PETROGRAPHICAL AND GEOLOGICAL INVESTIGATIONS OF CERTAIN TRANSVAAL NORITES, GABBROS, AND PYROXENITES AND OTHER SOUTH AFRICAN ROCKS

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Trieste

VITA.

THE author, James Alexander Leu Henderson, son of John Crosbie Aitken and Elizabeth Henderson, of Protestant faith, was born in London, England, on March 29th, 1874. The years from 1881 till 1892 were spent in South Africa, after which the author proceeded to Europe for the purpose of studying. He was educated first by private tuition, and afterwards at the Boys' Model Primary School, and High School, Durban, Natal. On various occasions between 1889 and 1892 the author was present on several extended journeys around the chief Transvaal and Cape mining districts, preparatory to studying mining engineering at the Royal Saxon School of Mines, Freiberg, Saxony, whither he proceeded in 1892, entering that institution in October of that year. After studying mining, metallurgy, and surveying, under Professors Beck, Brunck, Erhard, Kolbeck, Kretschmar, Ledebur, Papperitz, Richter, Stelzner, Treptow, Uhlich, Weisbach, and Winkler, until December, 1896, he took a first-class degree as mining engineer. The three sessions from Michaelmas, 1896, until Easter, 1898, were spent at the University of Leipzig, studying under Professors Credner, Pfeffer, Wiedemann, Wislecenus, and Zirkel. To all of his Professors the author is deeply grateful.

I.

INTRODUCTORY REMARKS.

SOUTH AFRICA affords a fruitful field of research and work to the petrologist, for it has furnished countless occurrences of eruptive and plutonic igneous rocks, which break through strata of every description, and which are met with at the surface, on the plains and table-mountains of the karoo and veldt, as the immense overflows and beds, conical and dome-shaped hills, diamantiferous pipes and koppies; whilst, underground, the miner is constantly interrupted in the pursuit of the gold reefs or other mineral deposits by the dykes of "greenstone" which he encounters in every direction. As a general rule the miner or field geologist classes these eruptive rocks under the very indefinite field term of "trap rocks" or "greenstones" without further notice, but a great many of the occurrences have been examined scientifically by able English and German geologists and assigned to their respective rock families. In the Transvaal, besides the British, German petrographers, e.g., Cohen, Goetz, Koch, Dahms, and others, as well as the present Transvaal State Geologist, Professor Dr. Molengraaff, have of late years carried out a good deal of petrographical research.

It is proposed in this paper to treat of some norites and allied rocks, which occur in the Pretoria, Rustenburg, and Marico Districts of the Central and Western Transvaal, and, if possible, to demonstrate any connection which they may have with each other, and with kindred rocks, already described by various authors, from these and other localities in the Transvaal and Orange Free State.

In these districts the principal sedimentary rocks are the so-called Magaliesberg Beds, consisting of ferruginous shales, flagstones, schistose sandstones rich in muscovite and sericite, quartzitic sandstones, and quartzites, with intercalated sheets of volcanic rocks. These beds are placed by Penning in his "Klipriver Series," which author also identified them with Cohen's "Schiefersandsteinformation" and Dunn's "Lydenburg Beds"; but Molengraaff names them the "Pretoria Beds" (Pretoria Schichten), and is inclined to place them in the lower beds of the Cape Formation, i.e. the Hospital Hill Series. Hatch, however, disputes Molengraaff's arrangement, maintaining that the Magaliesberg

Beds are identical with the Gatsrand Series, and assigns them to the uppermost place in the upper beds of the Cape System.

On the whole, volcanic activity was greatest during the deposition of the beds of the Cape System, and the eruptive rocks under discussion break through the Magaliesberg Beds, sometimes causing metamorphism of the sedimentary rocks in the neighbourhood. They are met with as large overflows, forming beds or sheets and plateaux, as conical hills, and as dykes. The lowermost rock of this part of the Transvaal is the granite; which crops out by Vredefort in the Orange Free State, again coming to the surface between Johannesburg and Pretoria, and disappearing between the Half Way House and the Six Mile Spruit in consequence of an extensive fault which runs in an east-westerly direction. The granite reappears afresh towards the north in the Springbok Flats, beyond the Zwaartkoppies.

The rocks in question occur in that part of the districts of Pretoria, Rustenburg, and Marico lying between the Magaliesberg hills on the south and the Pilandsberge and Dwarsberge on the north. The geological conditions of this part of the Transvaal have only been indicated by Hübner, Alford, Draper, Molengraaff, Hatch, and others; whilst in Hübner's sketch-map of the Transvaal,[1] and in the geological maps of Haevernick,[2] Dunn,[3] Schenck,[4] Struben,[5] De Launay,[6] Berghaus,[7] and Hatch,[8] only the most important strata or igneous rocks have been roughly located and sketched, no attempt at detail having been possible owing to the scarcity of exact geological data at command.

As is to be expected in a new mining country like the Transvaal, the geological observations and maps have been compiled more with a view to the economical than to the scientific interest; but under the able direction of Professor Dr. Molengraaff, after a scientific geological survey of the country, more detailed and reliable data and maps may shortly be expected.

Amongst the igneous rocks in certain districts of the Transvaal and Orange Free State, gabbro and allied rocks appear to take an important place, as a glance at the following list of occurrences will show. So far as the author has been able to discover from the literature

[1] A. Hübner, "Geognostische Skizzen aus Süd-Ost Afrika": Petermann's Mittheilungen, 1872, p. 422. Also, "Die neuesten Forschungen in der Transvaal Republik und dem Matabele Reich": ibid., p. 421, Tafel xxi.

[2] H. Haevernick, "Geologische Uebersichtskarte von Süd-Ost Afrika" (1 : 3,700,000): Petermann's Mittheilungen, Band xxx (1884), Tafel xvi. Also, "Geologische Skizzen aus S.O. Afrika": ibid., p. 441.

[3] E. J. Dunn, "Geological Sketch Map of South Africa," 1887, Saunders & McDougall, Limited, Melbourne.

[4] A. Schenck, "Geologische Entwickelung S. Afrikas": Peterm. Mitth., Band xxxiv (1888); with a "Geologische Skizze von S. Afrika" (1 : 10,000,000), Tafel xiii.

[5] F. P. Struben, "Geological Sketch Map of South Africa," Edward Stanford, London, 1896.

[6] L. de Launay, "Les Mines d'Or du Transvaal," map (1 : 17,000,000), p. 160; Paris, 1896.

[7] Berghaus' Physikalischer Atlas, Gotha (1 : 30,000,000).

[8] F. H. Hatch, "Geological Map of Southern Transvaal" (11·5 miles to the inch), with two sections, 1898, E. Stanford, London, S.W.

on the subject, the following are the only occurrences heretofore petrographically examined and investigated:—

(1) Cohen, E.,[1] *Hypersthene-Diallage-Gabbro* forming a dyke in granite, 8 miles east of Setigalanga, Lydenburg District, Transvaal.

(2) Maskelyne,[2] *Rock-forming Pyroxenite* at the Kornkopje, and also in the Wilfontein Bergen, near Holfontein, south of the town of Lydenburg.

(3) Cohen, E.,[3] mentions *Gabbro* in the Pretoria and Rustenburg Districts.

(4) Dahms, G.,[4] investigated a *Gabbro* which forms the principal rock of the Zwaartkoppies, Pretoria and Rustenburg Districts.

(5) The same author describes a *Gabbro*[5] from the neighbourhood north of Potchefstroom, a short distance south of this last-mentioned occurrence.

(6) Molengraaff, G. A.,[6] found a *Quartz-Gabbro* breaking through the Witwatersrand Beds at the Mooi River, south of Potchefstroom, near the Orange Free State border.

(7) South of this he also discovered[7] a *Quartz-Amphibole-Gabbro* which forms a part of the Rhenosterkop in the Orange Free State, not far from the Transvaal border.

(8) He also describes[8] another *Quartz-Amphibole-Gabbro* occurring in the dolomite at Otto's Hoop in the Marico District.

(9) In Bergrat Schmeisser's book[9] are published the results of Dr. Koch's investigations on *Quartz-Norite* or Quartz-Enstatite- (or Bronzite-) -Diabase from the farm Drietfontein near the Comet Co.'s Conglomerate bed, Boksburg, Witwatersrand (sample obtained from diamond drill core); also an

(10) *Olivine-Norite* from the Rand Victoria Mine, Witwatersrand, also obtained from a drill core.

(11) F. H. Hatch[10] mentions a *Hypersthene-Gabbro, or -Norite*, from the north side of the Magaliesberg hills, 8 miles north of Rustenburg.

[1] "Erläut. Bemerkungen zur Rostenkarte von Lydenburg," etc., p. 49; Hamburg, 1875.
[2] Phil. Magazine, 1879, p. 135.
[3] Bericht über die XVI^te^ Versammlung des Oberrh. Geol. Vereins zu Lahr, 29 März, 1883.
[4] G. Dahms, "Gabbro der Zwaartkoppies," etc.: Neues Jahrb. für Mineralogie, etc., Beil. Band vii (1891), p. 91.
[5] Ibid., p. 124.
[6] "Beitrag zur Geologie der Umgegend der Goldfelder a. d. Hoogeveld i. d. S. A. Republik": Neues Jahrb. für Mineralogie, etc., Beil. Band ix (1894), p. 264.
[7] Loc. cit., p. 286.
[8] Loc. cit., p. 220.
[9] "Über das Vorkommen und Gewinnung der nutzbaren Mineralien in der Süd Afrikanischen Republik," 1894, p. 57.
[10] F. H. Hatch, "A Geological Survey of the Witwatersrand and the Districts of the Southern Transvaal": Quart. Journ. Geol. Soc., vol. liv (1898), p. 76.

Cohen[1] also described a Quartz-Diabase free from olivine, from Colesberg, Cape Colony, containing diallage-like augite and primary micropegmatite.

The majority of these rocks contain no olivine. They weather with difficulty, the mineral constituents in hand-specimens taken from rounded boulders or exposed outcrops being nearly always quite fresh. The weathered surface is roughed by protruding grains of the less easily decomposed pyroxenic constituent, and coloured brown by a thin coating of iron-oxides, which result from the decomposition of the ferruginous pyroxenes.

The rocks herein described may be added to the above list of occurrences.

In dealing with the much discussed gabbro family, the following prefatory remarks may not be out of place:—The question as to whether the so-called "diallage" shall be regarded as an independent member of the pyroxene group, or whether the name "diallage" shall be extirpated, and the so-named mineral be simply called Augite, has often been debated by many eminent mineralogists and geologists, e.g., Zirkel, Judd, Rosenbusch, Hintze, Irving, Molengraaff, and others, and therefore may not be gone into in detail here. Zirkel maintains that there is every reason why the mineral should retain its distinctive name, because of its characteristic leafy structure, and its occurrence in rocks of very marked character. Judd[2] remarks that the diallage is probably only a plutonic form of the common augite, the characteristic structure and inclusions along the so-called "solution planes" being caused by chemical action and pressure. Hintze, again, in his new extensive Mineralogy,[3] after giving a short history of diallage, dismisses the matter very summarily, and does not treat the diallage as an independent member of the augite series. He considers the name "diallage" to be superfluous, and comments upon the subject thus:—"However, it is more natural to reject every appearance of independence for the 'diallage,' and only to establish the fact that the lamellar structure, which is rendered possible by the nature of the gliding planes after a (100), in the pyroxenes of the gabbros (and in other rocks characterized by the diallage) has attained a very high degree of perfection; at all events, one may speak of a 'diallage-like structure,' by which the etymological meaning of Haüy's old name of 'diallage' also retains its validity." Irving,[4] in his investigations on the gabbros of Lake Superior, in a footnote observes that "the distinction between diallage and augite is a valueless one, since not only are both found

[1] E. Cohen, "Geognostisch-petrographische Skizzen aus Süd Afrika": Neues Jahrb. für Mineralogie, etc., Beil. Band v (1887), p. 236.

[2] J. W. Judd, "The Secondary Rocks of Scotland" (Second Paper): Quart. Journ. Geol. Soc., vol. xxx (1874), p. 237. Also, "On the Tertiary and older Peridotites of Scotland": Quart. Journ. Geol. Soc., vol. xli (1885), pp. 379, 385, 387, and 408.

[3] Dr. C. Hintze, "Handbuch der Mineralogie," 1893, p. 1,032.

[4] R. D. Irving, "The Copper-bearing Rocks of Lake Superior": United States Geological Survey, Washington, 1883, p. 36.

in the same section, but every gradation is found in the rocks of this class, from augite to diallage." Again, Molengraaff,[1] referring to the monoclinic pyroxene constituents of some South African gabbros examined by him, says: "As soon as one demands a leaf-like structure, i.e. a parting after $\infty \breve{P} \infty$ (100), as the *conditio sine quâ non* for diallage, it will be impossible to designate this augite as diallage; however, in this case one will be compelled at least to speak of a *diallage-like augite*, in that a striation caused by a leaf-like structure after OP (001), present in these pyroxenes, is not totally absent in normal diallage, and the other characteristics, e.g. habit and colour, agree with those of diallage."

Molengraaff's remarks also apply to most of the diallage-like augites in the rocks described in this paper. It has, however, been found that, in many cases, the striation after OP (001) is caused by lamellar mutual intergrowth of diallage and hypersthene, parallel to the above-mentioned plane, as, for instance, in some of the Zwaartkoppies norites. If diallage be regarded as a monoclinic pyroxene characterized by lamellar or leaf-like structure parallel to any pinacoidal plane, and by the characteristic inclusions, together with the brassy metalloid lustre of the rhombic pyroxenes, then these pyroxenes may be termed diallage; but if any one of the above qualities be not present, Molengraaff's term diallage like augites should be used: in the latter case other authors would perhaps call them only augites.

However, without insisting upon its mineralogical independence by the use of this nomenclature, in order to avoid lengthy and tedious descriptions, these diallage-like augites will all be here shortly termed *diallage*. These norites and gabbros consist of a heavy plagioclase with high extinction, and usually two, but sometimes three, varieties of pyroxene.

The separation of the most interesting minerals of these rocks, i.e. the two principal pyroxenes, was a most tedious operation, which caused much loss of time, as both of the pyroxenes were almost non-magnetic, and very heavy, with a specific gravity greater than that of the most commonly used heavy solutions, such as Thoulet's solution or methylene iodide, the latter difficulty being increased in that the two minerals in question differ only slightly from one another in specific gravity, coupled by the fact that both pyroxenes are very intimately intergrown. Thus, after unsuccessful results attending the trials at separation by means of the Thoulet's solution and methylene iodide, as well as by means of magnetism, the Klein's heavy solution had to be resorted to. The latter proved to be a very serviceable liquid in every way, notwithstanding its lesser mobility, which rendered the separation of minerals of almost equal specific gravities the most difficult, and precluded the use of fine grains or powder of the mineral substance. The Klein's solution attains

[1] Loc. cit., p. 287.

a specific gravity of 3·36 at ordinary temperatures, but may be concentrated up to 3·6 in a higher temperature, about 70° C. As in some cases both the pyroxenes possessed a specific gravity greater than 3·36, they could be separated from one another only in a warm concentrated solution, kept at an even temperature, which is very troublesome to work with.

Naturally, in dealing with such intimately intergrown minerals, one could only make use of a very small percentage of the separated diallage or hypersthene for the analyses, namely, only the purest pleochroic hypersthene, and non-pleochroic diallage grains which possessed the extremes of specific gravity. The great bulk of the pyroxenes, which had a medium specific gravity, were of necessity rejected, being in an intimately intergrown condition, since the complete separation of both constituents would be only possible after fine pulverization. In this minute condition the minerals are nearly inseparable in Klein's heavy solution, since the latter is more or less viscous at high temperatures, and in a very concentrated condition.

References to special geological and petrographical literature, consulted by the author, will be given in footnotes where necessary, so that no special mention need be made here of the same.

The geographical distribution of these rocks has been chosen as the order of description, as it proves to be the most feasible method, and the various occurrences will be considered, starting from the east end of the Zwaartkoppies and proceeding in a westerly direction to Marico District.

II.

SPECIAL GEOLOGICAL AND PETROGRAPHICAL DESCRIPTIONS.

THE ZWAARTKOPPIES NORITES.

Professor E. Cohen, of Greifswald, has already described the occurrence of the "Gabbros" of the Zwaartkoppies, and their relations to the nepheline-syenite of the Rustenburg District. A free translation reads as follows[1]:—

"Somewhat northward of the Magaliesberg hills, which strike through the middle Transvaal in an approximately E.–W. direction from Pretoria across Rustenburg, runs a second chain of hills, the

[1] See Bericht über die XVI^te Versammlung des Oberrh. Geol. Vereins zu Lahr am 29 März, 1883, Stuttgart. Also, E. A. Wülfing, "Untersuchung eines Nephelin-syenit aus dem mittleren Transvaal, Süd Afrika": Neues Jahrb. für Mineralogie, etc., Band ii (1888), p. 16.