It comes under the heading pyrope; probably is pyrope.

The specific gravity, colour, analysis, and the mode of occurrence all agree with pyrope. The specimen is pyrope.

This method may be faulty, but it is given in detail, as a charge of "recklessly ignoring" is one not often heard in scientific circles. It will be for others to judge if the above process smacks of recklessness. I would conclude by saying that I value highly the privilege and right of every member of our Society to criticise papers placed before the members. But criticism of the kind to which I have now replied, surely goes beyond that limit of dispassionate and courteous treatment which we have all a right to expect.

SILL STRUCTURE AND FOSSILS IN ERUPTIVE ROCKS IN NEW SOUTH WALES.

By Professor T. W. EDGEWORTH DAVID, B.A., F.G.S.

[*Read before the Royal Society of N. S. Wales, November 4, 1896.*]

Introductory.—Sill structure has long been known to play an important part in the architecture of the earth's crust. The development, however, of sill structure in New South Wales is so wonderfully extensive and complex as to justify a special description, inasmuch as it promises to revolutionize prevalent ideas, at all events in Australia, as to the nature of the junction line between eruptive rocks and sedimentary rocks, and satisfactorily explains the apparent anomaly of the occurrence of fossils in eruptive rocks. I propose therefore to offer a short preliminary note on this subject.

Bibliography.—Professor Judd has described sill structure in the Mesozoic rocks of Scotland.[1] Reyer has described in detail

[1] "On the Ancient Volcanoes of the Hebrides and the Relations of their Products to the Mesozoic Strata.—Quart. Journ. Geol. Soc. 1874, XXX., p. 220 - 300, pl. xxii. - xxiii., and Abstract in 1878, Vol. XXXIV., pl. xxxi.

the extensive sills of Mount Venda in the Euganean Hills.[1] G. V. Rath and others have at an earlier date described the same district.[2] Topley and Lebour have described the Whin sill of Northumberland, which may be taken as the type of a sill on a large scale.[3] According to the description given by the above authors the Whin sill covers an area of from one hundred and twenty to one hundred and thirty Km., and attains a thickness of eighty-four feet and upwards. It cuts obliquely across the planes of bedding, so that it has a vertical range of over 1,700 feet. Sir A. Geikie has described the extensive sills of the Western Isles of Scotland.[4]

In Australia Mr. E. F. Pittman has described some interesting rocks from Hill End, which from their close resemblance to the Mandurama and Tamworth rocks of this Colony, as regards mode of occurrence, I have no hesitation in classing as sills.[5] He says, (*op. cit.* pp. 1—2), "The siliceous slates and sandstones appear to be quite unfossiliferous, but obscure impressions of spirifera, encrinites, and corals (*Favosites*) are rather plentiful in the metamorphosed conglomerates. This latter rock forms one of the most noticeable features of the district. In the physical peculiarities of its occurrence it somewhat resembles the diorites which are characteristic of the neighbouring gold-fields of the upper Turon (Sofala), standing out on the hill tops in huge rounded masses, and showing a somewhat bomb-like or concretionary structure when quarried. Here, however, the similarity ends, for the Hill End rock, on close inspection, is found to be free from hornblende, and consists of quartz and felspar crystals in a blue silico-felspathic

1 Die Euganäen, Bau und Geschichte eines Vulcans, 8° 1877.

2 Geognostische Mittheil. über die Euganäischen Berge bei Padua, Zeitschr. Deutch. Geol. Ges. 1864, XVI., S. 461 - Taf. XV. - XVI.

3 On the Intrusive Character of the Whin Sill of Northumberland.—Quart. Journ. Geol. Soc. 1877, XXXIII., pp. 406 - 421.

4 Trans. Roy. Soc. Edinburgh (1888) Vol. XXXV., p. 111, and Q.J.G.S., Vol. LII., 1896, p. pp. 373 - 381.

5 Annual Report Department of Mines, Sydney, 1879. Notes to accompany Geological Map of Hill End and Tambaroora.

matrix, while indistinct outlines of large pebbles of slate and sandstone clearly point to the fact that it is an altered sedimentary rock, the rearrangement of the particles with the production of the crystals of felspar and quartz being due partly to chemical action, and partly to heat and pressure caused by the shrinkage of the earth's crust."

Mr. C. S. Wilkinson, the late Government Geologist of New South Wales, was inclined to consider crystalline rocks, such as those of Hill End, which contained distinct traces of pebbles as being highly metamorphosed conglomerates, and the comparative absence of metamorphism from the fine grained strata between these pebbly crystalline rocks he considered was due to selective metamorphism. These views he explained to me in the field when we examined the tin-bearing quartz-porphyries of New England, at Emmaville in 1883. Quartz-porphyries were observed by us at Rose Valley and elsewhere near Emmaville to contain water-worn pebbles of other rocks scattered throughout them. The line of strike of the pebbles cuts somewhat obliquely across the trend of the dyke or sill of quartz-porphry, and, on tracing it beyond the limits of the sill, we found that in either direction it passed into a typical conglomerate, the pebbles of which were set in a sedimentary base instead of a base of quartz-porphyry. It did not escape the eye of so keen an observer as Mr. Wilkinson, that selective metamorphism was incapable of explaining all these phenomena, and he directed my attention specially to further investigating this point when studying the geology of the Vegetable Creek district. I was, however, unable to obtain a satisfactory explanation until the year 1890, when a clue was given by the geological structure of the Junction Gold Mines near Mandurama, N. S. Wales, examined by me in that year. A note on the remarkable structure of the eruptive rocks at the above gold mine was contributed by me at the time to the Linnean Society of N. S. Wales.[1]

[1] Proc. Linn. Soc. N. S. Wales, (Series 2nd) Vol. v., pp. 421 – 424.

The structure of the dioritic rocks of that neighbourhood described by me at that time as that of laccolites might, I now think, be more appropriately termed sill structure. A magnificent section illustrative of sill structure is exposed at "The Falls" above the Junction Mine, where a large dyke of diorite may be seen to have intersected the claystones almost vertically, and to have injected them, parallel or almost parallel to the planes of bedding, with sheets of rock from one-eighth of an inch to about twenty feet in thickness, and considerably over one hundred yards in length.

The following passage from my former paper describes the Mandurama sills:—"At first sight the precipitous hill side here appears to be composed of alternate beds of eruptive rock and altered sedimentary strata, at first mistaken by the author for a volcanic series of lavas alternating with fine tuffs. A closer examination, however, convinced Mr. Stonier and the author that these apparent beds were in reality intrusive laccolites, as evidenced by the slightly intrusive character of the junction line of their upper and under surfaces with the sedimentaries, their unbroken continuity with the diorite of the large dyke, the abundance of hornblende in them, and lastly the development of small light grey spots in the claystones near the point of contact, due probably to the formation of chiastolite. In places the laccolites have brought about a partial solution or fusion of the intruded sedimentaries, and where they pass into the so-called ore beds the author thinks they have intruded and replaced probably beds of limestone, absorbing into themselves the lime so as to form a type of rock of an ultra-basic character, for which perhaps the term *Manduramite* may be suggested."

The limestone at a neighbouring locality, on Mr. Rothery's Run, as I was informed by the late Professor Stephens, contains *Pentamerus*, and is therefore of Silurian or of Devonian age.

When the Australasian Association for the Advancement of Science met at Hobart in January, 1892, it was the opinion of Captain Hutton and some of the other members, including myself, that the gigantic masses of gabbro which are so extensively developed along the estuary of the Derwent, as well as along the south-east coast, including Freycinet's Peninsula, are in reality sills rather than old lava flows, as was formerly contended by some. Their intrusive character had been ably argued for previously by Mr. T. Stephens, F.G.S. A subsequent examination has convinced me that the bulk of these gabbro rocks, such as those which form the fine headlands of Cape Pillar and Cape Raoul, as well as Mount Wellington, are sills. The intrusive mass at Mount Wellington might perhaps by some be termed a laccolite on account of its great size.

During a recent visit to Tamworth, in company with Mr. Donald Porter, I examined several sections near the town and at Moore Creek. The intricate way in which granite sills are there intercalated between the planes of bedding of the sedimentary rocks, if it does not baffle description, certainly baffles mapping. A zone of sills about five miles in width girdles the intrusive granite. The zone is composed of sedimentary rocks alternating with sills. The sedimentary rocks are of Devonian or possibly Silurian age, altered at their line of contact with the main boss of granite into garnet and chlorite rocks. These pass into an outer zone of chiastolitic rock. The latter is succeeded by fine grained claystones, converted by the sills into chert and jasper, and by the thin radiolarian limestones with the coralline limestones of Moore Creek, from one hundred to about 1,000 feet in thickness.

The sills in this outermost zone are from a fraction of an inch up to several yards in thickness, and alternate so regularly with the claystones and radiolarian cherts and limestones that it is difficult to believe that the eruptive rocks are not interbedded. The whole zone for several thousands of feet in thickness is half sill half sediment. A careful examination of the sills shows that they trespass slightly across the planes of bedding of the sedimentary rocks, and the latter along their planes of contact with the sills, both above and below, show evidence of contact metamorphism with development of white spots due probably to formations of chiastolitic minerals. The thin sills, from one-eighth of an inch up to about one foot, are greenish-grey in appearance, resembling quartz-diorites. The thicker sills, from over a foot up to several yards thick, have a more definite granitic aspect. In places where the sills have partly replaced fossiliferous crinoidal limestones, casts of the crinoid stems may be distinctly discerned in the granitic base of the sill. This obviously is the correct explanation of the apparent anomaly of the occurrence of fossils in the eruptive rocks at Hill End.

The occurence of waterworn pebbles in the sills at the above locality and also at Emmaville is, I now think, undoubtedly due to the same cause. The sills of fine grained granite and quartz-porphyry have, when intruding the conglomerates, dissolved and assimilated the base of the conglomerates, but have not been able to digest the less soluble pebbles. This is the origin of the zone of waterworn pebbles, at Rose Valley, Emmaville, striking obliquely across the large quartz-porphyry dyke, and passing in either direction, as soon as it leaves the dyke, into a typical sedimentary conglomerate. I would further suggest that the granitic bosses of New England etc. are laccolitic in shape rather than conical. If they were conical it is hard to understand why they should not have had strength enough to uplift Lower Silurian, Cambrian, and Pre-Cambrian rocks, which would have subsequently been exposed at the surface through denudation. As a matter of fact the oldest sedimentary rocks in contact with the New England granite appear to be Upper Silurian. On the laccolitic hypothesis the absence of rocks older than Upper Silurian around the granite can be explained. Immense volumes of granite may have been squeezed through comparatively small punctures in the Pre-Silurian crust, so that the lifting power of the granite on the rocks forming the sides of these relatively small well-holes would be far less than it would be around the periphery of a cone, the area of the base of which would considerably exceed the area near the summit of the cone exposed by denudation at the earth's surface.