REPORT

ON THE

GEOLOGY AND MINERALOGY

OF THE

SOUTH-EASTERN DISTRICT

OF THE COLONY OF

SOUTH AUSTRALIA;

OR,

THAT COUNTRY LYING BETWEEN THE RIVER MURRAY, THE 141ST MERIDIAN OF LONGITUDE, AND THE SEA,

BY THE

Rev. Julian E. Tenison Woods,

FELLOW OF THE ROYAL GEOGRAPHICAL SOCIETY; OF THE ROYAL GEOLOGICAL SOCIETY; OF THE LINNEAN SOCIETY; OF THE ROYAL SOCIETY OF VICTORIA; OF THE ROYAL SOCIETY OF TASMANIA, &c., &c.

ADELAIDE:

PRINTED BY W. C. COX, GOVERNMENT PRINTER, VICTORIA-SQUARE.

1866.

REPORT

ON THE

GEOLOGY AND MINERALOGY

OF THE

SOUTH-EASTERN DISTRICT

OF THE COLONY OF

SOUTH AUSTRALIA;

OR,

THAT COUNTRY LYING BETWEEN THE RIVER MURRAY, THE 141ST MERIDIAN OF LONGITUDE, AND THE SEA,

BY THE

Rev. Julian E. Tenison Woods,

FELLOW OF THE ROYAL GEOGRAPHICAL SOCIETY; OF THE ROYAL GEOLOGICAL SOCIETY; OF THE LINNEAN SOCIETY; OF THE ROYAL SOCIETY OF VICTORIA; OF THE ROYAL SOCIETY OF TASMANIA, &c., &c.

ADELAIDE:

PRINTED BY W. C. COX, GOVERNMENT PRINTER, VICTORIA-SQUARE.

1866.

REPORT

ON THE GEOLOGY AND MINERALOGY OF THE SOUTH-EASTERN DISTRICT OF THE COLONY OF SOUTH AUSTRALIA, OR THAT COUNTRY LYING BETWEEN THE RIVER MURRAY, THE 141ST MERIDIAN OF LONGITUDE, AND THE SEA.

THE geological features of the above district are extremely interesting, presenting a very perfect series of the tertiary system, from the miocene upwards, and comprising peculiarities of upheaval and stratification, the knowledge of which may contribute towards the recovery of large tracts of land which are useless at present.

The formations represented are as follow, taken in the descending order:—

AQUEOUS OR SEDIMENTARY.

1. Blown sand or dunes.
2. Alluvial and diluvial deposits.
3. Recently raised sea or estuary beds, with existing shells.
4. Pliocene sands.
5. New pliocene—calcareous sandstone.
6. Older pliocene—limestone with bryozoa.
7. Upper miocene, Nos. 1 and 2.

IGNEOUS AND METAMORPHIC.

1. Basalts, lavas, and recent volcanic rocks.
2. Dolomite, saccharine limestone, and other altered rocks.
3. Granite, felspar, porphyry, and gneiss.

No older rocks than tertiary have as yet been found in the district; but I have no doubt that the granites on Lawson's Run, the Monster Rock, and various places through the Great Mallee Scrub, or South-east Desert, are nothing else than highly altered primary rocks, such as we find on the banks of the River Glenelg, in Victoria, just over the boundary line of the Province. Though the passage from the sedimentary into the crystalline state cannot be observed in any of our granites, it can be frequently seen in those in the neighboring Colonies to which I refer. I now proceed to notice the various sedimentary deposits enumerated above.

1. *Blown Sand or Dunes.*—Fronting most of the beach, from the boundary of the Province until the River Murray is reached, are loose hills of yellow, yellowish-white, and grey sand. It is no doubt washed up by tidal action, and owing to the dryness of the climate soon becomes so loose as to be easily drifted into hills. The sand is of two kinds. The first is a coarse yellow calcareous sand, entirely composed of large rounded grains or water worn fragments of shells, varying in color from a glassy transparency to orange and warm brown. In consequence of its coarseness it is very loose and shifting, supporting no vegetable growth upon it, but lying exposed as high rounded hills of bare yellow color. The uniformity of the color, the rounded outline, and the absence of any vegetation, gives them a bald appearance, and makes them very conspicuous objects, even at long distances. They are only found on those portions of the beach exposed to a heavy surf; and even there the winds sort them to a certain extent, so that fine sand, with a dense growth of rushes, acacia, and *Leucopogon Richei*, are often found in close contiguity, mixed up with a dark sand, with layers of such shells as *Turbo undulatus*, Lamk., and *Succinea*; the layers showing the several surfaces and the *Turbos*, probably human agency.

Another kind of sandhill occurs where the particles are finer, and is generally found round bays or inlets more or less protected from the action of the waves. The sand is entirely organic. The silicious particles are spongy spicules (mostly triradiate) and fragments of marine *Diatomaceæ;* the calcareous particles, forming, I should think, five-sixths of the whole, are shells of *Foraminifera*, particularly those frequenting shallow water. Such sand easily sustains coarse vegetation, and when slightly decomposed has a brown earthy look, very much like loam. Both these kinds of sand are drifted up from the sea by a process which is seen even now in progress. The tendency of this operation is to throw up a rampart of sand outside the innermost line of the surf, and by little and little to enclose arms of the sea, or long strips of salt water, which run parallel with the coast for miles. This has been the case along the Coorong, which is no more than a rampart of sand more than 100 miles long, which the wind and waves have cast up in front of the coast, leaving inside it a now stagnant saltwater lake about the same length, and from one to five miles in width. Similar ramparts are formed on the west coast of Africa, and the enclosed channels are there used as a means of internal navigation. The Coorong is only navigable, however, as far as the Salt Creek, and not even so far in summer, in consequence of one or two bars of sand. By clearing these, a small steamer might easily ply between Milang and the Salt Creek, which would save great mail expenses, and place the South-Eastern District within forty-eight hours' direct communication with Adelaide.

The Coorong is open to Lake Alexandrina at its northern end. The lake is fresh water, and the transition between the two waters is quite sudden—varying in position according to the season and the direction of the wind. There are many other salt lakes besides the Coorong upon the coast of this district, as a glance at the map will show; and though none have so regular an outline, yet they all have their length parallel with the coast line, and are all separated from the ocean by a sand rampart, which has been thrown up by the waves. In some few instances, the remains of trees which have been buried by the encroachments of this sand, are visible above the summits; but encroachments of that kind are not numerous. The blown sand is the most recent formation upon our coasts. It is derived from the sea, and not from the destruction of pre-existing rocks. The quantity of lime thus secreted from the waters of the ocean must, therefore, be immense, because these hills represent principally the secreting powers of various mollusca. The total effect upon seawater must, however, be very small, and not more appreciable than the absence of immense deposits of salt found in some of the dry lakes of the coast. The sand under notice must not be confounded with a fine siliceous sand to be subsequently spoken of, which is clearly a pliocene formation.

Alluvial Deposits.—Immediately succeeding these blown sands, but in the chronological order contemporaneous with them, we find certain deposits of alluvial soil throughout the district which are more or less grassy, and available for cultivation, or are covered by freshwater lakes and swamps, or saltwater marshes. Such soils are generally derived from the decomposition of the underlying rock, modified by decaying vegetable matter. I wish, however, to except from these deposits sandy soils, which differ only in the slightest possible degree from the underlying rock, and which, though supporting a somewhat thick growth of scrub, retain no water, except in a few clayey portions. The alluvial deposits thus restricted comprise black, grey, and blue clays, with black and red loams. It frequently contains loose cakes of limestone, which appear to have concreted there after the soil had formed. A reference to the map and accompanying section will show that the terraces which rise gradually from the coast, are hollow or depressed to some extent in their centre, so as to cause a sort of basin. In most cases these basins lie more towards the westerly edge of the plains, and are stopped from being drained into the lower terrace by an elevation which always occurs at the edge. Some of these basins are still filled with fresh water; but some have drained through gaps in the ranges, or western tilted edge of the terrace. In the latter instance, the limestone is a freshwater deposit, containing well-preserved fossils in every respect similar to the species of *Physa, Paludina, Planorbis*, &c., frequenting the neighboring swamps. The depth of this freshwater limestone is in most cases inconsiderable;

but occasionally it is quite thick enough to show that the commencement of these lakes dates back very remotely from any human records. The Township of Kincraig is built upon what was formerly an inland freshwater lake; but is now drained by the Narracoorte Creek, which runs through a gap in the range. I should say that this drainage has commenced within a very recent period, for the stream has a very modern aspect; but the relics of the former lake are many feet in thickness. The site of the Kincraig half of the town is on a perfectly level flat of dark black clay, very soft in winter, but rich and fertile. This flat, which is as level as a racecourse, is surrounded by a complete wall of low hills, broken only at the creek, and marking the former bed of the lake. Under the clay soil, at various depths, occurs an extremely hard and almost crystalline limestone of brownish yellow color, and with freshwater shells disseminated through the mass. Its fracture is conchoidal, and its lustre glimmering. The commonest shell is the large *Physa*, which is still found strewing the mud flats after every winter's rain. There are other dried beds of lakes besides the one now referred to at Narracoorte, the most notable of which are the flat at the back of Robertson's, which is drained by Mosquito Creek, and Inglis's Flat, in the Tatiara. Besides such dry lakes, there are very large tracts of land throughout the district which are inundated every winter, in consequence of the basin-like form of the land in which they occur. The soil in these cases is very much mixed with shells of *Physa*, *Paludina*,* &c., left there by the retiring waters. The amount of soil which has accumulated from these various causes may be estimated as varying from one to twelve feet. There is evidence to show that the present condition of the land is a state of things which has been subject to but little variation. Most of the permanent swamps or morasses have beds extending to some distance around them, and with a depth of soil of seven to eight feet—showing by the clearest evidence that it is a deposit derived from the same swamp formerly of a much larger size. This is not a proof that more rain fell at former periods than now; but that the swamps, in filling up the hollows by their accumulations, have slowly contracted their dimensions. As yet, in any of these surface accumulations, nothing but freshwater shells have been found, except at a native well, in the Tatiara, where a small fragment of bone was found imbedded in the freshwater limestone. It appeared to me to be a portion of the tibia of a kangaroo; but the specimen was too small to speak confidently as to its character. The occurence of such a fragment is, however, mentioned as an instance of what we may expect to find in these freshwater deposits.

* This *Paludina* has been described by Martens (*Annals Nat. Hist.*, Vol. XVI., p. 255) as *P. polita*, but as it is confounded with an allied species occurring on the Balonne River, I propose for it the name of *P. tortuosa*. The shell is rarely found in an entire state, but, when not decollated, the apex is twisted and oblique.

To suppose that nothing was imbedded but shells out of the many living inhabitants of this tract of country in former times, would be contrary to experience, not only in other countries, but in Australia. The bones of the gigantic *Diprotodon* are found in Queensland, on the banks of ancient lakes; and similar remains have been discovered on the edges of some of the lakes near Geelong. I am convinced, therefore, that a very extensive addition to our knowledge of the former animals of this Continent will be made as the lakes and swamps of this district are explored.*

Contemporaneous with the more ancient portion of these alluvial deposits must be regarded the remains which are found in the many caves of this part of the Colony. Their history belongs to the more ancient strata of the land, because they have undoubtedly only accumulated before the present creek system of drainage was established. Most of the caves that I know had formerly been used as channels for the drainage of the water, and it was during this period alone that the bones accumulated. But this may have represented a very long space of time. The caves are nearly occupied by level floors of stalagmite and alluvial deposit, and are broken only in their upper parts into fissures and cracks. Formerly, however, they must have been all cracks of very uneven surface. As far as I can judge, it was only the flood waters of the lake now drained by Mosquito Plains, which would flow through the cave, though in this I may be wrong; at any rate I am safe in saying that the freshwater limestone found in the flats, and the deposits in these caves are contemporaneous formations and represent the same lapse of time. I may suggest that the last eruption of Mount Gambier may have caused the creeks to arise, which drained the lakes, for they are both comparatively recent events;

* In sinking a well on the edge of a swamp fourteen miles north-north-west of Penola some bones have been dug up, which were this day (April 25, 1866) recovered by me. They comprise two tibias and two tarso-metatarsal bones of some extinct and very large bird. The extraordinary length of the former bones, and the absence of any articular surface on the inner and posterior surface of the metatarsal bones, show them to have belonged to some struthious bird very nearly allied to the emu (*Dromaius ater*, Viellot); but, as many osteologists are of opinion that specific distinctions cannot be determined by the skeletons of birds, this bird may have been something more than a mere species of emu. From the size of the bones, it was evidently a larger, heavier, and more clumsy bird. The bones are both of right feet. The lateral surfaces of the three articular prolongations of the distral extremity are very concave; and, at the extremity of the groove indicating the juxta-position of the metatarsal pieces, there is a large foramen extending from before backwards through the bone, perfectly enclosed on its inner side. In this respect the bone differs from our existing emu, in which the groove is quite open, prolonging the separation between the metatarsal pieces, and giving the external condyle a very long tapering appearance. In the fossil bone the condyles appear short and stout and very broad. I should propose the provisional name of *Dromaius Australis* for the bird until more bones are found. It is certainly quite extinct, but appears to have been contemporaneous with the natives, for these bones are marked with old scars, one of which must certainly have been inflicted by a sharper instrument than any in possession of the natives at present; there were, however, fragments of flint buried with the bones, and a native well about fifty yards away.

and there is evidence to show that they have happened since the fauna and flora of the district assumed its present character. There is, however, no direct evidence of a connection between the two events, though I think it highly probable.

3. *Recently raised sea or estuary beds.*—All round the coast, as far as I have been able to examine it, and indeed, throughout the coast of the south shores of Australia, a fringe of recent shell beds is found, containing either salt water or brackish water shells, river or estuary deposits, but differing only slightly from the mollusca found living in the immediate neighbourhood. The depth of these beds varies greatly, as also their distance from the sea; but in no case, that I am acquainted with in this district, are they more than twelve feet thick, nor have they been found further than twenty-four miles from the ocean. As to their height above the sea I have no means of judging; in the locality just referred to, I should say, they were at least eighty feet above the sea level, and no difficulty would be experienced in finding places where the altitude was greater than that, but the exact amount of upheaval which has taken place since they were deposited would be difficult to estimate without more extended observations. The shells in these beds have all a most recent appearance, always retaining their color, and only very slightly bleached; they are brittle and easily broken when first dug out, but harden on exposure. They are found very near the surface, and no great difference can be observed between those found at a distance from the shore and far inland and those dug out close to the seaside. This circumstance I look upon as very remarkable; if the process of upheaval had been very gradual and slow, the shells found at twenty-four miles distance inland should have a much more ancient appearance; moreover, it is impossible to understand, since these shells are within a few inches of the surface, how they could have escaped erosion by the long continued action of the waves, if they had been slowly upheaved. On the other hand, there is much to show that the upheaval was sudden and paroxysmal. All along the coast there are raised beaches on a succession of terraces, rising one above another like steps. These terraces are more numerous and closer together near the sea, occurring at longer intervals further inland, though never more than twelve miles apart; they are generally loose and arenaceous, but there are places on the Biscuit Flat, where they have hardened into the sandstone cement which surrounds them, making a very rough and hard building stone. At the Salt Creek, and indeed, on many other places along the coast, the stone is of a most durable and flinty description, and with the mass of unbedded shells serving to give it a pretty and curious appearance. It might be profitably worked in these places as an ornamental stone. Another peculiarity of the deposit is, the occurrence of beds of small shells, sometimes four or five miles

long and two feet deep; the majority of the shells rarely exceed one fifth of an inch in length; the species are very few, comprising principally two varieties of *Paludina (P. tortuosa* and *P. polita ?)*, one small *Cerithium*, and rarely a *Margarita* and *Nassa pauperata*. These shells indicate brackish water and probably inland lakes or enclosed arms of the sea, like the Coorong, and, like it, receiving freshwater drainage from creeks. The terraces near the sea are covered with shells of existing species, which are again hidden by a thin layer of soil, but so near the surface are the shells, that the trees are blown down by the slightest wind, and show their roots interlaced with marine spoils, forming as it were a wall of grotto work at the end of the overturned stem. In the line of the accompanying section the shells disappear from the surface at the very clearly marked ancient sea beach, which is flanked by a sudden rise or terrace of limestone and sand. It is not, however, to be supposed that this former sea beach terminates the post-pliocene deposits inland, as they occur, as I have already stated, twenty-four miles from the sea—in fact, this interruption is only partial, for as soon as the limestone escarpments and sandy hills of the terrace are passed over, sea shells are again met, but under a much thicker deposit of alluvial soil. The raised beach, to which I refer, is only about six miles from the sea, and its history can easily be seen. It is fronted by a chain of salt lakes, which are separated from the sea by a line of sandhills, and these have evidently been washed up by the action of the surf, much in the same manner as they have been at the Coorong, and of which they are in reality a continuation. I shall have occasion further on to point out that though the land, by a series of terraces, rises from west to east, it has also a fall or slope towards the north-west, and this is why neither Lake Eliza, Lake Sinclair, Lake George, nor Lake Bonney are continuous with the waters of the Coorong, though lying in the same line of trough. The Coorong, as it is followed up from the Murray River, becomes more and more shallow towards the south-east, at last it is nothing more than an extended flat of yellow sand, which finally becomes clothed with grass, with salt lakes at intervals, all more or less parallel with the coast line. I shall refer hereafter to the evidence which this fact affords, that the centre of unheaval has been in the south portion of the district. It is quite evident, however, that the ancient sea beach, which now forms the boundary of the recent deposit of shells, had been separated from the sea long after the land had assumed its present condition. The deposit of sea shell is, therefore, geologically recent, and only ceased forming as the outside rampart of drift sand separated the lakes from the ocean. Brackish water shells then ensued in many places as an upper deposit until the lake was slowly dried up.

As the pleistocene deposits do not extend, in many cases, to a

greater distance from the sea than twenty-five miles, and are no where much more than eighty feet above the sea level, this quantity therefore nearly represents the amount which this portion of the continent has been upheaved since the close of the pliocene period. The fact is interesting on many aspects, for we know that the European continent was, during the same period, undergoing that extreme amount of cold which the glacial deposits manifest, and was subject occasionally to very considerable disturbance. That this part of the world was more quiescent, we have the clearest evidence, and at the same time we see that Australia is not, as some have imagined, a mass of land, which is one of the most recent tracts reclaimed from the ocean.

It is sometimes also important to observe that there is not that evidence of remarkable cold which continued in Europe during the glacial period. If anything, the evidence is in favor of rather a warmer climate being prevalent. The recent shells, which strew our ancient beaches, are of a larger size than those at present frequenting the same latitude of the coast. This is quite the contrary to what has been observed in Europe. The shells of the same period are invariably smaller; and so well does this rule hold good for the whole glacial period that, even in the West Indies,* pleistocene shells appear to have been dwarfed or stunted in their growth by the prevailing cold. But not only are the shells of our deposits larger, but there are shells found among them which are only common now on much warmer parts of the coast. The notable instances of both these facts are *Buccinum Adelaidense*, Crosse, *B. alveolatum* Keiner, *Phasianella bulimoides*, Lamarck, *Bulla striata*, Lamk.; all abounding in the shelly deposits; but with the exception of *B. alveolatum*, not common in the same part of the coast now. *Venus aphrodinoides*, *Mytilus Maggelanica*, Chemnitz, *Pinna*, &c., are found still upon the coast, but never of the size which they attain to in the beds. The list above given could be very much extended; but among the most common existing shells are—*Bulla Australis*, *Purpura textilosa*, *Nassa fasciata*, *N. pauperata*, *Ostrea sinuata*, *Pecten lividus*, *Patella granatina*, *Conus anemone*, *Trochocochleæ atrata* (mihi), *Venus aphrodina*, &c. The latter shell is found in immense beds, crowded together in thousands, and of very large size. Near the Semaphore at Port Adelaide, they are found in the same manner, but alive. At Guichen Bay, the species is still found, but of small size and singly—never alive—in cockle beds, just below the surface of the wet sand, as in Adelaide. The fossil species, not now found at Robe, comprise—*Bulla striata*, *Haliotis excavatus*, *Risella aurata*, *Venerupis crenata*, *Tellina umbonella*, *T. deltoidalis* (probably still found at Robe), *Liotia Angasi*, *Pinna deltoides*, *Lutraria solenoides*, *Solenomya Australis*, *Turritella carinifera*,

* Geological Magazine, vol. 2, p. 256.

&c. Now all these shells are found at present in Spencer's Gulf, or in the Australian Bight, or S.W. Australia; and the extinct species of the pleistocene deposits of Southern Victoria, are also, I believe, representatives of shells now living in warmer seas on the *east* coast; so that it is not a migration westwards with which we have to deal. From long experience now, in sorting these fossils, if I find a fossil not now living at Robe, among the beds there, I am nearly certain to find it described by Lamarck, as occurring in Spencer's Gulf or Port Lincoln. If the fossil is from the pleistocene beds of Portland, or Warnambool (Victoria), it will be frequently found still living at Sydney Harbor, Twofold Bay, &c. The shells, where they do still exist, are *not near* the size of the fossils.

It is worthy of remark also that no strictly littoral shells are found, such as those abounding at present at Guichen Bay, viz.—*Monodonta conica*, Gray, *M. denticulata*, Gray, *Turbo undulatus*, Chem. *Trochus undatus*, Lamarck, *T. Ramburi*, Crosse, *Chitons*, &c. This would go far to support the view that the upheaval was not gradual; though, if the coast were exposed and without rocks, and then to be gradually shut off from the sea by drift sand like the Coorong—this alone would account for the absence of littoral shells. On the beach, outside the Coorong, none are observed.

Immediately succeeding the pleistocene formations and lying conformably underneath them, we find a calcareo-silicious rock, often decomposed into a fine dark brown or yellowish sand. Wherever the pleistocene rocks have been denuded away, the sands lie upon the surface; and though in passing from a hard limestone rock to loose and very fine sands, at the Stone Hut Range, for instance, one is apt to imagine that the sand lies above the limestone; in reality it is not so, and the sand is clearly the lower formation. This is more important to bear in mind, as the stone lying at the sides of the hill would lead persons to believe that a quarry might be found by digging for it; but the sand in these places often extends to great depths.* Pleistocene beds have not, however, been necessarily denuded away from the surface of the sand; for there is good evidence that the latter deposits have emerged from the sea, while the former were still in formation. Good sections can be obtained on many portions of the district, all showing the subordination of the sand to the more recent formation. At the Salt Creek, a cutting has been made with a view to drain Tilley's Swamp—an immense sheet of water of many miles in extent, which receives the drainage of the greater part of the district. The section there observed is thus shown. On the surface is a very hard limestone, full of recent shells. Two or three feet below this is a fine loose

* It is in these sands that the supposed petroleum beds of the Coorong are said to occur. The substance is a vegetable one, and bears *not the remotest* resemblance to any of the petroleum minerals. It is of great value, however, if found in quantity; though it does not exude from the ground, or extend below the surface.

silicious sand without shells. This deposit continues to the bottom of the section. In other places the pleistocene rocks are found resting upon calcareous and silicio-calcareous flagstones, sometimes of great thickness and seemingly composed of finely comminuted fragments of shells and grains of quartzose sand. The formation is generally exposed in sections of some thickness, but never more than 100 feet. The same rocks occur also very abundantly in the Colony of Victoria, and attain to a much greater thickness. Three hundred feet in one mass is found near Geelong; and it reappears in patches right round the coast, forming beautiful and bold headlands at Cape Northumberland, Cape Grant, Cape Nelson, Rivoli, and Guichen Bays. Tho stone is of a yellowish brown color, weathering into black from tho action of the sea. Some of the strata are more easily decomposed than others, so that its finely laminated beds weather out into the most fantastic forms, either like the edges of a book or ornamental grotto work. Usually it is too loose and friable to serve as a good building stone; and the same reason should prevent its being used as road metal. Unless in beds where there is a large proportion of lime, roads repaired with such a stone would soon become mere beds of sand. Those portions of the rock which have been exposed to the sea, and whose hydrated oxide and carbonate of iron (which all beds seem to contain in a small quantity) has become a ferruginous cement to the calcareous and silicious particles, have become very hard, and could be advantageously employed for any purpose.

Drift wood has been frequently found in these beds, often bituminized into a kind of brown coal. This has led to the belief that coal bearing strata might be found if worked for; but such an opinion, it is needless to say, is perfectly erroneous. If a bore were made in any part it would, at a moderate depth, strike upon the bryozoan limestone, which is exposed in section at Mount Gambier. The drift wood has been accounted for by supposing the beds to be no more than hardened deposits of blown sand which has drifted over trees. But by far the greater portion of this deposit is still under the sea. The character of the stratification would indicate a marine cement in which remains of drift wood are often found.

The peculiar "hummocky" appearance of the land wherever these deposits occur, and the absence of any extensive local upheaval to account for such inequalities, leads me to believe that the beds were deposited in patches and formed sandbanks, not much of which have been since denuded away. I do not, therefore, regard the formation to have extended continuously through the district—though this opinion differs from one which I have formerly expressed.

In the Colony of Victoria, these beds are regarded as post pliocene; and at one time I was induced to regard them as such my-

self. I am now, however, of opinion that they should be referred to the newer pliocene period for the following reasons. They always underlie the deepest of our pleistocene deposits, and, from their extensive distribution, belonged to a period much antecedent to the later upheavals of the coast line. They cover the older pliocene volcanic rocks, and their associations point to physical conditions which certainly do not belong to the recent periods and are in fact more ancient than is compatible with it. A great portion of these rocks are still under the sea; and at the time of their deposition the whole of this district was under water; for they are found capping the limestone near Penola, about 300 feet above the sea. A subsidence of this extent would submerge all but the volcanic peaks in the district; and the latter will be seen further on to be of a very recent origin. The beds are, therefore, newer pliocene, corresponding with the older drifts of England and the Norfolk "crags."

Underneath the calcareous sandstone we have in this district beds of coarse white, yellow, and red ferruginous sands, sometimes with layers of ironstone, and full of concretions of hydrated oxide and carbonate of iron. The thickness of the deposit varies in different places. At Bangham Station, Tatiara, I had an opportunity of descending a shaft sunk for water to a depth of seventy-five feet. The whole depth was occupied by beds of variegated sands of various thickness, the seams being sometimes lentil shaped. There was white sand, five feet; ochreous red sand, ten feet; yellow sand, seventeen feet; white sand, one foot; red sand with ironstone concretions, one foot; yellow sand, six feet; brownish red sand, two feet; yellow sand, ten feet; white, five feet; yellow sand, eight feet; coarse white sand and clay, ten feet—water in clay. From a well sunk within a few miles of the above, I was able to see the junction between the coralline crags and the sands. The material composing these beds is a somewhat coarse silicious sand, with much iron and sometimes rounded grains of pink felspar and mica. I have never noticed the two latter minerals, except within a few miles of granites, and therefore I should suppose them to be derived from the decomposition of such rocks. Another peculiarity of the sand is that it generally occurs in hills or ridges having entirely the appearance of wind-drifted sand dunes, only that it supports a thick growth of *Eucalyptus fabrorum* and scrubby underwood. Some of the hills are singularly abrupt and of considerable altitude. They are often separated from each other by clay flats on which the water lies in winter and which consequently support a somewhat better vegetation. It is upon these flats that the most of the scrub stations of the Tatiara are situated. Such tracts are mere strips which follow the line of the sandhills ranges. Seeing how they succeed each other regularly, at apparently the same level, one would be apt to imagine that they are drifted hills resting upon a clay stratum. But this would be an erroneous conclusion, as the

sand is below the clay, and the well to which I have already referred was sunk in the lowest part of one of these flats. Throughout the Tatiara country, except in the grassy spots already alluded to, the sand is much finer and of a yellow color. It often crops out upon the surface also as a hard kind of sandstone, waterworn into holes, and the most fantastic shapes. It is a very hard rock, as far as surface indications go; but on digging down for little more than a foot, the stone passes into a fine silicious sand.

The importance of this pliocene deposit and its influence on the physical geography of Australia cannot be overrated. It is spread very widely throughout the district, occupying probably about three-fourths of its area. It is this deposit which is the foundation and cause of our deserts, the worthless soil of our stringybark forests, and the one unfailing feature of our heaths. It is only in consequence of a small mixture of lime that it ever solidifies into a hard stone—and this fact prevents my supposing that the sandstone can even be made serviceable as a freestone. Occasionally it decomposes into a rich chocolate loam, but this is rare, and I believe only on the banks of watercourses. A section of such beds is obtained at a gap in Robertson's Range, through which the Mosquito Creek drains the ancient lake already mentioned. The ground on the immediate banks of the creek is rich and grassy, with slabs of calcareous sandstone cropping out upon the surface. The section exposes parallel beds of yellow sand, with finely laminated "false bedding" or diagonal stratification. These beds decompose into a white sand with ironstone concretions.

As far as I am aware no fossils have been found in this formation, though from the fact of its immediately succeeding the pleistocene deposits, there can be no doubt of its pliocene age. It is an open question whether certain shelly deposits, which are found in patches here and there, should not be referred to these beds, but as the shells are always completely broken up beyond the possibility of identification, nothing can be concluded about them.* I should say that they belong to the lowest beds of the series, because they greatly resemble in mineral composition the oyster beds which are found in other places in Western Victoria, lying upon the lower pliocene (upper miocene of the Victorian geologists). It is in the lower portion of the same sandy beds that the Victorian gold drifts are found, that is to say, a formation of coarse waterworn gravel resting upon Silurian slates and quartz reefs. The gravel of the deposit is derived from the wearing down of the underlying beds. It is entirely absent from any portion of our pliocene formations in the district. For

* I am now convinced that the shelly deposits do belong to this formation. Several of these oyster bed quarries have been opened on the road near the Reedy Lagoon. The large oyster is the only shell which can be identified, and as it appears to me to be new, I propose to name it *O. tumida*, from the rounded form of the lower valve.

an obvious reason. The pliocene sands rest upon more ancient tertiary marine beds, with fossils; and if gravel is at any time found, it will be formed of rolled flints from the coralline crag, or ironstone concretions. If the Silurian formations occur, it must be at an enormous depth, with, probably, Upper Silurian, Devonian, Mesozoic, and all the tertiary series lying above them.

I have referred to the pliocene sandstone and sands as underlying the calcareous sandstone with false bedding, which is seen at Guichen Bay and other places on the coast. There can be no doubt that the latter is the more modern deposit, but it would, in my opinion, be an error to refer them to such distinct divisions as upper and lower pliocene. They are evidently continuations of the same deposit, the lower part being a little more ferruginous and silicious, and containing no fragment of shells. What makes this very apparent is that the decomposition of the upper beds gives rise to a soil which differs in no remarkable particular from pliocene sand which has never been hardened into rock at all. At Cape Grant and Cape Nelson the soil which caps the calcareous sandstone is exactly like the soil of any of our heaths, and the same fact is observed at the section of Mosquito Creek.

In Victoria, the gentlemen of the Geological Survey have recognized two or three distinct gold drifts and two deposits of fossils, which are represented as older pliocene (Brighton beds) and newer pliocene (Flemington). As the nature and character of the beds and the peculiar ferruginous state of the fossils is very similar in both cases, I am in hopes that they will yet be referred to the same division, that is, newer pliocene. My reason for saying this is, that I cannot see how it will be possible to admit such divisions as pleistocene, newer pliocene, and older pliocene, into formations evidently deposited under the same conditions of climate and physical relation. The great thickness of the deposit is certainly a difficulty, for considerably over four hundred feet of strata would have to be referred to one formation, which, for a newer tertiary, is something very great; but, as it is in every case a drift in which the materials are heaped irregularly, the difficulty is by no means inexplicable. As, therefore, all our pliocene formations, according to the Victorian Survey, are drift, I would suggest that they be classed in one division as newer pliocene and pleistocene, the latter being confined to purely terrestrial changes or recent upheavals. Though the lapse of time and amount of change that this division would represent must be something enormous, yet I think that by this means the reference of fossil remains would be more easy, and certainly more in keeping with European correlative classification.

It must be observed, however, that my opinions are perfectly in unison with the gentlemen of the Victorian survey as to the position, subordination, physical character, and succession of the beds. My suggestion is simply one of classification, which is a mere

The terms Pliocene Miocene &c have been used by the G. S. simply to denote relative position in the series & not as indicative of per centage

matter of convenience. I do not think we are very near the time when we shall have established synchronism between any of our deposits and European equivalents; and, unfortunately, the prospect is all the more distant just now, as the later tertiaries form the debateable ground of geologieal classifieation.

It may be interesting to point out that the evidence of such enormous deposits of drifts shows the result of violent and sudden ehanges which the eontinent was at that time undergoing. It sueceeded a long period of tranquility, in which marine life was certainly abundant in the seas then rolling over Australia. Suddenly the reeords of life terminate, and their place is taken by an astonishing quantity of fine particles of quartz, felspar, miea, and sometimes tourmaline or alumina. It is no wonder that we find no shell, for mollusean life eould not exist in sueh a medium.

It is natural further to inquire whenee the sand can have been derived. As the lower drifts are found to be only fragments of the underlying rock in Victoria, so the sand may be traced there at least to the neighboring rocks. There are granite hills seattered throughout this district; and though now visibly confined to the northern part, I am convineed that there are granite roeks underneath the surfaee wherever the felspathic and micaceous sand appears. The sand is always coarser and whiter under those circumstanees; and, sinee durable stone is so rare in the district, it might be as well to try a few shafts in certain localities to see if a granite quarry could be reached at a moderate depth. The localities I should reeommend for the purpose would be the stringybark ranges near McArthur's home station and along that range generally.

Where the sand is yellow and fine, it would appear to have eome from a distanee, and it might easily be derived from the wearing down of platonie and other roeks brought to the surface by the intrusion of the granite, as well as the volcanie rocks whieh seem especially to belong to this period. From this it will be observed that I regard the intrusion of the granite as part of the close of the older plioeene period; and I may add that not only do the granites belong to this age, but also a great portion of the upheaval of the older roek. It is only, indeed, by supposing an enormous upheaval of land above the surface of the waters that we can aecount for the immense and sudden aceumulation of drift, both in this Colony and in Vietoria. A large and extensive movement of the earth's crust, together with the exposure to the influence of the waves of immense surfaces of roek, would fill the sea with sediment sufficient to account for our newer pliocene drifts. A great portion of the South Australian chain and very high mountain ranges in Victoria have no doubt been uplifted sinee the close of the miocene period; and it is not unreasonable to suppose that the turbulence and sedimentary character of the waters after such

an upheaval have given rise to the subsequent sedimentary rocks which we find. If we could certainly connect the birth of our South Australian chain with the drift, we should have a sequence of events which would go far towards giving a complete geological history of the continent as it at present stands.

Regarding the drifts as upper pliocene, the next rock found is the older pliocene, which introduces us to an important change in physical conditions, and one which we should naturally expect in passing between such divisions. We find loose, friable, very white limestone, or hard, yellow, creamy, crystalline limestone, divided into large divisions or strata, and very rarely any marks of minor stratification. The upper portion is generally decomposed by infiltration, and therefore is not fossiliferous. This is a hard and very durable building stone, much used for the purpose where no other stone crops out upon the surface. It is, however, a good deal honeycombed, and contains the ironstone nodules recemented into the rock, though derived from the upper pliocene.

Underneath the surface limestone, we meet at many places, but especially Mount Gambier, the loose friable limestone, as above described. Any further description of these beds at present is perfectly unnecessary, as they have been fully detailed in my volume of *Geological Observations*. It is only necessary now to state that generally the first twenty feet of strata are quite unfit for building stone, and would be useless, if quarried, even for road metalling. At a greater depth the lower beds are much harder and contain flint nodules, besides being richer in shells, and containing a much smaller quantity of magnesia, are of greater value for cement. There are, however, places where the upper stratum has been quarried successfully for building stone, as for instance, at Powell's quarry, upon Vansittart's Section, but even there the stone is of such soft texture as to be easily cut and dressed with saws and axes. With very little exception it is composed of Bryozoa, and is in all respects similar to the coralline or lower pliocene crag in England, with which formation it has some of its species in common. There are few other places in the district where it can be seen in section out of the immediate neighbourhood of Mount Gambier, but at Portland Bay, in Victoria, it occurs in fine cliffs, with no difference of mineral character, and only such variation in the organic remains as we could account for by difference of latitude and position.

I regard the beds as lower or older pliocene for the following reasons. I know of no formation intervening between them and those formations known to me as upper pliocene; and the course of events in the geological history of this district is represented with so consistent a sequence that I can hardly suppose a large formation to be missing without some circumstance to account for its absence. By subdividing what I term upper pliocene, I could, no doubt,

classify the Mount Gambier beds, as upper miocene, but I conceive two serious inconveniences which arise from this classification. The first is, as I have already stated, that I should subdivide formations which have all been deposited under the same physical conditions, and which, if the principles of classification are to be considered, certainly should belong to one geological period. Secondly, we should have, in consequence, to make a triple division of the miocene series—upper, middle, and lower—which will render the correlation of our geological chronology with that of Europe a matter of great difficulty and confusion, as middle miocene is not known to English geologists. Apart from this, I find more pliocene than miocene forms among the fossils—*Pecten maximus*, Linné; *Pecten pleuronectes*, Lam.; *Idmonea Milneana*, Mil. Edw.; and *Eschara monilifera*, Mil. Edw.—the latter of which is almost as common at Mount Gambier as it is in the coralline crag of Suffolk. The general character of the fossils is also pliocene, especially in the occurrence of a large Terebratula (*Waldheimia grandis* mihi) to correspond with the well-known *T. grandis*, though I do not attach much weight to such evidence alone. The genera in the two deposits are parallel in character and number, and, what is peculiar, a *Melicerita (M. angustiloba)*, which is only represented by one species with us. In all other respects the formations are very similar.

I must, however, candidly admit, that it becomes very difficult subsequently to separate these lower pliocene beds from the underlying upper miocene, for they have been deposited almost under, as similar physical conditions, as the depth of the upper pliocene. Still, I think I can point out sufficient physical, mineralogical, and palæontological differences to justify the separation. It must be remembered, moreover, that the same difficulty is experienced in drawing the line of demarcation between the lower pliocene and upper miocene beds of Europe. Mr. Lankester* has lately drawn up tables of fossils which would refer the Bordeaux faluns to the lower pliocene horizon, while all preceeding geologists have regarded them as upper miocene. A similar controversy has taken place as to the position of the Antwerp beds, which are regarded as lower pliocene or upper miocene, according to the views of different geologists; and the question is undoubtedly a difficult one.

There are, however, as I have said, certain marked features, which enable a separation to be made, and these I proceed to enumerate. In only few places do the upper miocene rocks come to the surface in this district. These places are on the upper part of the Red Cave Range, near the station of Mr. Adam Smith, Broadmeadows, and a good section at the garden of Mr. James Affleck's station, Kerbybolite, on the same range as Mr. Smith, but about

* Geol. Mag., vol. ii., p. 104.

nine miles north of the first named outcrop. The stone is distinguished by being of a brick red color when exposed to the weather, and though the limestone is white or yellowish when first quarried, it contains so much iron as to decompose into a ferruginous soil on the slightest exposure. Now this I hold to be a marked feature of all the South Australian miocene beds which I have seen. It is shown most in the lower miocene beds of Hamilton (Victoria), where the fossils are mixed up with masses of carbonate of iron; also near Harrow, where the weathering of a very thin stratum of lower miocene fossil has converted them into the so called iron-stone. Nothing of this kind is seen in the pliocene beds, but as they are followed down towards the junction, certainly traces of iron become more perceptible. A sufficiently extended examination enables me at once to pronounce on the miocene or pliocene age of any beds from the presence or absence of iron in the strata.

The next feature to be considered is the fossils. Now, although as the pliocene beds are followed down, the shells become more abundant (especially Pectens), and the Echini and Bryozoa more rare; yet the number of species is small, and shallow water or littoral fossils or corals entirely absent. Some of the shells are found in the upper miocene (such as *Pecten incertus, P. Gambierensis*, mihi), yet not *one of these appear to have survived* to the Mount Gambier upper beds, or to the recent portion of the series. The ferruginous or upper miocene beds, however, show a very different state of things; the fossils are often littoral in character, univalves are common, and corals; even in the upper beds we find the remarkable *Cyprœa eximia*, Sowby, which is never seen at Mount Gambier, and shows the last survivor of that remarkable series of *Cypreæ*, which are so characteristic of our Australian miocene rocks.

The fossil are not only different (shown especially in the *Bryozoa*, though one species, *Salicornaria sinuosa*, Hassall, is equally common in both); but they show different physical conditions at the time of the deposition of both formations. Our lower pliocene is a deep sea deposit, with a gradual subsidence going on, and the land, if any, very distant. The miocene is, on the contrary, almost littoral; and shows, at any rate, that land was not very far distant. The ferruginous character, which in the lower miocene of Hamilton is also accompanied with rocky particles, is due to the wearing down of rocks, traps, or granites, which were very slowly exposed by the subsidence to the waves. No doubt the pliocene formation is but the continuation of a subsidence which commenced at the close of the eocene period; but it differs in being the new state of things which ensued when all the land had disappeared or been worn away. Neither should it be objected that this should prevent any great division being made between the deposits, because such an objection would lie equally against a separation between our lower miocene

(Hamilton) and upper eocene (Schnapper Point), for they have much more characters and fossils in common than our upper miocene and lower plioeene. I do not know of many shells in our upper miocene which are not found in the lower beds of Muddy Creek; but a very great difference is seen between the fossils of Mount Gambier and those of the Kerbybolite beds. In so far, therefore, there is a difference and distinction between the lower plioeene and upper miocene. If I were asked to characterize it in a few words, I should say that the upper parts of Mount Gambier are distinguished by few shells of any kind except Brachchiopoda, abundance of Bryozoa and Echini, and no corals. The upper mioeene, I should say, has a few corals, abundance of shells, both bivalve and univalve, and few echini.

It is all the more important to determine the age of these beds in a satisfactory manner, as the question affects so large a portion of the Colony of South Australia. The well-known cliffs of the banks of the Murray expose good sections of some of these beds, which, in my opinion, are upper miocene, and which I believe is the age assigned to them by Mr. Selwyn, of the Victorian Geological Survey. At any rate, some of the tertiary series are to be found on the banks of the river; and if, in defining the chronology and succession of the rocks of this district, I should establish the age of those beds also, we shall have advanced a great way in the knowledge of the geology of the whole Colony.

I should distinguish between the character of the lower miocene beds which are formed on the Murray Flats, and that of the cliffs which are found in the upper portion of the series. I have always supposed that two formations are represented on the river from the fossils which I have had occasion to examine; and in the lower beds I have found more muddy creek forms than would be supposed, considering the distance (450 miles at least) between the two places.

The lower miocene and upper eocene rocks are not represented in this district—at least, upon the surface; but I have no doubt, from the conformable dip of the strata, that they succeed in regular succession, and correspond completely with the geological history of Southern Australia which can be traced elsewhere. Probably we have the older formations—both lower miocene and upper eocene—at a depth of not more than 500 feet.

IGNEOUS ROCKS.

I shall include in this description the granites and dolomites which are found in various places through the district, though they are neither, strictly speaking, igneous rocks, but belong to the metamorphic or altered rock series.

The most recent of the igneous formations are undoubtedly the ash cones and layers of volcanic debris at the extinct craters of

Lakes Leake and Edward, Mount Schanck, and Mount Gambier. The latter eruptions of the Mount Gambier belong to the recent period, probably within the range of history, and certainly long after the commencement of the pleistocene period. Layers of the ash are continually being quarried with impressions of ferns and grasses—*Banksia integrifolia* and *Casuarina equisetifolia*—all similar to trees and plants growing on the sides of the lake at the present day. There are traces of many different eruptions and many craters; but in the older ashes, lying under the older lavas, in the accompanying section, there is no evidence of plants or trees, or at least none have been found, which may be accounted for by the difficulty of reaching them. Bones have also been found embedded in ashes. They belonged to animals in all respect similar to marsupiata *(Macropus major, Phascolomys wombat)*, now inhabiting the neighborhood.

There have been many eruptions of volcanoes in the Colony of Victoria, which are proved to have occurred during the upper pliocene period; but I believe all the volcanic rocks of this district rest upon, and not under, the upper pliocene rocks. An older layer of basalt at Mount Gambier lies directly upon the lower pliocene fossiliferous limestone; but from other indications, there are places where the upper pliocene calcareous sandstone will be found intervening.

Next to the truly volcanic rocks in importance, we find the granite pretty extensively distributed throughout the district, but especially in the northern parts. It occurs always as isolated hills on worthless scrubby country; in this respect, perfectly resembling the isolated granite hills in the scrubs of Western Australia, and similar features in the country west of Port Lincoln, or about the Gawler Range. The granite is of a dull reddish color, of somewhat coarse character, and containing, as it appears to me, too large a proportion of felspar, and too little quartz, to be a very durable stone. The mica is black. It seems to resemble very much the granites which intrude through the palæozoic rocks to the east of the South Australian boundary, and which possibly may be altered palæozoic strata. The only difference is, that schorl or tourmaline is common in the Victorian granites, and I have seen but little in those of this district. The most southerly outcrop of the granite rocks is at Lawson's Home Station, about one point north of west of this, distant ten miles; a very large outcrop occurs, like a small chain of islands in the midst of a wide plain. The stone has weathered into huge boulders, and masses of rock detached from the side, and piled up into the most fantastic forms. The next outcrop known to me is what is known as the Monster Rock, distant about thirty miles north by east, with a dense and almost impenetrable scrub intervening. The hill is not so large as the preceding, but is higher, and commands a much more extensive

view. From its summit I could see a line of granite hills stretching away at various distances through the scrub, all apparently of a nature similar to the one I was upon.

I could not see that the sandstone (upper pliocene) round the base of the hills was in any degree disturbed, as if the granite had been intruded upon the other beds; but the junction is so overlaid by the decomposed detritus of both formations, that it is impossible to state which is the more modern, or how far the granite is intrusive, until a section is exposed. If, however, the granite is similar in character to the isolated hills in Western Australia, it will be found to be intrusive, and connected with the pliocene upheaval of the continent. If again the stone should be palæozoic in age, though of long subsequent alteration, it will prove that our lower tertiaries rest upon these beds without the intervention of the carbonaceous mesozoic rocks. This I believe to be the case, though the mesozoic formation may occasionally be found amid the faults and irregular disturbance the lower beds must have undergone. My reason for thinking this is that in the section exposed by the great cleft of the Glenelg River, we find fragments of our tertiary rocks (upper miocene, pliocene, and recent), lying on the upturned edges of highly altered palæozoic strata or granite. Faults sometimes bring the mesozoic strata to the same horizon.

The only other metamorphic stone occurring in this district is dolomite. It is found near Mount Gambier, and is being at present used as a building stone for the Protestant Church there. It is of yellowish red color and crystalline structure, easily worked, and capable, I imagine, of taking a good polish. Dolomite is a carbonate of lime and magnesia, containing about fifty-six of the former and forty of the latter in a hundred parts. Its origin is supposed to depend upon the action of volcanic gases upon limestone rock. Von Bush suggests magnesian emanations; but in any case the lower pliocene limestone in which it occurs possesses almost sufficient magnesia to account for the change, provided heat were applied. I have not examined the place from whence the stone is taken; but I believe it is sufficiently near the crater for it to have been connected in its origin with volcanic emanations. It must not, however, be attributed to a dyke. If the quarry be on Government land, the extraction of the stone should be regulated, because it is of value even as a cement, and of considerable importance where building stone of a durable character is so scarce.

MINERALOGICAL RESOURCES.

I intend in this section to speak of the actual products of this district, and of the probabilities of mineral deposits, as far as geological evidence goes. First of all I shall treat of the building stones, and those fit to be used as metalling for roads.

Dolomite, as already mentioned, is being used as a building stone,

and if it could be obtained in sufficient quantity, would no doubt be exported to the neighboring ports at a profit. The same stone has been used in the construction of the Cathedral at Milan, and the Houses of Parliament in London. The Parian marble is supposed to belong to this species, also the Iona marble in the Hebrides, though undoubtedly from an older rock than that of Mount Gambier. Dolomite is also highly esteemed for making cement, as its caustic properties are retained for a very much longer period after burning. For this reason, however, it should not be used as a manure.

The basaltic rocks at Mount Gambier are small in extent, and not situated conveniently for quarries or for building purposes. There is a thick stratum underneath the ash layer, as may be seen by the section, but it thins out rather rapidly, and could not be easily reached; if it were, it would make a beautiful building stone, probably the only very durable one to be found in this district.

Layers of flint and chert (a kind of white opaque flint) are found in sufficient abundance about Mount Gambier to be used as a road metal, it is very durable but somewhat destructive to horses' feet, and even their shoes, the tires of wheels, &c. It also takes some time to wear and break down, but for permanence it cannot be equalled.

The ash deposit, either the white or black kind is never sufficiently hardened to be of use, except when mixed with lime for manure; fragments of trap are often found imbedded in it, but they are never more than a foot or so in depth. It is important to bear this in mind, as many persons would be deceived from the compact way in which they lie upon the sides of the crater, into believing that a good quarry could be opened upon them.

Olivine is also found in small detached masses; also monticellite and hyalosiderite. All these are found in the newer lavas of Vesuvius; they are of no commercial value whatever, though pretty looking as cabinet specimens.

All the lavas at Mount Gambier are augitic dolerites, compact or cellular.

The granite of the northern part of the district would be very useful for metalling, and could be obtained in large quantities from the surface. Blocks for building stone could also be obtained; and, as grass and water can be found round most of the hills, no doubt they will eventually be worked as quarries.

Limestone and impure sandstone are found throughout the district, but as the quality varies for different localities, it will be better to indicate the nearest supplies for the different townships. Penola is very badly supplied in that respect. A little limestone crops out upon the surface on the whole of the slight elevation or range upon which Penola is built; but though durable, it is much honeycombed, and could hardly be used except for rubble mason work. Underneath the surface too, there are scattered blocks of

the same kind of stone lying in the red loam; they are abundant and even less decomposed than the portion lying on the surface, but still of inferior quality. Limestone, in places, occurs at a depth of about four feet from the surface, all round the town, but it is soft and friable, and easily decomposed. If, however, a deep and broad quarry were exposed, the stone would readily harden on exposure, and become very serviceable and easily worked. It could be obtained in any quantity, and is, I believe, of the upper miocene formation, though no fossils have been found. My conclusion is founded upon the ferruginous character of the beds and their position with reference to the Mount Gambier pliocene, and the Red Cave rocks which will best be seen from the section across the country.

Narracoorte has stone cropping out on the surface, and a good quarry at no great distance. All along the range between Penola and Narracoorte stone crops out at intervals, commencing at about five miles north of Penola. If good stone could not be obtained nearer for making any roads between Penola and Mount Gambier, the range would afford an abundant supply.

Tarpeena, both old and new, and the road for twelve miles towards Penola is very poorly provided with stone; neither do I know of any near locality whence it could be procured; outcrops of limestone and sandstone are found in a few places, but the district here about is too uniformly covered with newer pliocene sands to give much hope of extensive quarries being found. At Mount Edward (ten miles W.), commences a range of basaltic hills, from which good stone for metalling purposes could be obtained, though no quarry has ever been opened. Throughout the sand however, a ferruginous gravel could be got, by sifting, which would be of some importance; for "blinding" the upper surface of made roads, no better material can be found.

Guichen Bay and Lacepede Bay are both supplied, like all the coast towns, with a good and durable shelly limestone of pleistocene age.

Border Town has deposits of pliocene ferruginous sandstone near it, but not abundant. Good limestone has, however, been found in the neighborhood, about eight miles away, belonging, as I believe to the upper miocene formation.

There are no parts of the district in which metalling stone cannot be obtained, but good building stone is rare and confined to one or two localities. Bricks have been made to supply this deficiency in Penola, and at Mr. Jones' station, Binnum; clay suitable for such a purpose can easily be obtained on the subsoil of most of the upper miocene formation, but it is not a very good brick clay; when burnt the bricks are of a more ferruginous character than is consistent with good tenacious pottery.

Amber has been found in many places throughout the district,

and, like everything else that burns, is called petroleum; it is a beautiful deep hyacinth, and streaked with yellow. It is most abundant at Mount Schank, in the alluvial deposits, and the specimens from there are curiously pitted with small pea-shaped hollows. It is evidently derived by fossilization from the resinous gums of the eucalypti forests; some is found also on the sea-beach at Lacepede Bay, just as it is found on the shores of the German Ocean. It has all the electric properties of European amber, and, no doubt, could be collected in sufficient quantities to be of commercial value here.

Coal.—It is as well to touch upon the probabilities of this mineral being found in the district because an impure kind of lignite has been found in the calcareous sandstone, and has given rise to a suggestion in the public papers that a series of shafts should be sunk through the overland desert. The shafts, of course would be useful, as there is no surface water, and wells are much wanted, but there is no more chance of finding coal in such places than there is of finding it in the granite. It may be, that the mesozoic strata underlie the tertiary rocks, but certainly at a depth of not less than 500 feet. Supposing the upper members of the carbonaceous strata to be present, which is very doubtful, such strata have uniformly proved to be without coal-bearing strata for at least 4,000 feet, and they have been bored to that extent in Western Victoria without finding any coal. The lignite in the tertiary beds is too small in quantity to be of any commercial importance, neither need any regular strata be looked for, as the substance is of purely casual occurrence.

Gold.—None of the older gold bearing rocks are known to exist in the district. In the absence of the mesozoic carbonaceous rocks, the tertiary formation probably rests unconformably upon some member of the silurian system, which may hereafter prove to be auriferous, though it is not known to be as yet; if it were we might expect to find some drifts interposing between it and the tertiary rocks which it might reasonably be supposed would pay working even at such depths. It may take years to solve such a question, but it may certainly be stated as a fact that the passage of the Victorian auriferous rocks into South Australia takes place, probably, without the intervention of the secondary deposits, and that no place is so favorably situated for testing them as the eastern portion of the South-eastern District of South Australia. I should be far, however, from recommending any trial to be made until the gold fields of Western Victoria have been brought by prospectors much nearer to the boundary of the Province. I would also remark, that the upper palæozoic rocks of South Australia, and which form the greater portion of the formations in the South Australian chain may reasonably supposed to be absent here, because the granite of our anticlinal is flanked by the lowest

members of the system, as far as we can judge without the evidence of fossils.

Iron.—The iron ores are principally confined to hydrated oxides and carbonates on the upper pliocene and upper miocene rocks; it is poor in quality, and no certain supplies would be obtained.

Copper.—I mention this mineral merely to state that certain blue deposits found in the upper miocene rock have often been mistaken as indications of copper. They are *allophane*, an aluminous mineral, which shows traces of copper to the extent of about two per cent. It occurs in sedimentary rocks in England in drusic cavities, but is never considered an indication of any mineral deposit.

PHYSICAL FEATURES AND DRAINAGE.

I come now to the most important part of the subject, in which and with the physical features of this district, the assistance which geology affords is of the most valuable kind. The whole of the South-Eastern District may, with the exception of a small fringe at the coast line, be considered as a tableland gradually rising towards the boundary of the Province, near which it attains its greatest elevation. Like all tablelands, it is full of basin-like depressions upon its surface, and is consequently drained badly. Lake features, wherever they occur, are more often connected with table lands than chains of mountains; and, in one respect, this is fortunate, as in the absence of rivers they form sometimes important means of intercommunication, and are valuable reservoirs of water. Where, however, the rainfall is small, and the elevations moderate, such depressions are an inconvenience instead of being of value. They are not deep enough to be navigable, and during the greater part of the year are no more than unwholesome morasses. This is precisely the case in the South-Eastern District of South Australia, and what is worse, probably more than one-third of the best land in it is utterly unavailable in consequence. The importance, therefore, of draining such a tract cannot be overrated, and I am confident that an attentive study of the geological features, will show that this may be done at a very moderate cost.

The whole district may be described as a tableland, sloping from the boundary line westward towards the sea, and with a slight inclination towards the north-west, commencing about ten miles south-east of Penola.

The axis or range on which this slope depends is about ten miles east of the boundary of the Province, sometimes more and sometimes less; but it cannot be considered a proper axis. Properly speaking the country gradually rises in terraces right up to the foot of the Grampian Mountains, in Western Victoria; but the drainage is interfered with by the great north and south

fissure of the valley of the Glenelg. This valley is so evidently a rent or crack unconnected with the general features of the tableland, that at a distance of only six miles west of the river, in some instances, the waters may be seen flowing away to the north-west.* The Glenelg, in its upper part, flows also to the westward, until meeting the fissure (with granite outcrop), about fifteen miles west of the boundary of the Province, it suddenly flows down to the southward, sometimes in its course actually coming within the Province of South Australia.

There is, however, an axis dividing the water flowing to the southward by the channel of the Glenelg and those flowing to the north-west towards the Coorong, and that axis is granitic, lying only a few miles east of the Province boundary. It is in the latitude of Penola, about 250 feet above the level of the sea, and 230 feet above the same level may be considered the average height of the boundary line, northward from the Dismal Swamp. Penola, I should say, is about 250 feet above the sea, and Narracoorte something below this, though very little. Border Town, I believe to be higher; but I have no accurate means for determining this. Tarpeena is twenty-five feet below Penola, and the township of Mount Gambier is about 130 feet above the sea. All these measurements I have obtained approximately by barometical observations. There may be errors in them to the extent of a few feet; but I believe the road surveys and levels taken by the Government engineers are confirming them every day. Such elevations are, however, very contrary to preconceived opinions on the matter; as when they were first spoken of, some three years ago, they were received with hesitation, especially as the water remained upon the surface and showed such a feeble inclination to flow away towards the north-west.

Now, were the country between the boundary line and the sea to the west of it a uniform slope, there would be no difficulty whatever about the drainage. The fall would be more than four feet to the mile for some parts, and never much less than three. Not only would the water run off, but on the underslope there would be hardly any springs unless at great depth, and the country would be a perfect desert. But the slope is not gradual. It rises by a series of or parallel terraces with an average distance from each other of about six miles. These terraces are slightly elevated at their edges so as to look like ranges; but the fall from them is considerable, varying from ten to fifteen feet. The plains which separate them slope down very gradually to the edge of the lower terrace which being, as I said, slightly elevated, retains the drainage and prevents

* An instance is seen here of a lake with two outlets. A small lagoon near Mr. Edgar's station, Pine Hills, has a drainage on one side which flows into the Glenelg, and on the opposite side a brook flowing to join waters which ultimately reach the sea by the Murray mouth. The outlets are thus between 300 and 400 miles apart.

its further flow to the westward. It then avails itself of the north-western slope, and flows on the inner or eastern side of the terrace until it reaches the sea, through the Salt Creek. It must be remembered, however, that in flowing down towards the edge of the terrace, it takes a north as well as a westerly direction, or rather flows obliquely—such obliquencss varying according to the slope of the terrace plain. The terrace plain, or plateau, known as Mosquito Plains, slopes only very slightly to the westward, and therefore its drainage is nearly completely north-west, though there is a decided tendency in the waters to collect upon the west side and then to flow along the inside of the range. The next plain known as the "Heath," on the west side of the Cave Range, has, on the contrary, a very decided inclination to the westward, in consequence of which the water flows down rapidly and only very slightly north of west. It must also be remarked, that the north-western drainage on the inner edges of the terrace is very rapid in its upper course; but towards the lower part becomes much impeded by spurs from the range, and so flows sluggishly, collecting into swamps.

The edges of the various terraces here are called ranges, because they are much elevated, and appear like simple ranges of hills from either side. At various places they rise into considerable elevations, and nothing but a very close observation would convince any one that they are higher when seen from their western than from their eastern sides. They are due, I believe, to the tilting up of the edge of the upper miocene, lower and upper pliocene strata, caused by irregularity in the upheaving force. Whether or not the sole upheaving cause has been the intrusion of the granite is not easy to say; but, at any rate, it is the only evident one. The volcanic hills of Mount Gambier and Mount Schanck do not appear to have exercised much influence; because the tableland ascends by terraces, and reaches its greatest elevation away from them. Indeed, it is a remarkable fact that the volcanoes alluded to have produced only the most trifling influence on the physical features of the neighborhood. An observer would not at first be inclined to think so; for he will remark that, on approaching Mount Gambier from the north side, the surface of the country seems thrown into considerable undulations, which are abrupt and numerous. They are, however, composed of nothing but sand of the upper pliocene formation and seen drifted into this shape, while the underlying rock is perfectly horizontal—a fact which is of valuable service in reducing the roads to an uniform level.

But if the influence of the volcanoes has been very small, that of the trap hills of Mount Burr, the Bluff, Mounts Muirhead, Graham, McIntyre, and Edward, has been very considerable. These are intrusive mountains of basalt which have been thrust out in a solid state, apparently after the close of the pliocene period, or, at any rate, during the very latest parts of its history. It is to these

mountains we owe the decided inclination of the land northwards. They occur in the southern parts of the plateau. On proceeding northwards from Mount Gambier, the country rapidly rises by terraces covered with upper pliocene sands, and at about twelve miles a plateau is reached, elevated 225 feet above the sea. This is occupied by the Dismal Swamp, which is a channel of drainage from the trap mountains, already mentioned, and which lie somewhat within the edge of the plateau and a little west of north from Mount Gambier. These mountains cause a true division of the waters—the drainage of one side flowing eastward through the Dismal Swamp into the valley of the Glenelg, and that of the other into the Reedy and Avenue Creek, and so north-west into the Murray, by the Coorong. Thus the outlet of the two sides is about 350 miles apart, though before the Coorong was silted up the Salt Creek drained directly into the sea, and the outlets were, consequently, some fifty or sixty miles nearer.

The basaltic hills belong, as I have said, to the close of the pliocene period, but they may be more recent, because the elevation of the plateau is proved to be in some sense independent of them; they occur also within the edge of the plateau, showing in this part of South Australia the strong analogy there is with the north coast, where the plateaus are all fringed with recent basaltic rocks. The older trap rocks in Victoria are all of the earlier portion of the newer pliocene, but I would not connect these with them, though they may be so connected. My reason is, that the higher parts of the plateau in this district have all been upheaved before the pleistocene period, though at the close of the upper pliocene, but that these trap rocks appear to have been intruded after the plateau was upraised. That its elevation is not due to them may be seen from the fact that its highest portions lie at a considerable distance from them.

The highest terrace, or Penola range, takes its rise in a gradual slope of stringybark, south of Penola, but the range, as such, only becomes visible about five miles north of Penola, and then only as a small outcrop of limestone. Five miles further there is a gap (about three-quarters of mile south of Glenroy station), whence all the drainage from Lake Munday, Mount Julian, the Rocky Castle, &c. flows into the Mosquito Plains; the range then continues becoming very much higher (and probably the terrace on the other side, known as the Wratten Bully country is also considerably elevated), until Robertson's station is reached at about twenty-two miles north-west by north of Penola. Here there is a gap through which the Mosquito Creek runs, draining the ancient lake already referred to. Ten miles further on the same bearing brings us to another gap, the Narracoorte Creek, also described. The range now rises very much, and the plains at the foot become almost destitute of trees and very marshy. At sixteen miles from

Narracoorte, and fifty-seven from Penola there is another very remarkable and precipitous gap, known as "The Gap," giving a passage to Morambro Creek, the deepest and most rapid creek in the country, which arises from a lake (L. Kadnite), and terminates in Lake Roy, a distance of about twenty-five miles.

North-west of the gap the terrace continues, rather lower, however, for twenty miles, passing Lawson's station, and showing an outcrop of granite. It then suddenly rises at Campion's old station, and becomes a very elevated plateau of pliocene sand; this is the edge of the desert. From this the terrace takes a more westerly bend, converging rapidly to Tilley's Swamp, which is the receptacle of all the northern drainage.

The next terrace below forms the Mosquito Plains; it is a gentle slope towards the west, between about eight and ten miles in width. It can only be said to commence about Penola, and there it is very rich in its soil, though soft and boggy in winter, with many swamps upon its surface. Opposite the first gap in the Penola terrace below Glenroy it receives the drainage from thence, which runs through the centre of the plains in such a very serpentine course as to convince one at a glance that it has only a very trifling fall in any direction. This creek drains into the Great Swamp at Seymour's, as also the Mosquito Creek, which becomes a sort of morass before entering it. Northward of this point the terrace becomes much poorer in quality, timber scarce, the grass in tussacks and wiry, sedges abundant, and the soil a light clay. The state of things continues to the granite rocks already mentioned, and by this time the water has fairly made its way over to the western edge of the terrace, and drains a large swamp down to Tilley's Swamp, where there is a gap, and towards which all the plateaus sensibly decline in altitude. The range which bounds the terrace has no true gaps in it, but there are several places where it is so low as to be scarcely visibly elevated above the plains; the fall from it into the next terrace appears to me to be about twelve feet.

The next terrace goes by the name of the "Heath;" it is covered by the pliocene sands, and should be classed with next three terraces below it, which have all the same character. They slope very much to the westward, so that the slightest depression is used by the waters as a channel. Thus all the roads become creeks in winter, and when the weather is very wet, as in the year 1863, the water flows very rapidly and hollows out in the loose sands holes of considerable depth, which give the roads a most singular appearance in summer, and perfectly destroys their usefulness. As the soil is sandy and loose, water does not collect to any great extent, but seems to be absorbed rapidly. There are, consequently, no great swamps on the western edge of any of the heath terrace.

The first remarkable change occurs on the Avenue, whose

terrace seems a prolongation of a spur from the volcanic mountain known as Mount Graham. The edge of this terrace receives all the drainage from the north side of the trap hills already mentioned, the consequence of which is, that for the fifteen miles it is one continued swamp. At a place called the "Old South Avenue Station," the swamp seems to be stopped by a limestone ridge, and the surplus drainage much reduced in quantity, flows onward by the Avenue. The greater part of the water however, percolates slowly under the limestone barrier, and forms the head of the Reedy Creek, which soon becomes an uninterrupted broad morass, flowing north-west, and kept along the inner edge of the terrace, known as the Reedy Creek Range. If a cutting were made for about four chains at the head of the creek, no doubt nearly all the Mount Gambier terrace would be drained, and the Avenue swamps relieved of a very great portion of their surface water. Of course the Reedy Creek would be much raised in consequence, and the Avenue Flat would still retain a great quantity of that water which flows down the slope north of the Reedy Creek offshoot, but a low place on the edge of the terrace, about twenty-two miles north of the junction, would effectually drain the greater part of the good land. The Avenue Flat, if drained, is excellent soil, but it is all unsold, and as now situated, almost perfectly useless.

The Reedy Creek terrace is a narrow slope of well grassed, somewhat clayey, but good soil. The creek, however, occupies the greater part of its width.

The Biscuit Flat terrace, is about ten miles wide; the upper part of it is poor sand, and indeed none of it would be very excellent land. It is remarkable for the immense quantity of limestone biscuits lying upon its surface, and they occur also abundantly upon the Avenue and Reedy Creek Flat. I have already, in my work on South Australian geology, described them, and the way they are formed. The Biscuit Flat terrace becomes the receptacle of an enormous quantity of water in winter, in fact I have travelled in 1863, for eight miles on horseback through water up to the stirrups, with scarcely a single dry spot in the whole distance. This is on the road between Pearson's and the Stone Hut. The flat is generally destitute of trees, and covered with coarse grass.

On the western side of this terrace, on the line of Guichen Bay, another is found with an immense fresh water marsh upon its surface—Lake Hawdon. This would be drained easily, as it is flanked by the ancient coast line already described. Beyond Lake Hawdon is the raised beach with the salt lakes, and then the country declines by small terraces, sometimes covered with blown sand, to the ocean.

It will be seen from the above description of the various terraces that the expense connected with the cutting is the only difficulty

in the way of draining the district. As, however, not all of the land is worth drainage, I may indicate those places where cutting may be gradually employed with advantage.

The Mosquito Plains could be advantageously drained in places on the western side, and the whole of Seymour's great swamp, by a cutting to the northward; but it should be remembered that transverse bars of limestone and sand divide all the swamps, and a cutting to the north of any one will only drain the basin in which it occurs, unless the basins are connected by other cuttings. Very few such bars occur in the Reedy Creek; but they are rather abundant in the Avenue. If Seymour's Swamp were drained, the whole of the marshy flats receiving Mosquito's Creek would be relieved, and the northern swamps which carry off the surplus drainage. The lower terrace being heath and sand would readily absorb a portion of the water; but being useless soil, it would not be necessary to drain it for the present.

The Avenue might be relieved by a cutting at the old South Avenue, which would entail a trifling expense and reclaim a large tract of rich soil. A further cutting might be made near Wilmot's Crossing, which is about twenty-two miles further north. Both these cuttings would swell the Reedy Creek; and to relieve it, cuttings into the Biscuit Flat might be made, but not immediately, as the Reedy Creek is a natural and good channel. To drain it perfectly, the Biscuit Flat would have to be drained by several cuttings, and the terrace below relieved. It is, however, needless for me to specify the cuttings; because the physical features of the land being once understood, the possibility of drainage is no longer a question, and the mode may be left to engineers. I would, however, suggest that the drainage of the South Avenue, Wilmot, and Lake Hawdon, would be accomplished at such a small outlay (the two first especially), that they might be made at once as an experiment.

The Dismal Swamp has its outlet in the Colony of Victoria; but were all its basins in South Australia connected, it would almost drain itself. The soil is, however, sandy, though not so poor as it appears, for the same kind of soil supports the richest farms at Mount Gambier.

Until drains are made, it would be as well that road contractors should understand clearly that the flow of waters is northward, and that numerous culverts should be left on the roads which run east and west. For want of this precaution the road leading to the Reedy Creek Bridge (at Payne's) acted as a dam, and the waters flowed over it in 1863, making it most dangerous to horsemen, in consequence of the depth of water at either side, and destroying the road.

Lastly, the actual streams in this district show what drainage can effect in the land they flow through. If it were not for the Creeks

at Narracoorte and Robertson's, the back country would now be lakes. The result is best seen at Lake Wallace, which is an immense sheet of water, thirty-five miles east-north-east of Penola. It drains by a chain of large lakes, which occupy a great deal of good land as far as a very large and deep basin in Victoria, sixteen miles from the boundary known as Lake Borakite. This and the neighboring Lake Bolomof, when overflowing, inundate the whole of the Tatiara and then partly supply Lake Kadnite, which is drained by Morambro Creek into Cockatoo Lake, and the salt lakes, which have seldom been known to overflow. Lake Borakite has only been flooded once in the last twenty years, and then the country round was in a fearful condition for months.

The Tatiara is imperfectly drained by swallow holes in the limestone; but it does not appear that there is any other method of drainage, except at an enormous expense. It is a tract of land, running east and west, far inside the edge of the desert tableland and somewhat depressed below it. The Swede's Flat is another similar depression which appears to have been an ancient lake. There seems, however, to be something in these tracts of good land which lie, like oases, imbedded in sandhills which is peculiar to the Mallee Desert, which continue right through to the Murray. A station called "The Cow," about eighty miles from the river, is one. Cussens' Western Flat and home station, McLean's Flat, Jim Crow Flat, &c., are all instances of the same thing. They are marshy clay plains with poor grass and good timber growing on the surface. Contrary to the general direction of plains in this district, they run east and west.

Explanation of Map.

No. 1. Green—Pleistocene. Shelly and rocky calcareous deposits; where decomposed, good soil, supporting well grassed country.

No. 2. Light Brown.—Very sandy soils, heathy in the south and scrubby in the north parts of the district. The heathy portion support sheep; but little heath is found north of the dotted line C D.

No. 3. Yellow.—Sandy soils of poor quality; but better than the preceding.

No. 4. Darker Brown—Lower pliocene. Light sandy soils of excellent quality, near volcanic hills; but generally well grassed throughout the district, and, if drained, fit for moderate cultivation.

No. 5. Brown Pink—Upper miocene. No. 1. Good soils—clays and alluvial loams; but much occupied by swamps. North of dotted line C D, land poor and clayey.

No. 6. Purple.—Rich red chocolate soils in downs requiring but little drainage, the greater part fit for cultivation.

No. 7. Pink—Granite. Of small extent, fair soil.

No. 9. Red—Volcanic. Splendid soils, of almost inexhaustible richness, extending much beyond the limits of the actual rocks marked red.

N.B. The boundaries of all these formations are only approximately sketched out, and not from actual survey. Patches of sand also occur in places which are not marked on the map.

Adelaide: Printed by W. C. Cox, Government Printer, Victoria-square.

SKETCH MAP

OF THE

GEOLOGICAL

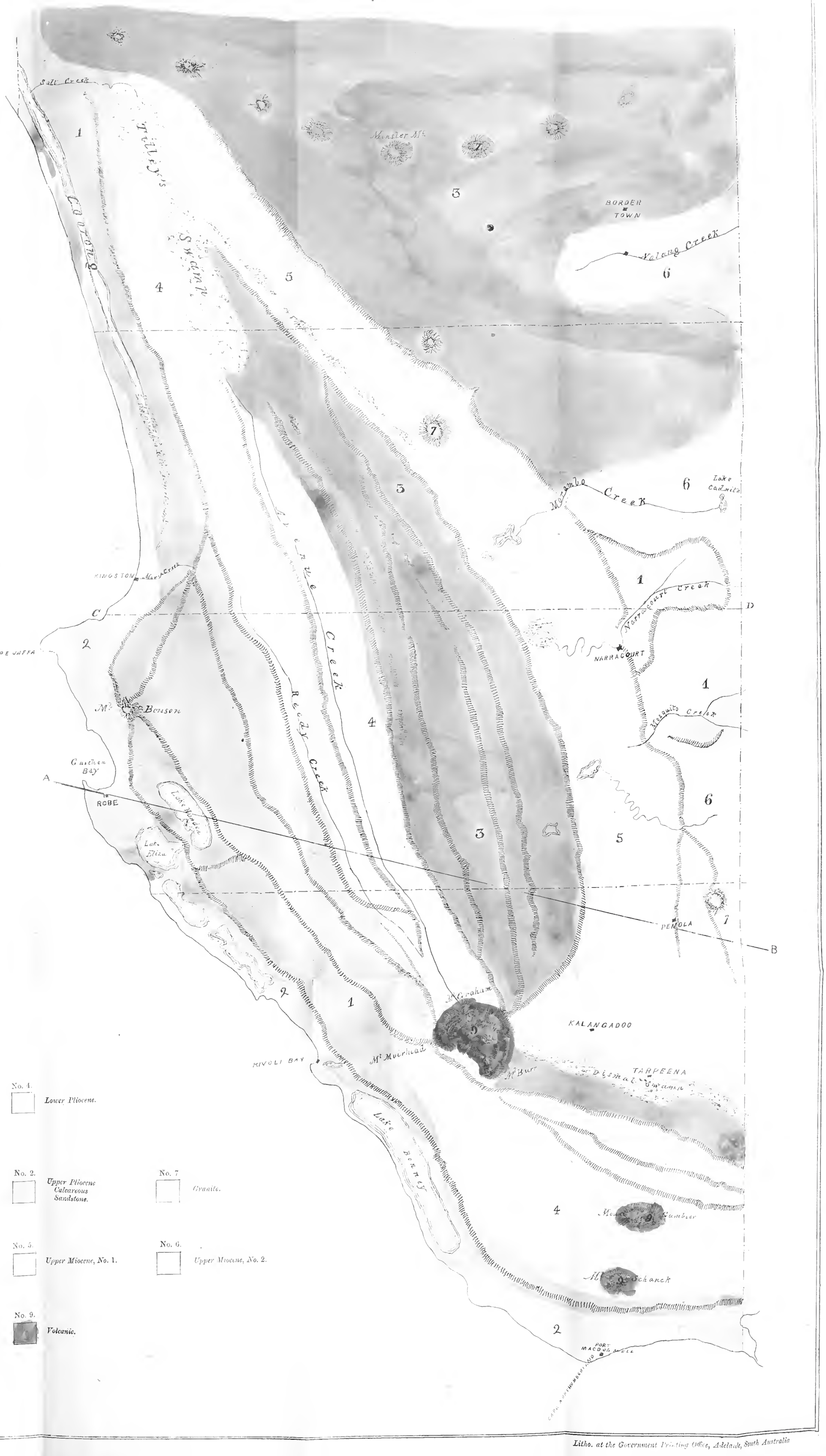
AND

Physical Features

OF THE

SOUTH-EASTERN DISTRICT,

SOUTH AUSTRALIA.



No. 4. *Lower Pliocene.*

No. 1. *Pleistocene.*

No. 2. *Upper Pliocene Calcareous Sandstone.*

No. 7. *Granite.*

No. 3. *Upper Pliocene Sands.*

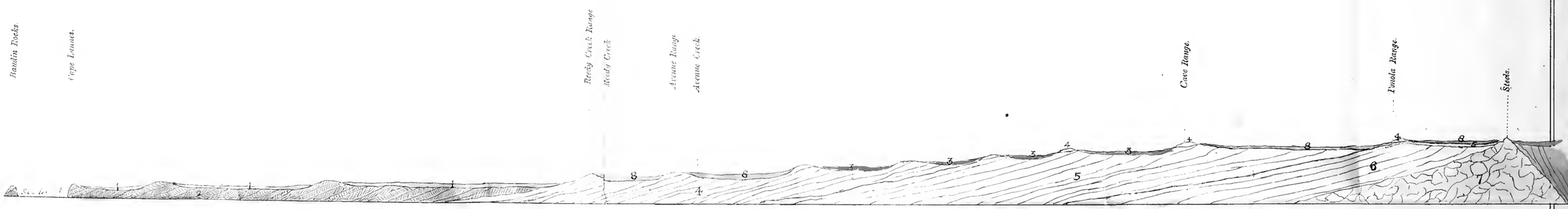
No. 5. *Upper Miocene, No. 1.*

No. 6. *Upper Miocene, No. 2.*

No. 9. *Volcanic.*

Litho. at the Government Printing Office, Adelaide, South Australia

SKETCH SECTION ON LINE A —— B, SOUTH-EASTERN DISTRICT.



No. 1. *Pleistocene.*

No. 2. *Upper Pliocene Calcareous Sandstone*

No. 3. *Upper Pliocene Sands.*

No. 4. *Lower Pliocene.*

No. 5. *Upper Miocene, No. 1.*

No. 6. ***Upper Miocene, No. 2.***

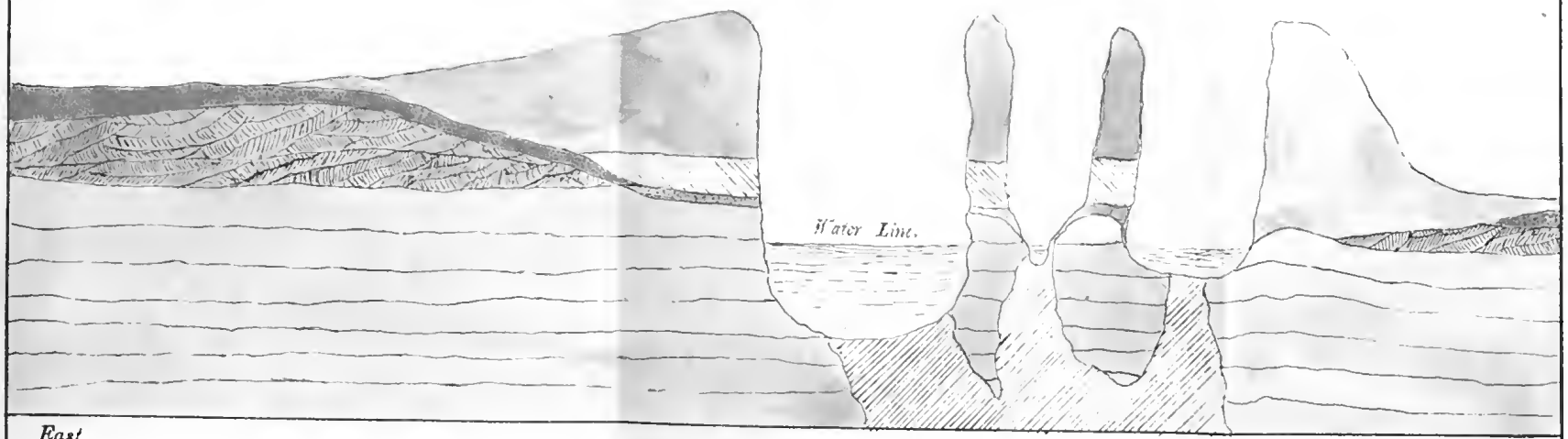
No. 7. *Granite.*

No. 8. ***Alluvial.***

GEOLOGICAL SKETCH SECTION

OF

MOUNT GAMBIER.



Ash.

Pliocene Calcareous Sands.

Pliocene Sands.

Miocene or Older Pliocene.

Older Basalt.

Newer Basalt.