On the occurrence of Bornite nodules in shale from Mashonaland.

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ABOUT the middle of 1911, I was commissioned to report on a copper mine known as the Umkondo, situated in the south-east of Mashonaland, the eastern province of the territory of Southern Rhodesia. The mine is in a very out-of-the-way spot, about 120 miles from Odzi station, the nearest point on the railway, and to reach it took five days of somewhat rough travelling by cart.

Although this mine was known to be in a sedimentary area and not amongst the Archaean and granitic rocks, which cover much the greater part of Rhodesia, there was no precise information available as to the geological relations of the ore deposit or the characters of the enclosing rocks. I had, however, formed the opinion[1], based chiefly on a few specimens I had seen, that the rocks were of the same age as the Waterberg series of the Transvaal. This view was amply confirmed during the journey to the mine. Apart from two short breaks where the underlying and older granite was exposed in the valleys of the Sabi and Devuli rivers, the beds for a distance of about sixty miles before reaching the Umkondo comprised a series of sandstones or quartzites above, with a shale series below, and, curiously enough, a basal limestone. The last is not apparently known in the Transvaal, but the lithological characters of the other beds are so closely similar, even in detail, to what is described of the Transvaal Waterberg series as to leave little doubt of the correctness of the correlation. An outlier of the coal series unconformably resting upon the older beds was also passed on the way. It may be noted that by some authorities the Waterberg sandstones are

[1] Science in South Africa, 1905; Quart. Journ. Geol. Soc., 1910, vol. lxvi, p. 368.

correlated with the Table Mountain sandstone of the Cape. If so, the beds are Silurian, or possibly in part Lower Devonian. This view is not, however, accepted by the Cape geologists, and they may be older still. They preserve, however, a quite unaltered appearance and have not been affected by any marked folding, crushing, or shearing.

At the Umkondo mine there are good exposures of the quartzites along the edges of the ancient workings, which are extremely large, as well as on the ridge to the south-west of the mine. They dip at a small angle (about 15°) to the north-east and have a rough jointing along the bedding which breaks them into slabs six inches to a foot in thickness. On the kopjes there is often a curious cellular weathering, the surface of the rock being covered with small hemispherical depressions. These evidently originate from the decay of large calcite grains, of which the glittering cleavage planes can be seen among the cementing material on fresh surfaces of the rock. False bedding is indicated in one or two places. Beautiful examples of ripple-marking can also be seen on some of the bedding planes. Though nowhere seen on the surface, it appears that in the flats at the foot of the quartzite ridge, as shown by the mine workings, there are shales which overlie the quartzites. These shales have at their base a remarkable bed which forms the ore body of the mine. It is finely laminated and some of the layers are of a reddish colour which gives it a distinctive aspect. Through it are scattered nodules of copper-bearing minerals, which vary in size from a pea up to several inches across. In the oxidized zone these consist of carbonates, which may also be seen in cracks in the sandstone, chessylite being especially prominent. Below water-level the carbonates are replaced by bornite, from the alteration of which they originated and which occurs to the exclusion of any other sulphide.

The ore body thus possesses unique characteristics and the origin of the nodules presents an interesting problem. It does not seem at all probable that they can be regarded as primary, and yet they have quite the appearance of concretions of pyrites such as are often found in clays or shales, for instance in the London clay of the Kent coast. It is perhaps most reasonable to look upon them as being replacements of original nodules of pyrites; and their external characters distinctly support this presumption. When separated from their matrix some of them show the projecting edges of good-sized cubical crystals. Bornite itself crystallizes in the regular system and is of cubic habit, but it is very rarely found in crystals, and then only in cavities where it has had every opportunity of crystallizing freely; moreover, the individuals are generally small and

occur in extremely confused aggregates from which their edges and corners project in all directions. The view, therefore, that the large cubes seen in the present instance are to be regarded as pseudomorphs after pyrites seems to have much in its favour.

Before concluding, it is worth noting that the shales associated with the ore-bed sometimes show well-marked pseudomorphs after cubical crystals of salt. Some of these are very sharply defined and have the usual hollow faces; others again are small and indistinct. The largest crystal I noticed had an edge of over half an inch long, but a more usual size is between one-eighth and one quarter of an inch. These pseudomorphs are of interest in view of the numerous native workings for salt in the Sabi valley, which are no doubt to be accounted for by the residuum left in these beds after the abstraction of the much larger amount represented by the pseudomorphs. These, it may be mentioned, are the first to be discovered, as far as I am aware, in any South African rocks. Their occurrence possesses a further interest from the fact that we have among the European Trias, where also salt and salt pseudomorphs are found, deposits of copper ore which occur distributed through particular beds of the Lower Keuper just as the bornite does in the much older shales of south-eastern Mashonaland.