek, North Australia, × 50 diam.

ON A NEW SELF-RECORDING THERMOMETER.

By H. C. Russell, B.A., F.R.S., &c.

[One Diagram.]

[*Read before the Royal Society, N.S.W., 7 November, 1888.*]

I need not remind the members of the Royal Society that the attempts to make a really satisfactory recording thermometer have been very numerous, and that it is probable that a complete solution of the difficulty in recording changes of temperature accurately has yet to be discovered ; but I think I shall be able to shew you that the one I have to describe this evening is in many respects an advance upon those which have gone before it.