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ORIGINAL ARTICLES.

I.—ON THE DIAMOND FIELDS OF SOUTH AFRICA.

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DIAMOND REGION.—The diamond-bearing region in South Africa, as at present known, is chiefly within the valley of the Vaal River and some of its tributaries (as the Modder and the Vet); but it is known also to extend down the Orange (Gariep) Valley for a few miles after the junction of its two great branches, the Ky Gariep (Vaal) and the Nu Gariep (Cradock River). Bloemhof on the Vaal, two hours (12 miles) south-west of Potscherfstrom (Transvaal), is the reported locality of the most northern diamond-find. Below, for a distance of 370 miles, the plain has yielded diamonds, at several places, on both sides of the river, at Hebron, Klipdrift (near Pniel), Zitzikamma, Vogelstruis Pan, Sitlacomie's Village, Sikoneli's Village, Nicholson's Farm, Kalk Farm (near Litkatlong), etc.; and on the south side of the Orange River, they have been found some miles north-west of Hopetown, at Probeerfontein, Roodekop, David's Pan, etc. Diamonds are also said to have been found a few miles east of Fauresmith, on a branch of the Modder, about 100 miles south by east of Litkatlong; also a few miles south of Winburg (also in the Orange River Free State), in the upper drainage of the Vet River, about 80 miles from the Vaal.

GEOLOGY OF THE DIAMOND REGION.—Owing to the country being mostly flat and very much coated with loose sand, its geological structure has not been fully understood as yet; and the endeavours of travellers and colonists to describe the rocks and minerals they have met with on the Vaal are, with few exceptions, so much enfeebled by want of exact knowledge, both of geology and mineralogy, that the very numerous and indifferently printed letters, lectures, and notices in the colonial periodicals fail to give us more than an imperfect sketch of the geological features and characters of this interesting region.

Among those who have contributed to our knowledge of the geology of the Orange and Vaal Valleys, are Mr. A. G. Bain, Dr. R. N. Rubidge, Mr. Wyley, Dr. W. G. Atherstone, Mr. Higson, Dr. John Shaw, Dr. Exton, Dr. Muskett, Dr. G. Grey, Mr. E. T. Cooper, Mr. Gilfillan, Mr. G. W. Stow, and Mr. C. L. Griesbach.

DIAGRAM SECTION OF THE ORANGE RIVER FREE STATE AND THE TRANSVAAL, IN SOUTH AFRICA.

VAAL VALLEY (DIAMOND FIELDS).

DIAGRAM SECTION OF THE STRATA OF ALBANY, SOMERSET, AND CRADOCK, IN SOUTH AFRICA.

In Mr. Bain's geological map and sections of South Africa (Trans. Geol. Soc., 2nd ser., vol. vii., pl. 20 and 21), the middle strata of his great "Karoo formation" range up to the Orange River in Lat. $29^{\circ} 30' S.$, thence along the Modder River, and, skirting the north side of the Winburg Road, they extend for a great distance to the north-east, thereby including the diamond-fields near Hopetown and Fauresmith; whilst that near Winburg lies on the upper portion of the Karoo series, according to his map and his section "No. 3." Whether or no the Karoo beds extended as far as the Vaal, was not clear when his work was published. Since then, however, more information has been obtained by Rubidge, Wyley, Higson, Gilfillan, Stow, Griesbach, and others.

Dr. Rubidge¹ noticed the occurrence of the Dicynodont strata in the Vaal Valley at Winburg and Harriesmith, also in the Draakenberg, and in the Transvaal at Magaliesberg.

Mr. A. Wyley (in "Notes of a Journey across the Colony in 1857-8") described the Hopetown district as consisting of sandstones and shales, intersected by dykes of igneous rocks, and as the same as the Karoo series to the south.

Mr. Gilfillan ("Grahamstown Journal," July, 1870) has noted the occurrence of horizontal, hard, blue shales (Karoo) between Hopetown and Litkatlong. Mr. Higson has satisfactorily described the Karoo beds on the Modder and the Vaal (see further on, p. 52).

Mr. Stow, in a paper lately read before the Geological Society of London, indicates that the Karoo beds pass northwards across the Free State. Lastly, Mr. Griesbach has informed me that he has seen sections of Karoo beds on the Vaal, and in its branches or "spruits" coming from the north; and not only that these beds exist in the Transvaal (Magaliesberg), but also farther north on the Zambesi.

It is observable that such scattered information as is given respecting the valley of the Vaal refers to a striking difference of scenery between that of the Cape Colony and that of the Orange River Free State;² where low and often rounded hills, in flat sandy tracts, have taken the place of high flat-topped hills, sharp points, and steep-sided valleys, of sandstones, shales, and trap-rocks. Such rocks, however, as have been observed in place in the Vaal Valley, where the superficial deposits have been removed by wind and rain, are referred (by Mr. Gilfillan, as above noticed) to "hard blue schist," north of Hopetown, between the Orange and the Modder, and to "yellow schist and conglomerate," at the junction of the Modder and the Vaal, with igneous rocks at both places. These, taking "schist" to mean hard shale, are not different from some of the Karoo beds further south, and their intrusive dykes, especially as the bedding is said to be horizontal. Quartzite ("quartzose crystalline sandstone"), however, is alluded to by Dr. John Shaw,³

¹ Quart. Journ. Geol. Soc., vol. xii. p. 237; 1856.

² Mr. Bain incidentally mentions that between the Bambus Bergen and "the magnificent Nu Gariep or Orange River . . . detached hills, separated by extensive and dreary plains," are the features of the country. Trans. Geol. Soc., 2nd ser., vol. vii., p. 58.

³ "Grahamstown Journal," January 20, 1869; "Cape Monthly Magazine," September, 1869; "Nature," November 3, 1869.

together with some kinds of gneissic and igneous rocks ("amygdaloidal wacké"), as occurring in a ridge parallel with, and distant a few miles on the north from the lower Vaal (reaching as far as Sitlacomie's village) in the same district. These are probably palæozoic rocks, cropping up from beneath, to the north of the river. Dr. Shaw says that "trap, metamorphic, and conglomerate rocks," occur all through the Vaal Valley, and that frequently there is "basalt protruding through conglomerate and amygdaloid trap;" but these so-called "metamorphic" rocks are not clearly defined, and the "binary granite,"¹ "syenite," "clay-schists," and "sandstone," if not débris of rocks from the Transvaal, to the north and north-east, may be remnants of the Karoo beds and of their igneous dykes, intercalations, and included boulders; whilst his "chalk or something like it" is probably the well-known superficial tufa of the district.

Dr. Muskett has noticed that sandstone, passing upwards into conglomerate, regularly stratified, traversed by trap-rocks, and similar to that in most of the hills between Graaf-Reinett and Port Elizabeth, forms the base of the (Lower?) Vaal Valley. This indicates the continuance of the Karoo beds.

Some extracts from the diary of Mr. G. S. Higson, published by Professor Tennant (with some notes on diamonds, etc.) in 1870, give the clearest account of the geology of the diamond-fields of the Vaal. He left Bainsvlei, near Bloemfontein, in March, and next day on the Modder, opposite Wonderkop, he saw blue and ochreous shales of the Karoo series, "capped with the common blue basaltic trap or 'ironstone' of the country." In the Middelveld, at the end of the next stage, he noticed that "one of the hills had a thick coat of coarse sandstone under the trap, and overlying the clay-shales." Passing several farms, he came to Bultfontein (or Du Toit's Pan), where many small diamonds had been found. Here in two water-pits "good sections of the shale-formation are brought to view, intersected and upraised by the basaltic dykes; in one, to an angle of about seven degrees, sloping off from each side of the dyke, and striking east and west; in the other the shales are tilted up to about 25°. This is contrary to the experience of the late eminent geologist, A. G. Bain, in similar Dicynodont formations in the Old Colony, where effusions of trap have not disturbed the horizontality of the shales. May not this have something to do with the local distribution of the diamonds?" Having left Pniel, he came upon a section "by the side of the road, going up the river, between the station and Mr. Hayward's farm," showing "where the clinkstone and amygdaloid had run over the basaltic trap." At the diamond-diggings below Pniel "the formations on both side of the river are similar — basaltic, greenstone, and quartz dykes intersecting the ground, and crossing through the river from side to side." Mr. Higson then adds—"Went about the hills searching, but without success. Examining a gully about 1½ miles down the river, I was

¹ A granilite, or binary granite, is alluded to by Mr. Higson (see further on, p. 53), as being the fundamental rock of the Vaal Valley.

successful in discovering an immense deposit of the underlying rock of the diamond region. It is a porphyritic gneiss, and no doubt has a very extensive range in South Africa. Mr. Hübner showed me specimens of the same fundamental rock, which he had found covering a large area of country to the north: it is the underlying stratum at the Tatin and northern gold-fields, at the Chief Machin's town, in the Bamangwato hills, and forms the great mass of the Maquassie range of mountains in the Transvaal; but Mr. Hübner had been unsuccessful in tracing it again after leaving the Maquassie. Mr. Hübner calls it a 'porphyritic granilite,' but I have rather adhered to the nomenclature of Dr. Atherstone and others. My thus finding the same underlying rock across the Vaal forms a connecting link between the mineral regions of this part of the country, the Transvaal, and the far interior.¹ Proceeded about 16 miles down the Vaal; formations the same as before."

Thus the Karoo strata continue not only up to the Vaal, but into and beyond the Transvaal, and form considerable portions of the region to the east, bordering on and forming part of Natal. In the diamond-districts they have been worn down to a low level, in some places, perhaps, to the lowest crystalline rocks, at all events down to the "Devonian" strata, which certainly come out to the hilly surface further to the north-east, where Dr. Carl Mauch found specimens of *Murchisonia* in Sekhomos and Mosilikatzes country, in the Transvaal Republic, in 1867.

Of the well-known "Karoo Formation" itself, we may say that it consists of an enormous series of shales and sandstones, rich at places with the wonderful remains of extinct Reptiles (*Dicynodon*, *Oudenodon*, *Micropholis*, *Galesaurus*, *Cynochampsia*, *Massospondylus*, *Pachyspondylus*, *Leptospondylus*, *Euskelesaurus*, *Orosaurus*, *Saurosternon*, *Pristerodon*, and others undescribed), and Palæoniscan Fishes, together with Coniferous Trees, Ferns, and other Plants (among which *Lepidodendron* has been noticed by Rubidge and Grey), and coal-beds also. These strata are crossed by frequent trap-dykes (doleritic?, dioritic, and syenitic) at different angles; and are often overlain by and intercalated with similar igneous rock. Being horizontally bedded and much denuded, this extensive series of strata constitutes table-lands and flat-topped hills, deeply divided by broad valleys. A remarkable feature in this great series of probably lacustrine deposits is its basement-bed of angular and rounded blocks of trap, granite, etc., massed together in a dense cement, which in some places appears to be felspathic, but elsewhere argillaceous. Hence this great persistent band has been variously termed "claystone-porphry" (Bain), "trappean conglomerate" (Wiley), "a species of trachyte" (Sutherland), and "Boulder-clay" (Sutherland and Griesbach). The late Dr. Rubidge thought that, on

¹ This "granilite" may possibly also be the same as Bain's binary granite of the Paarl and near Bain's Kloof, not far from Cape Town. Geol. Trans., 2nd series, vol. vii., p. 179.

the flanks of the Zuurberg (near Grahamstown), this great trap-breccia had received its felspathic character from metamorphic influences (Quart. Journ. Geol. Soc., vol. xv., p. 198).

The Karoo beds have been enormously denuded in the great catchment area of the Orange and the Vaal, on a scale proportionate to the vast destruction these strata have been subjected to throughout their extent, as indicated by Bain¹ and Rubidge,² and more elaborately described, in the case of the Eastern Province, by Mr. Stow.³

To the north-east of Cronstadt, the Vaal Valley comes into the sandstone district (continuous with, and a part of, the Karoo series), from off the old quartzites and gneiss of the Transvaal. These are broken through by volcanic rocks (with craters to the south-west of the Gats Rand, Transvaal), and associated with marble, and dyked with granite, on that watershed of some of the northern tributaries of the Vaal (Higson). The great Draakenberg or Quathlamba range supplies the other head waters of this diamond-sanded river. The Draakenberg consists of Karoo beds, intercalated and surmounted with trap-rocks (Sutherland and Griesbach).

The Wittebergen, also composed of Karoo strata and volcanic rocks, branch off westward from this great range, at about 29° S. Lat., and divide the head waters of the northern tributaries of the Vaal from those of the Caledon and Orange Rivers, which, rising in the Mont-aux-Sources or Bouta Bouta (about 10,000 feet above the sea), at the divergence of these mountains, run over the Karoo strata of Basutu Land, Smithfield, Colesberg, etc., to the neighbourhood of Hopetown, where our remarks began.

ALLUVIUM OF THE VAAL AND ORANGE RIVERS, AND POSSIBLE SOURCES OF THE DIAMONDS.—The superficial deposits of the Vaal Valley (we are told) consist, in some places, of a ferruginous unctuous soil, with or without sand and pebbles; at other places, of calcareous tufa, with or without pebbles; and elsewhere of drifting sand, or of clay of various colours. These lie either over gravel or on tufa, or on the basalt,⁴ conglomerate, or other bottom-rock. Superficial outspreads of pebbly gravel are frequent, with or without any of the foregoing. Ridges of shingle also occur; and sometimes angular quartzose gravel⁵ appears to predominate. Of what the stratified conglomerate (mentioned above as a bed-rock) consists is not stated; but the shingly deposits on the surface, whether loose or cemented with iron-oxide, are mainly composed of more or less rolled frag-

¹ Geol. Trans., 2nd ser., vol. vii., p. 57; 1845.

² GEOL. MAG., Vol. III., p. 83, etc.

³ In a paper lately read before the Geological Society of London.

⁴ The basalt is said by some to be a very different igneous rock from the abundant greenstone of the country to the south and south-west.

⁵ Dr. J. Shaw remarks that the angular quartz gravel is said to be bad ground for diamonds; and that the pebbly alluvium is better for the finders.

ments of chalcedony (agate and carnelian), with both rolled and fresh crystals of quartz, and with much broken garnet and peridot. A rusty coating of iron-oxide frequently obtains. Basalt, conglomerate, and sandstone, are among the coarser débris of the valley,¹ which is in some places "strewn with fragments of rock" (Cooper). The diamonds are found in the gravel and in the sandy soil above it; and occasionally in the tufa here and there associated with the gravel. The gravel or shingle occurs not only on the flats, but on the hills and hillocks called "kopjes" (over 100 feet high). Some at least of these seem to be protrusions of basalt, or outliers of strata and dykes, of limited extent, with rifts ("kloofs") and hollows on them. They are coated with sand and gravel, and the latter is said to be particularly diamantiferous.²

Mr. Gilfillan, in the "Grahamstown Journal," July, 1870, states that, "from the fact of the stratification being horizontal, and the diamonds being exposed after heavy rains, and so many of them having been found at intervals over a large surface (along the course of the Vaal River), and the surface having very little incline, I came to the conclusion that the South-African diamond deposits must extend over an immense tract of country, more or less immediately at the surface, along the valley of the Vaal, and that where the appearances are favourable, such as spots where there is little or no vegetation, with quantities of pebbles of quartz variously coloured (green and rose-coloured more particularly), and black and red and ribbon jaspers, and rolled fragments of iron-ore, scattered over the surface on a ferruginous soil, with conglomerate rock in the vicinity, diamonds will be found both on the surface and a few inches below it."

Opportunities of examining parcels of the Vaal River gravel (mostly sorted) have been afforded me by Messrs. Atherstone, Ochs, Grey, and others; and Prof. Tennant has kindly aided me in drawing up the following list of minerals from these diamond gravels, both by adding from his own parcels, and by determining some that were doubtful:—Chalcedony, Agate, red and white Carnelian, Mochastone, Semiopal; subangular and rounded. Quartz, pellucid, smoky, milky, opaque; both perfect and waterworn crystals. Amethyst. Jasper and Lydite, waterworn. Calcite, fragments. Selenite, crystals. Garnet (Pyrope) and Cinnamonstone:³ fragments of garnet very plentiful, perfect crystals rare. Chlorite. Natrolite and Mesotype, crystals and fragments. Olivine (Peridot), fragments plentiful. Diopside, fragments. Tourmaline, perfect and broken. Hepatic Py-

¹ Dr. J. Shaw writes of the materials of the alluvium thus:—"The pebbles of sandstone, quartzite, crystalline sandstone, granite, clayslate, agate, tourmaline, iron-pyrites, garnet, garnet-spinel [?], etc., which compose this alluvium, are all roundly polished and waterworn, and are imbedded at Klipdrift in a brownish fatty earth."—*Nature*, Nov. 3, 1870.

² All philologists must protest against the mongrel word "diamondiferous," partly English and partly Latin, that the Colonists have adopted instead of "diamond-bearing" or "diamantiferous."

³ Some of these have been quoted as "Rubies."

rites, perfect. Specular Iron-ore, Pea-iron-ore, and other Oxides of iron. Ilmenite, waterworn fragments.

Professor Tennant¹ has also received a large piece of greenstone-amygdaloid, having its cavities mostly filled with Calcite, a few with Chalcedony, and still fewer with Greenearth and Olivine.

If not denuded everywhere down to the underlying palæozoic rocks, possibly the Karoo basement-bed of "trap-breccia" or boulder-deposit (if it ever reached thus far)² may have been left exposed somewhere along this great valley, and yielded its granitic, trappean, and other blocks, which elsewhere along the outcrop of this remarkable band, in Natal and across the Cape Colony, are often of massive proportions.

Not only this great breccia, but other strata of the Karoo series contain granitic material;³ and some of even the highest of them are composed of it, some of the sandstones being quartzose with a little mica, and much decomposed felspar. Hence any simple minerals once in the granite or old schists may have been liberated, unaltered and unworn, on the further and perhaps recent degradation of old granitic débris. A perfect and delicately thin crystal of tourmaline, from the Vaal, now in Dr. Atherstone's possession, indicates this, as well as numerous perfect crystals of quartz, hepatic pyrites, etc. Many of the minerals in the gravel seem to be traceable to igneous (amygdaloid) rocks, and some to palæozoic rocks, *in place* not far off.⁴ Mr. Bain long ago observed⁵ that the Orange River, to the west of Aliwal, has "pebbles of serpentine, steatite, asbestos, agate, and amygdaloid, both of black and white colour; these minerals being entirely different from those which form the materials of the pebbles occurring in the river-beds within the Colony." Certainly for such soft minerals and rocks as some of those here mentioned, and for pieces of asbestos (tremolite) veins picked up on the Vaal (Grey), there must be such neighbouring sources as outcropping masses of metamorphic rocks would afford, like the "Asbestos Mountains" lower down the Orange River. Asbestos, serpentine, and steatite are elsewhere associated with metamorphic rocks, as they are on the Orange River and the Upper Vaal. The quartz and amethyst crystals might be derived either from amygdaloidal geodes (Gregory),

¹ See also Prof. Tennant's lecture on South-African Diamonds, *Journal Soc. Arts*, Nov. 25, 1870, p. 15, etc. Reported in the *Geol. Mag.* for January last, p. 35.

² The palæozoic rocks of the Transvaal having been at least a shoal, overlapped, if not wholly covered, by the Karoo formation, it is highly probable that the latter commenced with the boulder-bed here as elsewhere. It is possible, however, that the latest beds only of the Karoo formation reached thus far; and hence the enigma of Palæozoic coal-plants in the same section with the Mesozoic fossils in the Stormberg.

³ See also Dr. Sutherland's observations on the blocks of porphyritic granite in the arkose, or granitic sand, of the Karoo beds in Natal, as well as in the breccia (which in 1855 he thought to be of volcanic origin). *Quart. Journ. Geol. Soc.*, vol. xii., pp. 466 and 467.

⁴ There is selenite (small sagittate macles; Grey) of local origin, which may have resulted from decomposition of pyrites in the drift, and reactions with the tufa.

⁵ *Trans. Geol. Soc.*, 2nd ser., vol. vii., p. 58, 1845.

or from quartz-veins in Karoo beds,¹ in old schists,² or in granite. The abundant peridot or chrysolite of the alluvium, however, is referable perhaps to the amygdaloids of the Karoo beds, if not to the volcanic rocks of the Gats Rand, though it may have come from metamorphic rocks;³ whilst garnet is found in both igneous and metamorphic rocks.⁴ Diopside occurs in crystalline rocks. Ilmenite and hepatic marcasite are known only in metamorphic rocks.

The great abundance of agate in the river-alluvium necessarily points to the amygdaloidal lavas of the Karoo formation as the source whence the Orange, the Vaal, and their tributaries, have obtained a large proportion of their gravel (Rubidge, Quart. Journ. Geol. Soc., vol. xi., p. 7; and Atherstone, GEOL. MAG., Vol. VI., p. 212). There must be much amygdaloid *in situ*, or imbedded, judging from the unworn crystals of natrolite, peridot, etc. Agate gravel⁵ is traceable up the higher streams; but whether or no these

¹ Dr. Rubidge showed me a crystal of topaz in a piece of one of the Karoo auriferous quartz-dykes near Smithfield, described in the Quart. Journ. Geol. Soc., vol. xi., p. 4, and vol. xii., p. 237. Should some of the gold-bearing quartz-veins, such as occur on the Kraai River and near Smithfield, be continued northward to the Vaal, they would be probable sources of rock-crystal, topaz, and gold; but as the yield is very poor at the places named, we cannot reckon on the supply being great elsewhere. Dr. Musket (in a letter read at a meeting of the Port-Elizabeth Nat. Hist. Society, October 29, 1868) expressed an opinion that the diamonds may have been "set free by the disintegration of the highly ferruginous trap-rocks that abound near the spot where they have been found." We learn from Mr. Higson (quoted above at p. 52), that both trap-dykes and quartz-dykes of the Karoo series traverse the Vaal.

² Dr. Grey has sent to England tremolite, amethyst, quartz with galena, a workable variety of steatite, and massive prehnite, from the valley of the Vaal. (Exhibited before the Geological Society, November, 1870.)

³ Chrysolite is common in the Brazilian diamond-drift, though only metamorphic rocks appear to have yielded the débris.

⁴ The garnet-sand, washed for pyrope, near Bilin, in Bohemia, has been found to contain diamonds. Bull. Geol. Com. Italy, 1870, p. 175 (this fact, however, is doubted in Poggendorf's Annalen); and GEOL. MAG., 1870, Vol. VII., p. 348.

⁵ Agate pebbles are known in the upper part of the Caledon River; and pebbles of amygdaloid rock and rolled agates on the north-eastern branch of the Orange River, and in the Kraai. In 1856 Dr. Rubidge remarked that "the amygdaloid rock which supplies the agate-gravel of the Orange, Caledon, Kraai, and Vaal Rivers appears to exist in the 'Mont-aux-Sources' (Giant's Castle), in the Draakenberg, as an unworn specimen was found in the Eland River (a tributary of the Vaal), not more than twelve miles from its source."—Quart. Journ. Geol. Soc., vol. xii., p. 237.

In a footnote at p. 223, Trans. Geol. Soc., Second Series, vol. vii., 1858, mention is made of some drifted ossicles of Eocerinites, picked up, when Sir G. Cathcart returned from his unsuccessful attack on Moshesh, by a soldier, near the most easterly branch [Kraai?] of the Orange River, where they were associated with ferruginous casts of small turreted shells [*Murchisonia*?], with fragments of agate, quartz, and fossil wood, and with crystals of mundic. The occurrence of Devonian strata at the base of the Draakenberg is indicated in all probability by the fossils referred to; and, whilst the quartz and mundic may be referable to veins in such rocks, or to altered schists of the same or greater age, the agate and fossil wood are sure local signs of the Karoo beds.

So also the river-gravel from near the mouth of the Orange River, referred to in the same footnote, with its Eocerinital joints, rolled amygdaloid, waterworn agate, carnelian, cream-coloured chert, and greenstone, and fragments of micaceous shale and copper-ore, points to the Metamorphic, Devonian, and Karoo strata, through which the river runs, in escaping from the interior of South Africa on the western

torrents have, in relatively late times, supplied much of the agate that now coats the flats of the great valley, or if an old alluvium¹ has been re-sifted and reduced to lower levels, or if the degradation of the rocks in place during immense periods of time has left the agate gravel of the Free State, are open questions.² Again, has this degradation been due to atmospheric and pluvial action (Rubidge, etc.), or mainly to glacial action, as recently advocated by Mr. G. W. Stow? In either case, whether the diamonds and other minerals have come out of granite, palæozoic schists, or Karoo beds, even if they have been brought from some distance, they may have come without damage in the glaciers and the river-ice, or they may have been freed from their travelled matrix by subsequent degradation.

But what was their original matrix, and where is it to be sought for? If it be granite, that rock is still to be found, perhaps in local outcrops, and certainly not far up the Vaal, above Potscherfstroom; although the old granite shores bounding the Karoo formation have long since been worn down to lower levels even than those of the deposits once formed of and within them. Plentiful wrecks, however, of the old granite are contained in the Karoo beds, and often exposed, as before said.

If among gneissic, micaceous, talcose, argillaceous, or other schists the matrix of diamond is to be looked for, we are not without indications of the existence of such old altered rocks, together with marble, in and about this region; for they are not wanting on the north side of the Vaal and Orange basin; and they are all usually associated with granite more or less intimately.³

That some old schistose rocks contain diamonds in Brazil is well known, especially the granular quartzose rock, called "itacolumite" (sometimes flexible⁴), and certain argillaceous, micaceous, chloritic, side of the continent. As diamonds are associated with the ruins of such rocks in the upper part of this great river's course, possibly they may be found among the detritus of the same rocks crossed by it near its mouth. As Dr. Sutherland has shown that old crystalline palæozoic, and Karoo rocks are all denuded together in Natal, probably among their ruins diamonds are to be found in that country also.

¹ For Dr. Rubidge's views respecting the eastern source of the agates, and of the old high-level flats and terraces of agate gravel, see *Geol. Mag.*, Vol. III., p. 89.

² Dr. John Shaw ("Nature," Nov. 3, 1870) thinks that "a series of metamorphic and sedimentary rocks which lay above the present rock-system of the region," have been slowly worn down; the shifted and reduced débris, and a few local remnants of the series, being all that remain of these old rocks, which he thinks may have been the original seat of the diamonds. Dr. W. G. Atherstone says (*Geol. Mag.*, No. 69, p. 212):—"From the great distance of the finding-places apart, and their proximity to the several river-beds, which all proceed from the Quathlamba or Draakenberg sandstone ranges, I have little doubt that, on careful exploration, the real source of the diamond deposits will be found far to the eastward."

³ The finding of diamonds at Bloemhof, near Potscherfstroom, if well substantiated, is of great importance in our inquiry; for it shows that the presence of the Karoo beds is not necessary for their occurrence; since the Karoo formation does not reach so far, according to Mr. Higson's observations ("Natal Herald," August 8, 1867). In this case they must have come from the metamorphic or the granitic rocks of the Transvaal, as the drainage of the Magaliesberg, with its Karoo beds, goes northward.

⁴ The flexible itacolumite (or sandstone of quartz and rotten feldspar), associated with diamond-fields in India, is found beyond the Draakenberg, in Natal; and there it is accompanied with a kind of jade, as in Siberia.

talcoose, and hornblendic schists, associated with it. (See the memoir by MM. Heusser, Clarez, and G. Rose, "Annales des Mines," vol. xlvii., 1860; translated in the *Geologist*, vol. iv., p. 168, etc., 1861.) This granular quartzose schist, and the other schists with which it alternates,¹ are extensively decomposed and readily washed away in Brazil. They yield, besides the diamond, the minerals of metamorphic rocks and their vein-stones, such as:—Quartz and Amethyst; Sulphur; Euclase; Kyanite and transparent Andalusite; Felspar; Topaz; Chrysolite; Chrysoberyl; Tourmaline, black, green, and transparent; Amphibole; Hornblende; Garnet; Calcite and Arragonite; Specular Iron-ore and Hæmatites; Magnetic and Arsenical Pyrites; Copper-pyrites; Rutile, Anatase, and Brookite; Ores of Tellurium; Ores of Manganese; Chromate of Lead; Gold and Platinum.

In South Africa the abundance of agate in the gravel, leads us, as above said, to see if the Karoo beds might be the original matrix of the diamond there. The late Dr. R. N. Rubidge long since suggested² that the influence of the many veins of volcanic rock, traversing the plant-beds and coal of this formation, may have been a cause of the reduction of the hydro-carbons to pure carbon; and, though he could advance no arguments in support, he could point to the change of coal in the Stormberg into anthracite by that agency, and to the existence of South-African graphite, possibly due to a further change of the carbon in these rocks.³

Drs. Muskett and Atterstone, and perhaps Dr. Shaw and Mr. Higson, seem to think, with Dr. Rubidge, that the Karoo beds, or their dykes, are to be credited with the diamonds. But this origin for the gem is left unsupported, except by Rubidge's supposition that, given *coal altered to graphite by heat*, we may also have coal altered into diamond; and by the associated abundance of the Karoo agates and the prevalence of the débris of Karoo strata in the Vaal Valley (Griesbach).

After all, as above intimated, the diamonds may either have been native to the rocks out of which the Karoo deposits were largely formed; or, more probably, they may have been derived from the old rocks of the north-east, and from local outcrops of such rocks in the Orange River Free State itself. In this case agate and carnelian are not the chief signs to be looked for in diamond-yielding gravel, but an assortment of the minerals known to abound in metamorphic rocks.

¹ Limestone also occurs with these schists, which are thought by Agassiz and Hartt to be probably Silurian rocks, highly altered. See also the Rev. G. J. Nicolay's paper in the British Association Report, 1868 (Trans. Sect. p. 74), for an account of one of the Brazilian diamond-fields.

² Quarterly Journ. Geol. Soc., vol. xi., p. 7; 1855.

³ In the "Academy" for December, 1870, is an imperfect report of a discussion at the Geological Society of London, wherein it is intimated that Prof. Morris expressed an opinion that, as the Bamboo produces *tabasheer*, so the Conifers of the Karoo formation may have produced a resin that has since been converted into pure carbon. We must wait for the elucidation of this hypothesis. See also Prof. Morris's "Lecture on Diamonds," etc., *Mining Journal*, Dec. 17, 1870, p. 1063.

APPENDIX.—As bearing on the foregoing, I add the following translation of M. Chancourtois's remarks on the probable origin of diamonds, from "Silliman's American Journal of Science and Arts," 2nd ser., vol. xlii., p. 271 :—

"E. B. de Chancourtois has presented the view that the diamond has been formed from hydrocarburetted emanations, as sulphur is formed from hydrosulphuretted emanations, and that its origin is thus connected with the previous existence of petroleum-bearing or bituminous schists. In the oxydation of sulphuretted hydrogen in solfataras, all the hydrogen is oxydized, but only a part of the sulphur passes to the state of sulphurous acid in this humid process of combustion. So, in an analogous manner, the diamond was probably formed; that is, in the course of the humid combustion of a carburetted hydrogen, in which all the hydrogen was oxydized, but only a part of the carbon was transformed into carbonic acid. This view accords with the occurrence of the diamond in arenaceous rocks, or itacolumites, which are mostly metamorphic rocks of palæozoic age, and which may have once been bituminous, either by original formation or by emanations from lower rocks.

"M. Chancourtois supposes that the crystal would have formed only where there were fissures for the passage of the vapours of the carburetted hydrogen, and where the process could go on with extreme slowness." *Les Mondes*, July 19, 1866, p. 438.

The Editor of the *American Journal* adds :—"The author does not appear to connect the process of formation with that of the metamorphism to which the diamond-bearing rocks have undoubtedly been subjected, and which may have been essential to the result."

The Carboniferous strata of the United States, which in Pennsylvania yield anthracite instead of coal, have in Massachusetts been so much further metamorphosed that they consist of gneiss, quartzite, bands of plumbaginous anthracite, pyritiferous clay-slate, mica-schist with garnets and veins of asbestos, and graphitic schists (Hitchcock and Lyell). At places where further metamorphism may have affected such granitiferous and graphitic schists, diamonds may of course be looked for, in association with garnets, etc., in the local drift.

II.—NOTES ON FOSSIL OSTRACODA FROM THE POST-TERTIARY DEPOSITS OF CANADA AND NEW ENGLAND.

By GEORGE STEWARDSON BRADY, C.M.Z.S., and H. W. CROSSKEY, F.G.S.

PLATE II.

WE are indebted for the material from which the following notes have been compiled to Principal Dawson, of Montreal, and to the Secretary of the Portland Society of Natural History, to whom our best thanks are due for the opportunity thus afforded us of comparing the fossils of the North American Clay Beds with those of our own country. By carefully washing the clays kindly forwarded to us, we have obtained many specimens in excellent condition for examination.

Of the thirty-three species here noticed, twenty-three are well known to us as occurring in the Scottish Glacial Clays, twenty-five are living inhabitants of the British Seas, while six (*Cythere cuspidata*, *C. MacChesneyi*, *C. Logani*, *Cytherura granulosa*, *C. cristata*, *Cythero-*pteron complanatum**) are new to science, being here for the first time described.

We know too little of the recent American Ostracoda to institute any very precise comparison between them and the fossil fauna represented by the following list of species; but when compared with British collections, we find the contents of the Canadian fossiliferous