ART. XX.—*On the Mineralization of the Gold-bearing Lode of Passagem, Minas Geraes, Brazil*; by ORVILLE A. DERBY.

IN an article published in the *Zeitschrift für praktische Geologie* for Oct., 1898, on the gold-bearing lode of the Passagem mine near Ouro Preto, State of Minas Geraes, Brazil, Dr. Eugene Hussak concluded from a detailed mineralogical and petrographical study of the contents of the lode and of the immediately adjacent portions of the country rock, that it is of eruptive origin representing the ultra-acid phase of a pegmatitic apophysis from a neighboring mass of granite. Since the lode is, in all essential respects, a typical quartz-pyrite one, this conclusion has attracted considerable attention on account of its bearing on the general question of the genesis of ore-bearing bodies of this character.

With regard to the metalliferous portion of the lode (the ore proper, consisting of a mixture in varying proportions of arsenical, magnetic and common pyrites with traces of various other sulphides, associated with a large amount of tourmaline) Hussak expressed somewhat reservedly the opinion that it should be classed among the primary constituents of the lode. This opinion was based on the constant and characteristic association of the metallic sulphides with the tourmaline, which was regarded as a contact mineral and thus practically contemporaneous with the intrusion of the granitic apophysis. A fine suite of specimens recently presented to the Geological Service of Brazil by Mr. Arthur J. Bensusan, the able superintendent of the mine who is always on the alert for new developments that promise to be of scientific interest, suggested the hypothesis that the lode might possibly have become mineralized by an introduction of sulphides and tourmaline subsequent to its formation; and to gather additional evidence on this important point, an examination *in situ* of a recently opened section of the mine that revealed certain features not hitherto observed, was made by Mr. Jorge Ferraz of the staff of the Geological Service.

A drift now being driven through sterile quartz in search of an ore shoot, begins to show on one of the walls and in the heading a beginning of mineralization in the form of small patches and streaks of massive tourmalinized quartz accompanied by a small amount of arsenopyrite, and at the same time a porphyritic appearance due to isolated polyhedral inclusions of a greenish mineral sharply defined in a white or black groundmass according as they occur in the sterile or in the

mineralized portion of the lode. The occurrence (see fig. 2), in the broken-down material, of pieces of stratified quartzite shows that the wall of the drift must be in close proximity to the contact of the lode with the country rock, although the plane of contact is not yet clearly exposed in the working. This circumstance suggests that the inclusions may possibly represent a contact mineral developed locally in the marginal zone of the lode, rather than an original constituent, but for the purpose of the present study this question is immaterial.

The accompanying figures present, about half natural size, four of the most significant slabs of the lode rock that came to

FIG. 1.

hand. No 1 is a mass of typical glassy vein quartz studded with inclusions which in part show sharp cut crystalline outlines, while fig. 2 shows a corresponding part in the central zone (B), flanked on one side by a zone (A) of country rock and on the other by a zone (C) of highly tourmalinized quartz with a certain admixture of pyrites.

The inclusions consist of sericitic mica, in place quite coarsely crystalline, in milky white flakes (as in the central and left portions of the one at the middle of the lower border of fig. 1), but for the part in cryptocrystalline masses of a light greenish color. In places the characteristic luster and cleavage of an original feldspathic mineral are preserved, but for

the most part even in these cases the microscope reveals only a micaceous aggregate which treatment with the acid shows to be heavily charged with calcite. A single inclusion only (3 in fig. 2) amongst the score or more examined retains the feldspar substance in a sufficiently fresh condition to permit of a satisfactory microscopic and chemical examination. The microscopic sections show in great perfection the characteristic twinning bands of a plagioclase feldspar with an extinction angle indicative of a nearly normal oligoclase, and an approximate analysis confirms this reference, as does also the external

FIG. 2.

form, since with careful work many of these inclusions can be completely detached from the matrix in ideally sharp-cut crystals.

These inclusions are, therefore, original feldspars that have become sericitized by some agency that has reached them through an apparently impervious involucre of dense vein quartz. In their immediate vicinity the quartz shows fissures large and small, filled with tourmaline and pyrites which have evidently been introduced by solutions, or gases, carrying boron, sulphur and arsenic along with iron and, rarely, gold, silver, copper, bismuth, lead and probably tellurium. A relation between the two phenomena of the sericitization of the feldspar and the mineralization of the lode, with boron and sulphur compounds, is at once suggested and fortunately definite evidence on this point is at hand.

The almost absolutely fresh feldspar crystal (3) in fig. 2 lying in the quartz band *B* is, on the face photographed, completely surrounded with quartz free from tourmaline and pyrite, in a zone of the width of two centimeters or more, while at the back of the block scattered crystals of these minerals can be traced up to its margin, and here a portion of the crystal shows incipient sericitization. Its neighbor 2 is still comparatively fresh, while 1, which abuts directly on a strongly mineralized part of zone *C*, is so completely altered that all traces of the original cleavages have been obliterated. In many cases it is clear that the mineralizing agent has only

FIG. 3.

reached one face of the feldspar crystal and that this contact has been sufficient to effect the alteration of the latter. This is well shown in fig. 1 in the case of the two grouped crystals at the middle of the upper margin in which narrow bands of pyrites (distinctly seen in photograph) are interposed between the two feldspar individuals and between the left-hand one and the quartz, while at the right the contact between the quartz and the inclusion is perfect. All the other inclusions on this slab show the same phenomena of a narrow, almost linear, mineralized strip (with pyrite predominant over tourmaline) along one face and a sharp cut contact with the quartz on the others. Evidently the mineralizing agent entered through small fissures which, on meeting a feldspar crystal, passed along one of its faces, which, in the case of all those shown in fig. 1, was always on the same (left) side.

The specimen represented in fig. 3 exhibits some other phases of the mineralization process. The fissures of the fractured quartz-feldspar rock are here of considerable width and the filling is exclusively of tourmaline with only here and there a small isolated crystal of pyrite, of which not more than a dozen can be counted on the considerable surface here shown. The feldspar is completely sericitized and it is thus clear that this effect was produced by the agent that introduced the tourmaline rather than the one that brought in the metallic sulphides. It is also evident that two distinct agents were involved and that, in places at least, these acted quite independently one from the other. In the lower part of this specimen

FIG. 4.

the tourmaline has a small admixture of granular quartz giving a friable *tourmalinfels* with a slight development of a schistose structure. Elsewhere on this and the other specimens figured, the vein quartz is impregnated with tourmaline, giving, as Hussak has already remarked, a massive rock resembling the luxullianite of Cornwall.

The block of ore represented in fig. 4 shows a mass of distinctly schistose *tourmalinfels* charged with arsenopyrite (white in the figure) which clearly fills fractures along planes of schistosity, and across the intervening plates of rock. This case completes the evidence, suggested by figs. 2 and 3, of the independence of the tourmalinization and the sulphurization of the original vein rock, and shows that the former process preceded the latter. Other specimens showing larger fissures filled with a somewhat spongy mass of a granular arsenopyrite have scattered needles of tourmaline with every appearance of having been formed *in situ*, so that it is tolerably certain

that the sulphide invasion took place before the complete cessation of the formation of tourmaline.

A partial analysis of one of the sericitic masses, made with the view of determining the constituents that cannot be referred to the original feldspar crystal, gave 4.14% of combined water, 4.1% of carbonic acid (combined with lime as calcite) and distinct traces of fluorine, and it is thus evident that these elements played a part in the tourmalinization of the original pegmatitic vein and in the alteration of its feldspathic contents.

The Passagem lode thus presents evidence of three distinct processes of filling, and the succession of events in its formation may be summarized as follows:

First—An extensive fissure opened by stress along (above, below and across) a bed of brittle rock (quartzite) enclosed between more tenacious schists, was closed by an invasion of pegmatite running off into clear quartz. At this stage the lode contained only the minerals characteristic of a granite magma such as is represented in the neighborhood by a boss of granite; or, possibly, some others that may have been formed near the contact through reactions with the country rock.

Second—A subsequent stress, acting in substantially the same place and manner as the first, fractured this pegmatitic quartz, rendering it accessible to a pneumatolitic action characterized by silica, boron, water vapor, carbonic acid and fluorine ("after effect" of the granitic eruption?), which filled its fissures with tourmaline, sericitized the feldspar of the pegmatite wherever fissures, often quite minute, permitted access to it, and probably produced the characteristic contact phenomena noted by Hussak.

Third—A third stress, coming near the end of the second phase of the lode, fractured the tourmaline filling and gave access to a pneumatolitic action characterized by sulphur, arsenic, metallic oxides and metals (gold and silver), which filled the fissures of the lode, invading to some extent its pre-existing portions, and probably also some of the adjacent and enclosed country rock.