2. *On some POINTS in SOUTH-AFRICAN GEOLOGY.* By GEORGE WILLIAM STOW, Esq., of Queenstown, South Africa.—Part I.

(Communicated, with Notes, by Professor T. Rupert Jones, F.G.S.)

[Read Nov. 23, 1870*.]

- I. On some of the Formations of Port Elizabeth and its neighbourhood.
 - § 1. The Jurassic Formations (pp. 497–514).
 - § 2. The Posttertiary Formations (pp. 515–522).
 - II. On the Dicynodon-Formation; its Forest-zones and other strata (pp. 523–534).
 - III. The Climatal Changes of South Africa, as indicated by its Geology and Fossils; and especially the Glacial Denudation of the Karoo Strata (pp. 534–546).
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PART I.—§ 1. THE JURASSIC FORMATIONS.

Introduction.—Whatever advances geology has made during the last twenty-five years in South Africa (with which the names of Bain, Atherstone, and Rubidge will be ever connected), it must be confessed that we are but mere students in the elementary portion of this part of the great “stone book of nature;” and it may be expected that every new investigation will bring to light facts, and lead to conclusions, of which at present we have but a feeble and imperfect notion.

To the present time geological knowledge in South Africa has progressed but slowly. The great broad outlines of the geology of the country have been traced by those whose names have been mentioned; but the minutiae have yet to be filled up. The South-African explorer labours under many serious disadvantages, not only from the horizontal position of many of the strata, but from the want (with the exception of a few mountain-passes) of great road-cuttings, and from the absence of mining operations, so that he has to depend upon the escarpments found along the river-valleys and mountain-sides, leaving large intervening tracts that must still remain in some degree of uncertainty until opportunities shall arise for their more definite examination.

With regard to the fossiliferous strata in the neighbourhood of Port Elizabeth, and of the Zwartkops and Sundays Rivers, for a long time I had felt that too much had been done in the way of curiosity-hunting, by *mixing* and generalizing all the fossils of what has been termed the “Uitenhage Formation,” from whatever part of it they may have come; thus shells from the upper and lower parts of the Zwartkops River have been massed together, as well as those from the Upper and Lower Sundays River, although many miles intervene between the different localities—a plan that can only lead to a confused idea of the different strata; and I felt certain that this was one of the causes that prevented just conclusions being arrived at with regard to the formation in question.

As a commencement towards getting more perfect results, I sepa-

* For the other papers read at this meeting see pp. 29–33.

Fig. 1.—Collated Sections on the Zwartkops River. (Section D of the Author.)

rated the various fossils I obtained ; and the longer I continued the examination the more I was convinced that not much practical good would be effected until not only the fossils from each locality, but also from *each particular stratum*, had been separately arranged. In this paper I record the results of these observations, imperfect as of necessity they are, doubting not that future investigators, with more lengthened opportunities than I have had myself, will most probably modify some of my conclusions.

A. Trigonina-beds of the Uitenhage Formation.—In following up this subject I shall first treat of the fossiliferous strata of the Zwartkops River, and then of those of the Sundays River. After that I shall proceed to describe the more recent deposits in the neighbourhood of the former river and Port Elizabeth.

Lower Zwartkops River. Section at Rooke's Bluff.—The portion of the Lower Zwartkops River that has been most frequently examined is a part of the heights not far from the mouth of the river, named by the geologists visiting it "Rooke's Bluff," after our friend and fellow-labourer Colonel R. H. Rooke. It is situated about a mile above Rawson's Bridge, on the east bank of the river. Here the lowest fossiliferous band is found in an old road, and is marked No. 13 in Section A* and fig. 1 (see also fig. 3). From it *Isastraea Richardsoni*† was obtained. The most characteristic fossil of this stratum is *Astarte Bronnii*. *Pleuromya lutraria* and *Astarte*

* The sections mentioned but not figured in this memoir are preserved in MS. in the Society's archives.

† Quart. Journ. Geol. Soc. xxiii. p. 162.

Herzogii are rather frequent. The other shells are *Gervillia dentata*, *Pholadomya dominicalis*, *Exogyra imbricata*, *Arca Jonesii*, and an *Ostrea*. In the bed, marked No. 12, near the upper part of the bluff (figs. 1 & 3) we find *Exogyra imbricata* very abundant; *Astarte Herzogii* and *Pleuromya lutraria* are numerous; but of *Astarte Longlandiana* only one specimen has been found, and one of *Trigonia Cassiope*. The other fossils known to occur, in bed No. 13, are:—*Arca Jonesii*, *Cucullæa Kraussii*, *Pinna Atherstonei*, *Placunopsis subjurensis*, *Trigonia ventricosa*, *T. conocardiformis*, *Ostrea*, *Pecten*?, *Ammonites*. No. 13 is about 50 feet above the level of the river, and No. 12 about 200 feet. The rocks in this section dip 2°–4° from the river inwards, and are surmounted by Pliocene (?) limestone.

Upper Zwartkops River. Section on the Old Road.*—Some miles further up the river, on the old Grahamstown Road (fig. 1), above the drift (ford), another fossiliferous bed (No. 11) is exposed along the hillside and across the road, as shown in Section B (fig. 3), some hundred feet above the river. The dip of the strata here, said by Dr. Atherstone to be about 8°, is inwards from the banks of the river. It is here that *Cucullæa Kraussii* is found more frequently than in any other of the fossiliferous bands, together with *Trigonia Herzogii*, *Astarte Herzogii*, and *Pleuromya lutraria*, all of which are very numerous, and may be looked upon as the characteristic shells of this stratum. The *Cucullæa*, especially, seems to have flourished at the time of the formation of this bed, and must have grown to a large size, as its fragments show. The other fossils are:—*Pleuromya lutraria*, *Ceromya papyracea*, *Trigonia Herzogii*, var., *T. conocardiformis*, *T. var.*, *Exogyra imbricata*, *Pecten*, *Pinna*, *Patella*.

Section at Cuyler Manor.—Still further up the stream, near Cuyler Manor (fig. 1), is another exposed portion of this formation. I have not visited this locality myself; but Mr. Longlands, who examined it in 1867, very kindly furnished me with the section shown in Section C (fig. 3).

In the stratum of friable sandstone, marked 10, he found *Ammonites*, and very numerous specimens of *Trigonia Herzogii*; in fact the latter abounds so much that it may be looked upon as the most characteristic fossil of this section. He also found a few specimens of *Exogyra imbricata*, and a few fragments of *Trigonia conocardiformis* and *Pleuromya lutraria*.

Remarks.—As the whole of the Zwartkops strata dip inland, and along the course of the river, which has a somewhat rapid fall towards the sea, I think these circumstances tend to prove that these fossiliferous bands, as shown in Sections A, B, & C (fig. 3), are not one and the same stratum, but form a *parallel series*, as is shown (in an exaggerated form) in fig. 1. Thus the stratum No. 13, in which *Astarte Bronnii* abounds, must be the lowest; the bed, No. 12 at Locke's Bluff follows, with its multitudes of *Exogyra*; the *Cucullæa*-bed on the old Grahamstown road is the next in succession; and,

* The word "upper" here used in reference to the Zwartkops and Sunday Rivers does not indicate the highest parts of those rivers, but some portions towards the furthestmost range of the Trigonia-beds traversed by them.—T. R. J.

finally, the *Ammonites*- and *Trigonia*-zones of Cuyler Manor succeed; and these positions, I believe, will be fully proved upon more mature investigation.

Lower Sundays River. McLoughlin's Bluff, or Prince Alfred's Rest.—I will now describe the Sundays-River strata, commencing with those nearest the mouth of the river, and following up our examination along the course of the stream. The first section is that of a bluff, about a couple of miles from the mouth, which has been named by some of my geological friends "McLoughlin's Bluff," after "mine host" of a small inn*, now called "Prince Alfred's Rest,"

Fig. 2.—*Range of Hills near the mouth of Sundays River.*
McLoughlin's Bluff on the right (—).

in the plain below. This Section, E (see fig. 3 and Sketch, fig. 2), is the most marked of any I have seen of the *upper portion* of the "Ui-tenhage Formation." The rocks of this series appear to be *superior* to those exposed along the lower banks of the Zwartkops, shown in Sections A & B. Unfortunately, the lower part of the bluff is so thickly covered with brushwood that no definite conclusion could be arrived at with regard to the underlying strata; but in the water-course of a somewhat precipitous kloof, at a little distance from the bluff (see Section F) was found a lower fossiliferous stratum containing *Astarte Herzogii*, *Trigonia Herzogii*, and *Pleuromya lutraria*. This bed seems to be nearly similar to the stratum No. 11 (fig. 1) on the lower part of the Zwartkops River. Intervening between this and the fossiliferous band marked 5 in this section (F), which bed is evidently the same as that indicated by a similar number in Section E (fig. 3), were sandstones some 250 feet in thickness; but here, as at the bluff, the brushwood and débris prevented an accurate examination

* Formerly referred to as "McLoughlin's Inn" in the papers by Atherstone and Rubidge. The fossils from Sundays-River mouth and those from "Prince Alfred's Rest" (or McLoughlin's Bluff) were unnecessarily separated in the paper in Quart. Journ. Geol. Soc. vol. xxiii. p. 170.—T. R. J.

Fig. 3.—Collated Sections of the “Uitenhage formation” (Jurassic). (Section H of Author, including his Sections A, B, C, E & F, and G.)

being made. The existence of this *Astarte*- and *Trigonia*-band seems to point out that the position I have given to the sections (on the Zwartkops) is the most probable one.

The fossiliferous strata Nos. 6 & 7, in Section E (fig. 3), were evidently deposited under very different circumstances from any of the others; and wherever the one I have styled the *Modiola*- and *Hamites*-zone (No. 7) makes its appearance, it possesses the same lithological character. I have given this name to it on account of the numerous specimens of *Modiola Bainii* and fragments of the *Hamites africanus* found in it. In this locality (McLoughlin's Bluff) this stratum is full of small fragments of carbonized wood, which rub down to black powder under the finger. These minute fragments seem to indicate that the sedimentary matter of which this particular portion of the bed is composed, must have been the deposit of some current of water laden with innumerable small pieces of vegetable drift, such as we see washed up in the present day on the seashore, after rains, near the mouths of small rivers.

Some miles further up Sundays River, where this bed is again exposed, and where its thickness is much greater, these specks of carbonized matter are wanting—an indication that this latter portion was most probably deposited further off shore, or from a different direction; but I shall have again to allude to this in my observations on the Upper Sundays River. The shells also of this stratum are, with few exceptions, of a very different character from those of the *Astarte*- and *Trigonia*-beds, the shells of the latter being, for the most part, strong massive shells, fit to live along the coasts of an open sea, whilst those found in the zones of which I am now speaking are, most of them, thin and fragile. The rock itself is of a much looser texture than the associated non-fossiliferous sandstones—while these latter, which intervene between this bed and the uppermost layer, increase in friability as they ascend, and show a considerable difference from the compact sandstones of the Lower Zwartkops. The rock composing the *Hamites*-zone is patchy in colour, appearing in some places of a reddish sandy tint, but more frequently grey. This was the bed (No. 7) in which the large, coiled, broken fossil, thought to have been an *Ancyloceras* (?), was discovered by Major (now Lieut.-Col.) Rocke. In no other, that I am aware of, have *Hamites africanus* and *Belemnites africanus* been found: fragments of the former are here exceedingly abundant; but the latter is rare. *Modiola Bainii* seems almost exclusively confined to this stratum. Fragments of either *Hamites* or *Modiola*, found in the debris of the neighbouring cliffs, are always a sure indication of the close proximity of this band. The principal shells characteristic of this zone, are:—*Hamites africanus* (very numerous), *Ancyloceras* (?) (two specimens), *Trigonia Goldfussi*, *Tr. conocardiformis* (young), *Crassatella complicata*, *Modiola Bainii* (numerous), *Mytilus Stowianus*, *Mytilus Rubidgei*, *Belemnites africanus* (rather scarce); also, I believe, *Alaria coronata*, and small specimens of *Astarte*, *Cyprina* (?), *Psammobia* (?), and *Ostrea* (narrow, curved).

There cannot be the slightest doubt that, if future explorers will arrange the fossils they obtain from these different strata according to the *particular band* from which they are derived, the scanty lists here given will be greatly enlarged.

There is another somewhat remarkable feature in the shells of this (No. 7) and the stratum (No. 6) immediately above it—namely, that the large *Trigonæ* are wanting, although there are numbers of the smaller kind, and young individuals. Future investigations will perhaps modify these conclusions. The *Hamites* and *Modiola*, from which I have named the zone, may be found to extend into others in reduced numbers; but in this particular zone they have a great numerical superiority.

In the bed marked 6, the same type of shells appears as in No. 7. The rock is also apparently of the same kind. But only a few small fragments of *Hamites* are found; and in the bed above, marked 5, the *Hamites* seems to have disappeared entirely, and apparently all the peculiar shells that accompanied it—their places being supplied by others of a different character. Amongst these the principal is the beautiful *Trigonia ventricosa*. It abounds here, and is, in fact, the characteristic fossil of the bed in this particular locality. A few isolated specimens have been found in the Zwartkops strata; but here they are, in some places, massed together in thousands, outnumbering every other shell. *Trigonia vau* is also very abundant; and hence, in the general Section (fig. 3), I have called this (No. 5) the *Trigonia-ventricosa*- and *T.-vau*-zone. Fine specimens of *Gervillia dentata* also have been obtained from it, together with *Ecogyra imbricata*, *Pecten Rubidgeanus*, and *Turbo Stowianus*.

In bed No. 4 the *Trigonæ*, compared with those in No. 5, are not only very much fewer and smaller, but, from some alteration of circumstances, apparently were disappearing from this part of the ancient ocean. The remains of other shells are also far less abundant than in the lower zones. The sandstone above No. 4 is much altered in character compared with those underlying it, being, as I have before remarked, less compact, and far more coarse and friable than those below. This difference of texture increases the nearer we approach the upper portion of the section, where the sandstone seems to assimilate in lithological character more to the upper sandstones of the Koega, and to those interlaminated with the clays at the Bethelsdorp Saltpan (see further on), than to any others.

Immediately above these, as shown in Section E (fig. 3), is a shell-bed, from 3 to 5 feet thick, composed of small fragments of shells, thickly interspersed with a species of *Ostrea*. This stratum seems to be of Pliocene or Postpliocene age, and to be the equivalent of the upper shell-limestone on the Zwartkops and the Koega. Above this, again, is a conglomerate, varying from 3 to 6 feet in thickness. This is capped with tufaceous limestone, from 2 to 3 feet thick; and above the limestone is a red, sandy, marly clay, varying, according to the inequalities of the surface, from 4 to 6 feet. I send a sketch of the bluff (fig. 2), the better to show the formation.

Above the Modder Drift (Ford).—The country for a distance of some 10 miles in a straight line between McLoughlin's and Modder Drift, on the Sundays River, I have not been able to examine; but from the Modder Drift, for several miles, to the krantz (precipices) below the Addo Drift, at Tunbridge's, three distinct fossiliferous bands make their appearance at intervals—that is to say, wherever the rocks are sufficiently exposed on the slopes of the hills that bound the S.W. side of the river.

Unfortunately, it is here the same as lower down the river, and the hill-sides are too much covered with débris and brushwood to enable any one to make a very accurate survey of the intervening strata. The belts vary from 2 to upwards of 3 feet in thickness. The lowermost, No 3 (see Section G, fig. 3), contains large numbers of *Trigonia Herzogii*, young and adult; but *Trigonia conocardiformis* is more abundant, and appears to be the characteristic shell here. *Trigonia vau* is often found, but it is far scarcer than those just mentioned; also *Cyprina rugulosa*, *Astarte Herzogii*, and *Ostrea*.

The middle band, No. 2, Section G, is composed of a fossiliferous rock that appears to be, as before alluded to, the equivalent of the "*Modiola*- and *Hamites*-zone" at McLoughlin's. At present, however, I am not aware that any fragments of *Hamites africanus* have yet been found in this locality. Only in this bed, and in Nos. 6 & 7, at McLoughlin's, is *Modiola Bainii* found, as far as I have been able to learn; and the accompanying shells, much like those found in the corresponding zone shown as No. 7, Section E, are *Ammonites subanceps*, *Gastrochæna dominicalis* (in fossil wood), *Alaria coronata*?, *Cardita nuculoides*?, *Astarte Pinchiniana*?, and small specimens of *Astarte*, *Cyprina*?, *Psammobia*?, *Ostrea*.

The differences are that, above the Modder Drift, this stratum, No. 2, is much thicker than No. 7 at McLoughlin's Bluff, as it here attains, in some parts, a thickness of 3 feet; the rock also is of a closer and harder texture, and of a more uniform grey colour, whilst the black specks of carbonized matter which characterize the "*Hamites*-zone" at McLoughlin's are, as far as I could observe, entirely wanting, owing most probably to the sediment of which this rock is composed having been deposited in deeper water. This stratum makes its appearance, as I have said, at intervals, wherever the mountain-side is sufficiently denuded of the superincumbent soil: thus it is exposed a little above Modder Drift, again in a kloof (gully) called by Drs. Rubidge & Atherstone, from the number of *Ammonites* they found there, "*Ammonite Kloof*," and again some six miles above the Addo Drift, and beyond Com-mando Kraal on the Sundays River. These indications therefore enable us to trace this "*Modiola*-zone" from the bluff, in Section E, to the last-named spot, a distance of upwards of fifteen or sixteen miles. Other indications of this same bed may most probably be found between these different and widely separated points; but the difficulties of making a thorough examination, as I have previously explained, are very great, covered as many of the hills are with dense entangled brushwood, while at the same time there

are few either natural or artificial cuttings through these strata anywhere.

In the uppermost stratum, No. 1, Section G, I found a number of *Astarte Longlandsiana*. In one small mass of rock I obtained upwards of twenty specimens of different sizes. In a small kloof near the top of one of the hills, near the Modder Drift, Col. Locke and I discovered a place where this fossiliferous bed was exposed, containing innumerable remains of *Pinna Atherstonei*. I have never seen such a collection of these shells at any other spot. From this circumstance we named it "Pinna Kloof." *Trigonia Herzogii* is also numerous here. If these rocks prove to be, as I suppose, the equivalents of those at McLoughlin's, there is to be noticed that, whereas at the latter place the whole series occupies a space of but some 40 or 50 feet in thickness, here, above the Modder Drift, the fossiliferous beds are not only thicker themselves, but are separated by wider spaces of non-fossiliferous rock, it being a height of some 200 or 250 feet from the lowest stratum to the top of "Pinna Kloof."

I was not able to make any satisfactory observation of the dip of these lower rocks during my visit; but some four or five miles to the west, on the plateau over which the road passes from the Bay to Tunbridge's, I found that the dip of the upper sandstones was at an angle of 9° , with an apparent direction of 32° E. of S., taking a slope from the higher portions of Grass-ridge towards the coast. These latter rocks, where I obtained this observation, are at a higher elevation than those examined along the banks of the Sundays River; but whether the dip here taken is likely to indicate the true dip of the lower rocks under notice I am not at present able to say. A quantity of fossil wood was strewed among the débris of these strata, although I did not find any *in situ*; and Dr. Rubidge informed me that he had found Ammonites in the same locality.

As a recapitulation of the foregoing, I would observe that the facts here stated, imperfect as they are, and modified as the conclusions here arrived at no doubt may be with increased information, show that most of the fossiliferous bands in the different localities of the "Uitenhage Formation" form portions of a series, and are not continuations of the same zone, as was once thought. This, I believe, will be proved to be the case, very convincingly, as soon as their fossils are more accurately tabulated. Thus, in No. 13, at the old road near Locke's Bluff, *Astarte Bronnii* is in very large numbers, both valves of most of these shells beautifully perfect. This is the only band from which this *Astarte*, as far as I can learn, has been obtained, while I am not aware that a single *Trigonia* has ever been found there. In No. 12, *Exogyra imbricata* is exceedingly numerous; but not one specimen of *Astarte Bronnii* has been discovered in it. Here one or two *Trigonia* make their appearance, but are very scarce; while in No. 11, near the drift, on the old road to Grahamstown, *Trigonia Herzogii* becomes one of the characteristic shells. In No. 11 also, *Cucullæa Kraussi*, *Astarte Her-*

zoggii, and *Pleuromya lutraria* are very numerous, these, in fact, being the predominant forms of this zone. Whether No. 8, in the kloof near McLoughlin's Bluff, is a continuation of this (No. 11), as seems probable, will require further proof. Again, in No. 10, near Cuyler Manor, are numerous Ammonites and *Trigonia*, and the *Exogyra* of the lower strata has very considerably diminished in numbers; while in No. 9 we find a perfect "*Trigonia*-zone" very similar to that marked No. 3 in Section G, of the Upper Sundays River*.

Again, in Section E at McLoughlin's Bluff, we find No. 7, a zone containing numerous Hamites and *Modiola* associated with a large *Ancyloceras* (?). This bed seems to have its equivalent in No. 3, Section G, of the Upper Sundays-River strata; and, lastly, we have No. 5, in Sections E and F, with multitudes of *Trigonia ventricosa* and its accompanying *Trigonia* *var.* To show my meaning better, I have massed the foregoing Sections A, B, C, E, F & G into one general one (fig. 3).

B. Saliferous beds of the Uitenhage Formation.—I will now proceed to notice some sections I have made at the Government and Bethelsdorp Saltpans, the Koega River, and the Salt Vlei near Port Elizabeth. These sections represent the stratified clays and sandstones of the "Saliferous deposits" of the "Uitenhage formation," which have been placed by some investigators† as underlying the Zwartkops fossiliferous sandstones of which we have been speaking.

Government Saltpan between the Zwartkops and Koega Rivers.—The first locality I shall mention is that of the Government Saltpan between the Zwartkops and Koega Rivers (see fig. 6, 7, and 7). This section (Section I) has been figured and described by Dr. Atherstone‡. 1, 2, & 3 are, as he says, thin bands of hard, highly fossiliferous, dark ferruginous sandstone, about 3 or 4 inches thick, containing broken shells (*Trigonia*, *Ostrea*, *Turritella*) and spines of *Cidarites*. These hard bands alternate with saliferous shales and sandstones, with a dip of 8° towards the north-east§; the hard band (1), overlying porous sandstone, forms the bed of the salt-pan; and marls (without salt) and soil cap the uppermost band. It is very difficult to obtain specimens of the numerous fossils, as they are very perishable. Both Mr. Longlands and myself failed, during a somewhat hurried visit to the locality, to obtain any.

Sandstones on the Koega River.—The sandstones on the banks of

* Mr. G. W. Stow has sent to England specimens of *Trigonia Herzogii* and fossil wood with *Gastrochæna*, from the Zambesi, that perfectly resemble in zoological and lithological characters these fossils from the Sundays River; and they have their associated Selenite, as at Geelhoutboom.—T. R. J., Oct. 19, 1871.

† See Dr. Atherstone's "Lectures on the Geology of Uitenhage," Eastern Province Monthly Magazine, vol. i. 1857, pp. 581, 584, &c., and Quart. Journ. Geol. Soc. vol. xxiii. pp. 149 & 167.—T. R. J.

‡ See Dr. Atherstone's sketch section, East. Prov. Mag. *loc. cit.*—T. R. J.

§ The beds up the Sundays River (near Geelhoutboom), which Dr. Atherstone considers to be equivalent to those of the Saltpan, have a dip, he says (*loc. cit.* p. 581), of 8° to the south-west.—T. R. J.

the Koega seem to be very similar in character to those of the Government Saltpan—so much so that one is almost led to believe that they must be a continuation of them. Section K (see fig. 6, e) was made by me near this river, not far from the old road to Grahams-town. In this section, No. 1 (at the top) is a marly clay, interspersed with very numerous, small, calcareous seams. This is comparatively recent, and rests on a conglomerate of quartzite pebbles (No. 2). Immediately beneath this is clay (No. 3), resting upon a coarse loose sandstone (No. 4), and this upon a hardened clay.

Two or three miles lower down the Koega, where I obtained another section, the sandstones appear to be very similar, in their lithological character, to those shown in the section (Section L) of the upper rocks at the Bethelsdorp Saltpan (see fig. 6, 4). I have not found any fossils in them, nor have I heard of any being found; we must therefore look for some further proofs before a positive opinion of their identity can be formed. This last-mentioned section on the Koega is capped with the same Posttertiary shell-limestone as at the Zwartkops.

Bethelsdorp Saltpan.—On the west side of the Bethelsdorp Saltpan is a very good section of the saliferous clays and sandstones. Commencing from the lowest in Section M 1 & M 2 (see fig. 6, 5), No. 22 is a coarse, gritty, rather loose sandstone, the thickness of which is at present unknown, as is also the thickness of the belt of clay (No. 21) resting upon it. It is highly probable, however, that the latter, if properly exposed, would prove to be banded clay and sandstone, some 2 or 3 feet thick, similar to Nos. 15*a*, 17, and 19. No. 20 is a hard, compact, fossiliferous sandstone, not more than 1 foot thick. In this the characteristic fossils of the locality are found, namely the remains of *Cidaris pustulifera*. Its plates and spines are obtained here in large quantities. Judging from the numerous remains, one is led to the belief that it was during the period of the deposition of this particular zone that it most flourished, while at the Government Saltpan these fossils appear scarce. *Ostrea Jonesiana* is also frequent in this belt, whilst other small *Ostreae* are scarce. Dr. Rubidge found *Crassatella complicata* here. Above this fossiliferous bed we find fifteen alternate bands (altogether 10 feet 9 inches) of a reddish clay and sandstone (stratum 19), each bed being very distinctly marked. These bands seem to be non-fossiliferous, as well as the other strata from No. 19 to 14 in Section M 1 & 2, and from No. 11 to 8 in Section L. More diligent search, however, may discover traces of life not only in these rocks, but also in the upper strata before alluded to, on the banks of the Koega (Sect. K, fig. 6, e). Above No. 19 in Section M 1 & 2, is a coarse non-fossiliferous sandstone (No. 18), 8 feet thick; then follow banded clays and sandstones (No. 17) 3 feet 6 inches; and above these, 4 feet 8 inches of sandstone (No. 16); again alternate bands of clay and sandstone (No. 15*a*), 5 feet 3 inches thick; then 2 feet of a light-coloured friable sandstone (No. 15*b*), on this a band of 8 inches of clay (No. 15*c*), and above that 4 feet 4 inches of a light-coloured and very friable sandstone (No. 14). On the top

of all these lies an irregular deposit of a sandy calcareous tufa, covered with a reddish sandy clay. The remarkably uniform thickness of the several clays and sandstones in these sections is worthy of notice.

From another Section, marked L (see fig. 6), that I was able to obtain in a higher bank about 300 or 400 yards to the N.N.E. of Section M 1, No. 14 does not appear to be the uppermost in this series. This higher section shows nearly the same dip as the lower one; and in it we find a broad band of sandy clay (No. 11) 8 feet in thickness, interspersed with a great number of calcareous stripes near the top. Above this is 2 feet of clay (No. 10) of a pale-greyish stone-colour, (No. 9) six inches of a sandy yellow and brownish striped clay; and above that, (No. 8) two feet more of the same clay as No. 10, with a superficial loam. In the foregoing sections, we therefore obtain (if the uppermost bands belong to the series) a combined thickness of more than 52 feet of these stratified clays. The latter section is capped with the same reddish sandy clay as the former; and I have not been able to find in these two places any trace of a deposit that might be considered the equivalent of the Zwartkops and Koega Posttertiary shell-limestone.

The Salt Vlei near Port Elizabeth.—About five miles nearer to Port Elizabeth, in the clay-pits, at a place called Salt Vlei, we find another excellent section of the stratified clays. This is shown in Section N (fig. 6, 2). In these pits the lowest uncovered rock is that marked No. 18 in the section—namely, a marly, gritty sandstone. It is exposed for a depth of 14 feet; the remainder of it (whatever the entire thickness may be) is covered up with the débris of the excavation. It appears, as far as can yet be seen, to be non-fossiliferous. Immediately above this is a belt of clay (No. 17), and on the clay a band of nodular concretions (No. 16) fourteen inches thick. These nodules are irregular in shape, and of various sizes, some of them being upwards of 2 feet in length; when broken they all display the same fracture as that shown in specimen No. 16*, with a powdery nucleus as in specimen No. 16a†. *In situ*, they lie as if they had been regularly packed, their greatest length being in the direction of the dip.

Above this noduliferous band is a sandy clay, No. 15, 2-feet thick, of a yellow-ochre colour. Upon this follows a dark slate-coloured clay, No. 14, also 2 feet thick. The strata Nos. 14, 12, and 10 are clays to all appearance exactly alike, as regards colour and texture, and must have been deposited under similar circumstances. No. 13, 1 foot thick, is the first zone (in this section) in which were found traces of fossils. It is full of small marine shells [*Astarte* (?) and *Natica* or *Phasianella* (?), T. R. J.]: some are very beautiful; and all were so delicate in structure as to be very difficult to remove.

No. 12 is a clay, 3 feet thick; then comes a single line of nodules, No. 11. These nodules are placed either singly or in groups, as shown in the section, all in the same line of bedding. No. 10 is

* No. 16. Ferruginous sandy nodule, with ochreous centre.—T. R. J.

† No. 16a. Dark red-purple earthy hæmatite.—T. R. J.

a clay, $7\frac{1}{2}$ feet thick. No. 9 is an indurated shell-band, 3 inches thick; its shells are different from those found in No. 13. Some of the species that make their first appearance here go on increasing in numbers in the deposits marked 8 and 7. Specimens 9, 9a, 9b, contain numerous fragments and casts of shells, obscure gregarious bivalves [possibly *Cyrena*, T. R. J.].

No. 8 is a clay, from 18 inches to 2 feet where thickest, interspersed with streaky patches of shells [*Cerithium*?, T. R. J.], the intervening clay being devoid of them.

No. 7 is a deep-red clay, with yellow stripes running through it. This, like the preceding, has bands of shells (small bivalves and univalves).

It is remarkable of these three last-mentioned strata, Nos. 7, 8, and 9 [which may be of estuarine origin, T. R. J.], that they gradually thin out.

The deposit No. 6 is a light slate-coloured clay, 9 feet 2 inches thick. No. 5 is a narrow band of clay, varying in width from 1 to 3 inches, full of fragments of shells, with a small *Ostrea* in abundance. Above this is a deposit of a similar light slate-coloured clay, No. 4, 8 feet 6 inches thick; and upon this a stripe of a yellowish sandy clay (No. 3) or, rather, a loam, pulverizing between the fingers; and above it is a clay similar to Nos. 4 & 6, two feet thick. This is capped with a sandy kind of marl, No. 1, varying from 2 to 4 feet

* The sides of this outlier were too thickly covered with débris for me to obtain a good section; but I imagine that it must be similar to the stratified clays at the Bethelsdorp Saltpan, as the spines of *Cidaris pustulifera* are found in the débris.

thick, interspersed with calcareous stripes. From this stratum (No. 1) small burrows or pipes have been sunk through the strata Nos. 2 & 3, and form cavities in No. 4, as delineated in Section N. Some of these curious excavations are several feet in depth; and in some instances the lower part is 18 inches wide, while the pipes leading to them are only a few inches in width; they appear to be the work of some of the old inhabitants of that ancient sea. They are now all filled with the sandy marl of No. 1, with which are mixed small nodules, and, in some of the pipes, fragments of shells, evidently all washed in from above, when the apertures leading to them were open.

These clays dip E. by S. at an angle of 20° , and have been denuded, as shown in the Section. The sandy marl and the outcrop of the clays are covered with surface-soil, the lower part of which is interspersed with beds of well-worn quartzite pebbles, in some parts to a thickness of from 1 to 3 feet. In some places there is a small deposit of calcareous tufa between the underlying clays and the surface-soil.

In another excavation, near the same spot, I obtained a rather different section of these stratified clays exposed for about 39 feet, as seen at *c*, in Section O (fig. 4). The dip here varied from 10° to 20° . Whether the clays of these two last-mentioned Sections (N

Fig. 5.—*Section of the beds marked d in Fig. 4*.* (Section P of Author.) From an excavation made for a large tank.

and O) are continued across the Salt Vlei to the opposite outlier *d* in Section O (fig. 4), I am not able to say, as the sides of this hill are

* Possibly this section includes some Posttertiary deposits.

too thickly covered with soil &c. to obtain a trustworthy section; nor can I, of course, say whether its strata assimilate rather to the clays and sandstones of the Bethelsdorp Saltpan; but Dr. Rubidge told me that he picked up a number of the spines and plates of *Cidaris pustulifera* among the débris of this outlier. All I can speak of with certainty is from Section P (fig. 5), which I was able to make during the excavation of a large tank on the top of this outlier. In this section the surface-soil was interspersed with shingle (as in Section N). Below this was a band of tufa, from 12 to 18 inches in depth; then 2 feet of friable sandstone, interspersed with carbonate of lime, as shown in the section; again tufaceous limestone, from 5 to 7 inches; beneath that, 13 inches of sandstone, interspersed with carbonate of lime in the same manner as the sandstone above; again 1 foot of limestone, then sandstone 3 feet; below this, three uneven belts of sandy limestone and sandstone, respectively 6, 7, & 6 inches thick; these were followed by 1 foot of sandstone, of the same character as the thick band above; and beneath them all, at the bottom of the excavation, was a reddish sandstone, the thickness of which is at present unknown.

Very little is accurately known of the fossil contents of the strata shown in the last three sections. They evidently require attentive examination, and promise a rich harvest to future explorers. Since my departure from Port Elizabeth, Messrs. Kemsley & Burness have found fossil Ferns in some of these clays, but have not been able to identify them with any of those from Geelhoutboom, on the Sundays River*. The clay in which they were found "rested upon sandstone containing immense fragments of leaflets and petioles of *Zamia*, mixed with pieces of wood." To this discovery I shall have to allude again (p. 513).

Résumé of the Strata of the Saliferous Group.—None of these sandstones that I have examined possess the close, compact nature of those found among the rocks of the Lower Zwartkops in Section A (fig. 3); but they are all of a coarse gritty texture, very like those I have spoken of as being found on the Koege (p. 506).

In looking over the various sections of these stratified clays and saliferous sandstones (namely I—P), one cannot help being impressed with their diversified aspect, each section differing widely from the others; and they seem to indicate that we are not examining a single wide-spread deposit, but a partially consecutive series, something similar to, but of more limited extent than, those of the Uitenhage formation before considered. This becomes more apparent by looking at the diagram (fig. 6), in which the foregoing sections are collated and compared.

Here the section near the Salt Vlei, noticed by Messrs. Kemsley and Burness (fig. 6, a), becomes an important addition, as by it we find that *Trigonia*, *Turritella* and a *Gervillia* were obtained from the lowest stratum of sandstone in this formation, while the clays with *Ostrea* and *Tellina* (?) are above. This sandstone deposit appears to be one of the oldest, if not the most ancient, of this Saliferous formation.

* Quart. Journ. Geol. Soc. vol. xxiii. p. 145 &c.

Fig. 6.—Collated Sections, showing the probable succession of the Clays and Sandstones of the Saliferous Group.

(Section Q of Author, embracing his Sections I, K, L, M, N, O, and S.)

1. Outlier near
the Salt Vlei
(Sects. O, P,
figs. 4 & 5).2. The Salt Vlei
near Port Elizabeth
(Sect. N).3. Near the Salt
Vlei (Kemley
and Burness)
(Sect. S).4. Near
Bethelsdorp
Saltpan
(Sect. L).5. Bethelsdorp
Saltpan
(Sect. M).6. Koega
River
(Sect. K).7. Government
Saltpan
(Sect. I).

The strata of the Government Saltpan seem to follow, with (according to Dr. Atherstone) *Trigonia*, *Turritella*, *Ostrea*, and *Cidaris pustulifera*. At the Bethelsdorp pan *C. pustulifera* is found in the greatest abundance; and spines and plates of the same *Cidaris*, found scattered on the sides of the outlier at the Salt Vlei, near Port Elizabeth, indicate the position of the associated clays on the opposite side of the Vlei (Section O, fig. 4), with their innumerable specimens of small *Ostrea* unmixed, as it seems at present, with the remains of *Cidaris*. As I have already said, so little is yet accurately known of the fossil contents of all these different strata that nothing can be done to decide the question of position with any degree of certainty until the fossils shall have been more fully studied and classified.

On looking at these collated sections (fig. 6) we at once see how much they differ from the apparent uniformity of the sandstones of the Zwartkops and Sundays Rivers (Sections A–G, fig. 3). These latter exhibit the features of an extended and uniform deposit, while the former display local differences of a very diversified character. Further, the more I have studied them the more I have been impressed with the idea that the position at present assigned to them * is not correct.

The following reasons may be given to explain this opinion. It is said that these strata are an earlier formation than those of the Zwartkops and Sundays Rivers series; but has this been convincingly proved? As far as I could obtain information, no good section has yet been pointed out (that is, anywhere between the quartzite hills of Port Elizabeth and the Grass-ridge) where these clays &c. are so situated as to demonstrate distinctly that they are really below, and the Zwartkops *Trigonia*-beds above. Even should we find them in a depression *apparently* lower, still this would prove nothing without a satisfactory junction in which the *Trigonia*-beds could be shown to be placed above the stratified clays; whereas sections have been found the reverse of this. It might as well be argued that the red clay (*g, g*, in Section O, fig. 4) spread over the surface in different parts of the Oliphants-Hoek and Port-Elizabeth Divisions, instead of one of the most recent clays, is a very ancient one, because in the former locality it has been found (in sinking wells) to be upwards of 100 feet in depth, and in the latter, near the New Prison, about 70 feet—lower levels than either the sandstones or stratified clays have been found at. This clay has evidently been deposited in hollows, eroded out of the more ancient rocks; and in the same way, I cannot help thinking, these “Saliferous Strata” have been deposited in positions where denudation had removed some of the earlier formations. This was especially the case where I examined the strata of the Government Saltpan; for there *these rocks*, as far as I could judge, when the dip of the *Trigonia*-sandstones is taken into consideration, must be placed above those of the Zwart-

* That is, *below* the great *Trigonia*- and *Ammonites*-series of the Uitenhage formation. See Atherstone, *loc. cit.*, and Quart. Journ. Geol. Soc. vol. xxiii. p. 149.—T. R. J.

kops. Again, as a proof that their position is below the Zwartkops *Trigonia*-beds, it has been stated that these saliferous rocks are found resting unconformably on the quartzite and clay-slate, in the direction of Bethelsdorp and Chatty. But, again, this of itself is no proof; for near the Shark's River one of the most recent shell-deposits also rests directly on the quartzite.

Dip.—We will therefore first enter into the question of dip, especially that of the Government Saltpan—in the first place, however, premising that *between* this Pan and the saliferous deposits of Bethelsdorp and the neighbourhood of Port Elizabeth the strata of the Zwartkops, as shown in sections B & C intervene. The Pan itself is in a denuded depression; but this hollow is not very deep, as is indicated by the rising ground that surrounds it, and from the top of which a plateau stretches on the same level as the upper edge of the Zwartkops Heights—in fact, is continuous with them, as is seen at *d'* in Section R (fig. 7).

Dr. Atherstone * says that the strata at Geelhoutboom dip S.W., towards the centre of the ancient estuary, at an angle of 8° , and those of the Zwartkops conversely N.E.; and he gives the dip of the Saltpan rocks at the same angle to the north-east, that is, in the same direction as those of the Zwartkops. Now it is certain that for a number of miles together the dip of the Zwartkops strata continues with great uniformity at nearly the same angle. But an angle of 8° gives a depression of about 1 foot in 15; and if continued two miles (about the distance of the Government Saltpan from the top of the Zwartkops Heights), there would be a total fall of some 1500 feet. The highest hills anywhere in the neighbourhood are the Koega Kopjes; and they are only 480 feet above the level of the sea. The depression of the Saltpan is certainly not 300 feet below the level of the Amsterdam Flats, the plateau from which these Kopjes rise, as that would place it below the level of the sea, which it decidedly is not; but, even allowing it to be so, the angle given would place the Zwartkops sandstones, if they extended as far as the saliferous strata of the Saltpan (which I think is not doubted), 1200 feet below them. A dip of 4° (the same as at Rocke's Bluff) would allow rather more than 700, or some 400 feet below: and even the small angle of 2° would still leave the *Trigonia*-beds between 70 and 80 feet lower than the deposits of which I am speaking.

Fossils.—At the Government Saltpan (p. 505) Dr. Atherstone has found *Trigonia* and *Turritellæ* associated with *Ostreæ* and *Cidaris pustulifera*. I cannot help thinking that this is the oldest portion of the saliferous strata that has been yet examined. The stratified clays of the Bethelsdorp Pan and those at the Salt Vlei are, I believe, more recent. At the former of these *Cidaris* and *Ostreæ* are abundant; but no *Trigonia* are yet known there; while at the latter spot no specimens of either the one or the other have been obtained, although *Cidaris* has been found on the sides of the outlier (Section O, fig. 4) on the east of the Vlei. This outlier, I believe,

* *Loc. cit.* p. 581, and woodcut, no. 1.

will prove to be older than the clays of the Salt-Vlei section, and probably equivalent to those of Bethelsdorp.

At one of the meetings of the Natural-History Society of Port Elizabeth, Dr. Rubidge published a section (Section S, fig. 6, s), near the Salt Vlei (see a notice of their Proceedings in the 'Port-Elizabeth Telegraph'), at the top of which is a bed of clay, "No. 1, apparently about one foot." This is the stratum in which Messrs. Kemsley and Burness discovered the Ferns (see above, p. 510). "The stratum of clay which contained the Ferns rested on a sandstone containing immense fragments of leaflets and petioles of *Zamia*, mixed with pieces of wood, and that on a clay with shells (*Tellina*, *Orbicula* [?], *Myacites* [*Pleuromya*], *Ostrea*, &c.); no 2, some three feet thick. Below this was a shelly sandstone, containing *Turritella Rubidgeana* (Tate), with imperfect specimens of *Trigonia Goldfussi*, and a new species of *Gervillia*. The discovery of these shells, which are on the opposite hill (near Mr. Graham's house) associated with *Cidaris pustulifera* (Tate), at the Bethelsdorp Saltpan with the same and with *Crassatella complicata* (Tate), *Ostrea Jonesii* (Tate), and at the Zwartkops Heights with *Trigonia*, *Astarte*, &c., is of great interest, as showing clearly the relation of the whole series of the beds of the ancient Mesozoic bay to each other."

I wrote to the late Dr. Rubidge upon this subject immediately after the publication of the report, to ask him his opinion whether this did not confirm the conclusion I had already arrived at from the study of the dip. Unfortunately I did not receive an answer.

Distribution of Fossils in the several members of the Uitenhage Formation, according to the corrected lists of named species.—T. R. J.

		Species yielded.	Species peculiar.	Community of species between
I.	{ 1. Near the mouth of Sundays River..... 2. Higher up Sundays River..... }	62? { 28 46	12 29	1 & 2 = 12? I. & II. = 16
II.	Zwartkops River	28	9	I. with II. & III. = 6?
III.	{ "Lowest strata of the Zwartkops Crag (cliff)" }	15	9	I. & IV. = 2?
IV.	Saliferous strata.....	9?	3	II. & III. = 0 II. & IV. = 0 III. & IV. = 1?

C. *Conclusion.*—Let us now take a retrospect of the various fossiliferous beds I have mentioned. In the lowest Zwartkops stratum no *Trigonia*, as far as I can learn, have been discovered, and certainly not the *Crassatella complicata*, *Hamites*, and some other shells. As we proceed upwards *Trigonia* become abundant, and increase in number of species. Ammonites also become frequent in some strata. At M'Loughlin's Bluff on the Sundays River *Hamites africanus*,

Crassatella complicata, and *Trigonia Goldfussi* make their appearance. These rocks, it will be remembered, I have looked upon as the uppermost of the Zwartkops- and Sundays-River strata. At the Government Saltpan, *Trigonia* and *Turritella* are mixed with the remains of *Cidaris*—while in the section near the Salt Vlei (Sect. S, fig. 6, s) we find *Crassatella complicata* and *T. Goldfussi*, together with a *Gervillia* (shells found in the uppermost Sundays-River strata), imbedded in a sandstone, immediately above which are found stratified clays containing shells which, together with *Crassatella complicata*, are associated with *Cidaris pustulifera*, the characteristic shell of the fossiliferous zones of the Saliferous Strata, and, apparently, the *Trigonia*, Ammonites, and their associates are absent. This explanation proves, I think, the regular sequence of the shells.

Mr. Tate, in his paper "On some Secondary Fossils from South Africa," says* :—"Species of this type (*Cidaris pustulifera*) exist at the present time, and are found in the Tertiary and Cretaceous rocks; species of the type with crenulated bosses characterize Oolitic deposits. There are, however, some exceptions to these rules, and for the present the African species may be regarded as another exceptional example." If I understand this rightly, some species of *Cidaris* (this fossil, remember, is associated with *Crassatella complicata*) are indicative of Cretaceous rocks; but this is an "exceptional case." If, then, these same deposits are placed in the position which I believe is their true one, the exceptional condition vanishes; they take their right place, and prove that the law which regulated, with regard to periods, the development of particular races was the same in the southern as in the northern hemisphere.

Origin of the Salt.—The author thinks that the *Trigonia*-series, having been deposited in open sea, would be less likely to contain salt than shallow-water beds succeeding them and formed in narrowing creeks and lagoons. The saliferous series he believes to have thus succeeded the *Trigonia*-beds, and to have become impregnated with salt. At the present time the same causes are at work on a smaller scale, in the mouths of some of the minor rivers of South Africa, where the entrances are blocked up with sand and thus communication with the ocean is cut off, except when broken through occasionally by a freshet after heavy rains. During the time that these mouths are thus land-locked the evaporation is more rapid than the supply; and as a natural consequence, the water in the enclosed basins becomes more intensely salt than that of the neighbouring sea. The deposits formed within them are saturated with this extra-saline fluid, so that when a flood bursts through the opposing barrier, and the water of the imprisoned river falls with the tide, banks of brackish mud are exposed in many places; and these soon prove themselves to be saliferous deposits; for, as they dry in the sun, they become covered with a white saline efflorescence. Such, one cannot help believing, is the explanation of the mode of formation, although on a grander scale, of the saliferous strata we have been considering.

* Quart. Journ. Geol. Soc. vol. xxiii. p. 163.

PART I. § 2. TERTIARY OR POSTTERTIARY STRATA.

[Abridged*.]

1. *Pliocene or Postpliocene Strata of the Interior*.—Having thus noticed the older rocks, I will now proceed to make a few remarks on the so-called “Tertiary Limestone”†, which covers in many places the rocks we have been describing. This series caps the top of the Zwartkops Cliffs, extending from Rocks’s Bluff (see Section R, fig. 7), along the top of the hills towards Uitenhage, and resting upon the Jurassic sandstones. The greatest accumulation appears to be on the Amsterdam Flats and the Grassridge. At the Koega it is found upon the friable non-fossiliferous sandstones of that locality (see above, p. 506). At the Sundays River it is seen on McLoughlin’s Bluff as a narrow belt. These positions are shown in Sections E and R (see fig. 7). From the Zwartkops to the quartzite ridges of Port Elizabeth, I am not aware that any traces of it have been found. Mr. Pinchin, who has paid much attention to this formation, states (in a letter) that “it covers the upper part of the plain (Amsterdam Flats), extending westward to Hitzeroth’s (the Old Government) Saltpan, and along the tops of the hills to within a mile of Uitenhage; it covers the whole of the Grassridge

* The sections and sketches sent by the Author for this portion of his Memoir are deposited with the others in the Society’s Archives; and the large collection of recent and fossil shells &c. sent by Mr. Stow, in illustration of his views as given in this paper, awaits examination by Mr. W. S. Dallas, who kindly promises a full report.—T. R. J.

† This is the limestone termed “Tertiary” in Mr. Bain’s Geological Map of the Cape Colony, Geol. Trans. 2 ser. vol. vii. pl. 20.—T. R. J.

2 N 2

to within three miles of Prentice Kraal, and nearly in the same meridian as Blaaw Krantz. This latter place, however, is some three or four miles off the limestone. It is seen upon Landman's Kop, a hill lying just eastward of the Sundays River's mouth, and at Deep Kloof and Groof Water, in Oliphant's Hoek, twenty miles south of the Sundays River. To the southward of Port Elizabeth the limestone hills of Buffel's Vontein, Chelsea, and Van Staden's River, are probably of the same formation."

Mr. Pinchin's professional duties have given him opportunities of visiting every part of the district. The places which I have examined are:—Rocke's Bluff; a quarry on the flat between the Government Saltpan and the Zwartkops Heights; on the banks of that river, to a deep kloof, a little below the drift (ford) on the old Grahamstown Road; the old waggon-track on the north bank of the Koega, near the Kopjes; different spots on the Grassridge; and at McLoughlin's Bluff. It seems to be a single deposit, and not a series like the others (see p. 519). It varies very little in all the localities that I visited, being from 4 to 6 feet thick, except at McLoughlin's Bluff, where it is much thinner. It is highly fossiliferous, and abounds with fragments of shells, and now and then with some that are nearly perfect. Of the bivalves only single valves are found, and the majority have been broken by the action of the waves. In some localities there are immense deposits of a large species of *Ostrea*. Out of 22 different species of shells, nine are not at present found on the neighbouring coast, five are still doubtful, leaving only eight of the number that are positively recognized as being inhabitants of the present sea.

2. *Pliocene or Postpliocene Strata on the Coast*.—Following this limestone, and with an evidently wide interval, is a series of deposits which are spread out from Port Elizabeth to the mouth of the creek (or Ferreira's River), and thence, in detached spots, to the Zwartkops. The oldest deposit appears to be a sandy tufaceous (?) limestone, interspersed with many patches of conglomerate, formed of small quartzite pebbles. It is very fossiliferous. Out of twenty-five species of shells that I collected from this bed, twelve have not been found in the adjoining sea. The greater portion of these are fragments. This deposit was certainly laid down under widely different circumstances from those of which I shall have to speak presently, and in which the shells, however fragile and delicate, are in a beautifully perfect state.

As far as I could judge from an excavation I had made at the foot of the cliff, I found this stratum to be from four to eight feet thick; but I found great difficulty in obtaining a good section, as, at the lowest level arrived at, the water flowed in so rapidly that we could not proceed. The bed extended from a quarter to half a mile inland, where it was hidden under the æolian sandhills. It was covered by a non-fossiliferous limestone, a few inches thick; and above that was spread a layer of loose pebbles of the same kind as those in the pebbly limestone itself.

In two other diggings, instead of the loose shingle, occurs a clayey sand, mixed with small pebbles and numerous shells (*Cerithium* &c.), out of twelve species of which, seven have not yet been found on the present beach. Most of the shells are broken and worn, owing no doubt to their having been rolled in shallow water with the sand and small shingle in which they are imbedded.

Further south, after digging in a bed representing that last described for about eighteen inches, the influx of spring water prevented the examination being carried further. Above it was a hard limestone without fossils, and above this a band of pale slate-coloured sand from 9 to 18 inches thick, equivalent to the pebbly clayey sand above mentioned. It is mixed with grit and small pebbles, and contains numerous specimens of the straight *Cerithium* which occurs in the equivalent bed; but all the shells found in it are broken and waterworn. Near the Creek there is a bluish sand; and the shells in it are more perfect than in the beds previously mentioned. I had no opportunity of obtaining a measurement of its greatest thickness. From this particular band I have collected forty species of shells, of which there are eighteen that have no living representatives on the present sea-beach. I imagine that their descendants will have to be looked for further to the eastward along the coast.

There are two strata in the southern part of the section whose equivalents I have not been able to trace further north. One is a bright yellow sand, from 1 to 2 feet thick, containing numerous perfect specimens of *Loripes edentula* (Chenu) and *Mactra*, with both valves complete. The other is a pale slate-coloured sand, slightly clayey, varying from 2 to 5 feet in thickness, and containing numerous beautifully perfect shells. From the immense numbers of the *Akera* found in it, I have termed it the *Akera-stratum*. This deposit is in some places worn away, and divided in detached portions, as represented at *a, a, a* in Section T. It is at many places capped with a layer of waterworn fragments of shell-limestone, pieces of shell-grit containing small pebbles, and also waterworn shells of the present ocean. These last were, of course, left in the position in which they are found during the retreat of the sea to its present level. The number of species of shells that I have already obtained from this stratum is 71; of these, 27 have not been found on the present coast, and of 10 others it is doubtful whether they are still living in the neighbouring bay. The straight *Cerithium*, the *Pectunculus*, and others have sometimes been picked up by shell-collectors on the beach, mixed with recent shells; but, possessing none of the fresh appearance of more recent shells, they have always borne evidence of having been disinterred.

§ 3. *Pliocene or Postpliocene Strata (Raised Beaches) on the Coast and Inland.*—The next deposits, so far as at present known, in succession to these, are shell-banks that are not only found along the coast, forming a raised sea-beach, as on the south side of the Zwartkops River's mouth, but also extending inland as raised banks nearly as far as Cradocktown. They are evidently far more extensive than those we have just been considering. The principal parts

that I have examined are:—the raised beach just mentioned, which is about half a mile from the river's mouth, and 40 or 50 feet above the present sea-level; on the south bank of the Zwartkops, near Rawson's Bridge; and along the banks of the creek and Ferreira's River, towards Cradocktown. No trace of these shell-beds is found on the surrounding highlands.

This formation is also found protruding through the red clay that forms a portion of the flat, between the outlier marked No. 1 in the section (fig. 4) near the Salt Vlei and the sandstone on the coast near Port Elizabeth. See *f* and *g g* in that section (p. 508).

In each locality mentioned this deposit extends a considerable distance. Thus it can be traced from a spot where it is exposed by a cutting through the north bank of the creek, on the Grahamstown Road, across the raised flat over which the road passes towards the Zwartkops, until you reach the wide alluvial flats that extend from the south side of the river. Again it stretches from the road mentioned to the sand-hills along the coast. This portion, however, is covered with soil, thickly interspersed with shingle, mainly composed of pebbles of quartzite, from the distant hills. Wherever any wild animal has burrowed through the soil and shingle, or where any excavation has been made, the shells of this deposit are almost invariably exposed to view. In like manner it evidently extends towards Port Elizabeth—as it there again makes its appearance, as indicated in the section alluded to (fig. 4). We must note that we have here the shingly beds with the red clay superposed; I shall have again to refer to the last-named deposit.

I have found the shells from these ancient shell-banks on the coast near the mouth of the creek, evidently washed out and spread over the surface.

Returning to our first point of departure, we can trace the shell-bed, exposed at intervals, along the banks of the creek and Ferreira's River, towards Cradocktown, as before mentioned; and, after passing the mud-flats on the south side of the Zwartkops River, we find it again, extending along the banks of the same for more than half a mile. In this locality it was evidently at one time of much greater extent than at present, and must have occupied the very course of the present river; but it is being rapidly worn away by the action of the stream.

In some parts (at the bridge) this deposit is nearly 30 feet thick. It is composed principally of sand, the upper portion being inter-laminated with bands of limestone. This is especially the case at the western (or what was its inland and most sheltered) extremity. In these bands are imbedded large quantities of shells. At this spot a large and characteristic *Panopæa* is found. It is generally buried in the lower part of the stratum, and rather frequently with both valves entire. This is the only bank in which I have found this shell, with the exception of a solitary specimen in the raised beach before mentioned. At the creek and the banks of Ferreira's River, I have not found any indications of it. At this place (Rawson's Bridge) a large *Solen* is also very plentiful, as well as a *Macra* and

a *Tapes*; these shells are perfect; but, although they are so numerous, many of the shells found in the banks at the creek and Ferreira's River are wanting. It is worth considering whether or not this indicates a *series* of these deposits. All the shells in the lowest part of the stratum at this spot have both valves perfect, some of the *Mactra* still retaining a portion of their colour; those imbedded in the limestone, nearer the surface, are in a more fragmentary condition.

The section I have called "*the raised-beach*" is, as above stated, some 40 or 50 feet above the level of the sea; but unfortunately the upper portion is the only part sufficiently exposed for examination. From the indications on the beach below, it most probably rests on a sandstone there shown. Almost every shell in the remains of this ancient beach is broken, in the same manner as those now found on the present sea-shore where exposed to the full action of the waves rolling in from the ocean.

At the creek on the Grahamstown Road this deposit has been cut through for some 12 feet in depth. Here, again, most of the shells are perfect, and do not seem to have been exposed to the action of rough water. This is eminently the case with the contents of the shell-bank further up Ferreira's River, and near Cradocktown. At this place the deposit rests upon a bank of drift, with bands of large angular pieces of quartzite; this drift overlies a loose gritty sandstone. In the drift there are scarcely any indications of fossils; but in the deposit above there are strata of innumerable shells in a sandy calcareous matrix. This shell-bed, capped with a red clay, several feet thick, is the most prolific portion of the deposit we are now treating of. The shells are all perfect, with the most delicate ornaments preserved.

With the exception of a *Psammobia*, none of the shells found here have, up to the present time, been found on the shores of the bay. Still, in the whole series of shells collected, there is a nearer approach to those of the present ocean, while there is a marked difference in character between these fossils and those obtained from the *Akera*-stratum.

These shell-deposits at Ferreira's River &c., must have been laid down in the waters of a bay, stretching from the Zwartkops to the Port-Elizabeth hills, and extending some miles inland. On the intervening ridges no signs of them are to be traced. In fact, it seems almost certain that the ridges must have stood out of the surrounding waters as islands. This is remarkably the case at the creek, where the high ridges alluded to will be seen. When standing on the shell-bank at Ferreira's River, one cannot help being strongly impressed with this idea, and that the sea must have been as calm there as in a land-locked bay, protected as it evidently was from the roll of the open ocean. The appearance of the shells themselves strengthens this view of the case, from the beautifully perfect state in which almost all of them are found—with all their most delicate outlines preserved, and the bivalves almost invariably having both valves uninjured and closed. These

indications must surely prove that here they must have been deposited in still water, below or beyond the influence of the tidal and other waves; while, on the other hand, the shells of the "raised beach" appear to have been deposited on a kind of outer reef, exposed to the full force and constant action of the sea, which broke them into fragments, and rounded off their fractured edges.

§ 4. *The Red Clay*.—The deposit which seems to follow these is the red clay, as shown at *g g*, in Section O (fig. 4). The exact position of this clay, to which I have before alluded (p. 518), requires more careful examination than has yet been given to it. There appears to be little doubt, from the section just referred to, that it must be more recent than the shell-deposits we have been describing; for upon the flat, at a little distance from the north end of Port Elizabeth, they are found cropping up through it. These shell-beds, judging from their fossils, are identical with those of Ferreira's River. However, as I have said, little is at present known of this clay, except that it varies considerably in thickness in different localities: thus it may form merely a superficial covering to the shell-banks mentioned; while the late Dr. Rubidge informed me that at the New Prison it is some 60 or 80 feet thick; and, at Oliphants Hoek, Dr. Atherstone states it to be 100 feet. Whatever may be its thickness, it must have been deposited under totally different circumstances from any thing preceding it. The transition from the one to the other is so sudden that, with the limited information we have about it, it will have to be left to future investigation before its history can be written, as well as to discover (what is probably the case) deposits on other parts of the coast that may intervene between the shell-banks and the clay, and others between the clay and the formation which follows, thus more clearly explaining the changes that led to its deposition.

§ 5. *Latest Shell-beds*.—The next known deposit of the ancient sea is that marked C, C, in section T No. 1, and C in T No. 2. This is evidently the most recent, previous to the existing order of things. In the Bight, as shown in the section, it is found in detached mounds of drift-sand, with a thick horizontal bed of shells on the top. These, however, from their position and structure, are merely the isolated remains of what, at one time, was a continuous and wide-spread deposit. It is found on different parts of the coast, and is especially remarkable on the south side of Port Elizabeth, towards a small indentation called the Shark's-River Mouth. In this locality the quartzite rocks (near the top of the ridge, and at an elevation of 180 feet above the sea) have been worn away to a long slope by the action of the waves &c. About one-third up the ascent, and resting upon the quartzite, is a mass of conglomerate composed almost entirely of quartzite fragments imbedded in limestone, with fragments of shells. There is another accumulation of conglomerate at the same place, at a lower level, composed of waterworn pebbles. These conglomerates have been found at other parts of the coast. Upon this conglomerate, or, where it is wanting, upon the quartzite itself, are

high mounds of sand, such as those before alluded to, with immense masses of shells imbedded in their upper portions.

Some of the shells, although identical with those now living on different parts of the coast, are not now as numerous on this particular part of the coast as they were when the shell-mounds now under consideration were deposited; they are, however, still very numerous in other, but somewhat distant, bays.

Some have supposed that these accumulations, at such elevations, are somewhat similar to the "kitchen-middens" of Denmark; and they wish to account for this immense accumulation of shells by imagining that they are the remains of the feastings of some ancient races who at some time inhabited the sea-coast. But, after a careful study of the locality, I cannot arrive at the same conclusion. These shells, judging from their appearance, must have been deposited by the sea where they are now found. The quartzite has been (as before mentioned) worn away until it forms a long steep slope of some two or three hundred yards. The rush of the tidal waves over the surface of this rock (and they have left evidence of their action) would sweep every thing off it; and their recoil, carrying the shells and sand to the lower levels, would deposit them there in comparatively quiet water, and thus form the stratum we now find.

Between this spot and Port Elizabeth, there are a number of places where this same band of shells is exposed; but in these instances there is a deposit of sand many feet thick above it. At the spot to which I am now confining my remarks, however, this upper deposit has been denuded, or blown away, leaving the large masses of shells I have described exposed on the surface. Here and there they look, at first sight, as if they had been placed in piles; hence, no doubt, the mistaken opinion about them; but on examining these detached heaps, they are found to be parts of the original deposit, the surrounding and intermediate portions having been worn away, and the shells having become broken and pulverized by atmospheric influences. There can be little doubt that at one time the exposed portions of this shell-deposit were covered, as before suggested, with a thick layer of sand; for in many parts very large quantities of fossilized roots, stems, and branches are spread over the shells. Specimens of these must, from their perfect state of preservation, have grown on the spot, and could not have been washed from a distance. In some instances, where the sand is left, they are still partially enveloped in it. The probable cause of the change they have undergone has been that the water which permeated through the sandy and shelly soil in which they grew, became so charged with lime that, when the roots &c. decayed, the carbonate of lime itself was deposited, as in a mould, in the spaces left; and these casts, when the sandy matrix was removed, either by strong winds, which so often prevail along the coast, or by other causes, have been laid bare. I have found the same on the coast to the east of the Great Fish River.

Numbers of teeth and bones are frequently discovered imbedded in this shell-deposit near the Shark's River. The position in which

these are found would also tend to prove that they and the shells were entombed together by aqueous agency, and that they were not the refuse of the repasts of a primitive race. Thus the bones were perfect, and, in some instances, large portions of the skeleton were together in the proper positions, not scattered and broken, as they would have been had some savage been feeding on them. Unfortunately these relics would not bear removing, but broke up into small fragments as soon as they were dug out and handled.

The facts here stated must, I think, satisfactorily prove that these shells have been accumulated in the position they are now found in by the cause and in the manner here assigned. This deposit is one of the latest, if not the very latest, prior to the last elevation of this part of the South-African coast, and must have immediately preceded the present order of things. Since that time a gradual emergence of at least 150 feet must have taken place—since the ocean-waves broke upon and wore away the sloping quartzite rocks before mentioned.

Table of Postpliocene and Recent Deposits between Port Elizabeth and the Zwartkops.

Feet.	Name.	Remarks.
20 to 30.....	Shell-deposits with bones and fossil wood.	Raised 60 or 70 feet above the present level of the sea. All the shells are the same as those now found on the South-African coast.
30 to 100	Red clay.	
About 25	Shell-bank at Zwartkops Bridge.	<i>Panopea</i> , <i>Tapes</i> , <i>Solen</i> , <i>Macra</i> , &c.
Exposed 6	Raised beach near the Zwartkops mouth.	All the shells broken.
15 to 18.....	Shell-bank at Ferreira's River.	All the shells perfect. <i>Loripes</i> , <i>Tapes</i> , <i>Cardium</i> , <i>Cerithium</i> , &c.
18 to 20.....	Drift and gravel upon which one portion of the last shell-bank rests.	Angular pieces of quartzite, intermixed.
18	Strata at the Bight, Port Elizabeth.	<i>Akera</i> , <i>Cerithium</i> , &c. &c.