On Certain New Mineral Species associated with Carnotite in the Radio-Active Ore Body near Olary.

By D. Mawson, B.E., B.Sc.

[Read September 4, 1906.]

Introduction.

The occurrence of carnotite, a vanadate of uranium and potassium, was reported by Mr. Chapman, the Government Analyst, as a filmy coating in the crevices of a sample of ore sent to him for analysis. As the yellow powder was scarce his determination rested on qualitative investigation only, but was substantiated by physical tests made by Professor Bragg, who demonstrated its high radio-activity. This information was made public in the daily press of May 3 last.

The same day Mr. H. Y. L. Brown, the Government Geologist, visited the locality of the find, Radium Hill,* situated 24 miles in a direct line east-south-east of Olary, and 1½ miles south-south-west of Teesdale's Dam. In the Adelaide press of May 5 appeared a short report made by him on return to the city.

Mr. H. G. Stokes, after a visit to the field, made comments through the press of May 9, doubting the correctness of the mineral determinations.

Extracts from the final official report appeared in the *Advertiser* of May 16, in which announcements were made by the Government Geologist and Government Analyst, and by Mr. G. A. Goyder, Public Analyst. In this report the Government Geologist, suspecting that the carnotite originated as a decomposition product, states:—"It appears most probable that it has been derived from the solution and redeposition of other uranium compounds below, and that, therefore, such ores, in addition, will be found by exploitation in depth." Both analysts reported the yellow compound to be probably carnotite. Magnetite and magnetic titanic iron were reported; also gummite.

Only within the last month have representative samples been obtained at the University. Extreme variation in physical characters, exhibited by different portions of the black mineral, at once attracted attention. It was evident that instead of a single black constituent previously described as

* As this spot has so far remained unnamed, "Radium Hill" seems appropriate.

ilmenite or magnetic iron, five distinct varieties could be isolated. The high economic value of many such heavy black minerals attached additional interest to further investigation.

However, though iron and titanium could readily be detected by simple means, yet this was far from satisfying, as the variety of types could not be reconciled with known species. Added to this, the nature of the occurrence and the ore itself were suggestive of the presence of minerals of a rare type.

At this stage it was highly desirable that careful chemical analyses be made. The laborious work, rendered specially difficult by the presence of an excessively high percentage of titania, was undertaken by Professor Rennie and Dr. Cooke, with results as stated in the succeeding paper.

Mineralogical Notes.

The locality of the find was visited a fortnight ago, and the following observations made:—

On the original claim,* pegged out by Mr. A. J. Smith, there are several parallel veins, averaging a full two feet in width, and continuing in a direction N. 30° E. for a distance of several hundred yards. Altogether the ore has been traced for at least a quarter of a mile. The veins are nearly vertical, slightly underlying to the east, and run in the direction of the country; the latter is possibly Pre-Cambrian in age, and where best exposed is a metamorphic sandstone, in which mica flakes have been largely developed. In proximity to the lode, on either side, the mineralizing waters forming the vein-filling have metamorphosed the country, developing a selvage of solid black mica.

Basic dyke-like intrusions, many yards in width, have cut perpendicularly across the lode country in two places, respectively north and south of Smith's claim. These may have been introduced subsequently to the lode formation, though possibly contemporaneous and genetically connected with the ore bodies.

The outcrops of the lodes stand a few inches above the level ground, and are typically composed of heavy black minerals of somewhat varying types, and notable amounts of coarse black mica and highly-coloured vanadiferous decomposition products. In the case of the main lode a considerable bulk of quartz, usually tinted pinkish, occupies the central vein-filling. In it are occasional bunches of mica and sporadic masses of the heavy black minerals. The shoading of these latter minerals on the surface renders prospecting easy.

* The ground was originally taken up, expecting that the black mineral so abundant would prove to be wolfram or tin oxide.

The veins are all of the pegmatite class, and no doubt have their origin in some intrusive mass below. The most western reef is somewhat different from the others, being chiefly composed of micaceous hæmatite and quartz, with occasional copper stains, and no radio-active minerals have so far been detected in the outcrop. The main reef is about 60 yards further east, and has been opened to a depth of 15 feet. The vein matter is distributed in a roughly symmetrical arrangement. A massive mineral (1) with an uneven iron-black fracture and specific gravity, about 6, composes laminated zones some four inches wide next the walls. On analysis this proved to be chiefly composed of iron and titanium, though, as evidenced in the thin slice prepared for microscopic examinations, it is not homogeneous. The central portion of the reef is occupied by a more compact body of a brighter black mineral (2), with slightly less specific gravity; also accompanied by quartz and a varying quantity of black mica. Occasionally streaks, scattered grains, and cuboid crystals of a rarer black mineral (3), with specific gravity in the vicinity of 4, are observable, which, on account of its very brilliant lustre and glassy fracture, is readily distinguishable. These latter two minerals have been shown by Professor Rennie and Dr. Cooke to contain over 50 per cent. of titania, a large quantity of iron, and a notable amount of rare earths, uranium, vanadium, and chromium.

So far as can be judged at present, the brilliancy of lustre indicates increased percentage of titania chiefly, and to some extent rare earths. Several degrees of brilliance are shown by primary heavy black minerals of the general type of (2), and it is inferred that analysis will reveal a considerable diversity in chemical composition. The mineral (1) is likely to be to some extent an alteration of (2), the heterogeneity exhibited by it aiding in this conclusion. Type (3) is best developed in the main vein, at the contact with the siliceous central filling, and has all the appearance of having formed at a period after the reception of the main bulk of the ore body. In such situations it is also frequently met with crystallized, embedded in the quartz, or presenting idiomorphic faces in its direction. The quartzose gangue in the central portions of this lode contrasts noticeably with the titanium-rich iron minerals and micas forming the general filling, and indicates, at least an alteration in character of the contributing circulation. The inception of the new chemical and physical conditions accompanying this change in circulation has been to partially alter the mineral (2) near the contact, leaving two additional minerals in its place, one resembling micaceous iron (4), the other a dull brownish-black ferriferous mineral

(5); from the extracted matter, the bright black mineral (3) appears to have had its origin.

Another reef 10 yards to the east is characterized by consisting chiefly of the heavy black minerals and abundant mica. It has been opened to a depth of 18 feet.

Still further east is another reef, chiefly composed of the heavy black minerals and quartz.

The portions of the lodes exposed by development show ample stains of the lemon-yellow powdery substance determined by the Government Analyst to be *carnotite*. It is found coating the black minerals and insinuated into microscopic cracks. Undoubtedly this substance is of secondary origin, the field occurrence indicating a derivation by decomposition of some primary constituent of the ore body; no doubt the black minerals referred to above.

In one part of the main lode a secondary micaceous mineral of a bright green colour is rather abundant, and, as it re-acts strongly for vanadium, is no doubt *roscoelite*.

Just as recorded in the cases of the Colorado and Utah occurrences, a large variety of yellowish and greenish minerals in various shades, both amorphous and crystalline, are also met with in this material. Their very sparse development has, so far, not allowed of sufficient quantities being collected for analytical purposes.

The bright black mineral (3) is an entirely new type, though details are not yet available for complete description. We propose to name it *davidite*, after Professor T. W. E. David, of Sydney University, whose personal ability, wise counsel, and enthusiasm have done so much to further the interests of the science and economic application of geology in Australasia.

Conclusions.

Carnotite is known from one other locality only, namely, as scattered occurrences in a Mesozoic sandstone formation, distributed through an arid district comprising western Colorado and south-eastern Utah, in the United States of America. Roscoelite has been reported from three other localities only—Placerville, in Colorado, and neighbouring locality, and Placerville, in California, both in the United States of America,* and at the Boulder Mine, eastern Coolgardie, Western Australia.†

* "On Carnotite and Associated Vanadiferous Minerals in Western Colorado," by W. F. Hillebrand and F. L. Ransome, p. 9, Bull. No. 262, U.S.G.S.

"Vanadium and Uranium in South-Eastern Utah," by J. M. Boutwell, p. 200, Bull. No. 260, U.S.G.S.

† See W.A. Geol. Survey Reports.

The further association of these rare minerals at Radium Hill is of special interest. The only known occurrences of carnotite are with roscoelite and other vanadium minerals. The existence of mineral vanadates of uranium, such as carnotite, on theoretical grounds, should not be unexpected, as these elements have a powerful mutual precipitating action.

In the case of the American deposits, deposition has taken place in fissures, and as a replacement in a Mesozoic sandstone formation, evidently from percolating waters. The ore bodies are wholly of aqueous or secondary origin. The South Australian occurrence is the result of weathering of certain rare and new minerals in pegmatite veins traversing Pre-Cambrian strata. This latter occurrence is specially interesting, for the fact that the primary source of the uranium and vanadium can be ascertained.

A further and most notable fact is that the element vanadium was first discovered by Seffstrom in the titanic iron ore deposit of Taberg, south-west of Lake Wetter, in Sweden. The Taberg ore is characterized by the presence of 0·12 per cent. to 0·40 per cent. of vanadic acid. The ore stock has also in its field relations much in common with the Radium Hill lodes.*

No trace of gummite, as recorded in the official report, was noted in any of the lodes, and its occurrence is extremely doubtful.

Pegmatite lodes, of the character of those at Radium Hill, often carry tin and wolfram, though so far these substances have not been reported from the locality, and the absence of even traces of them in the analyses suggests that, likely, the ore body is a pegmatite of a basic rock, and that, in all probability, such minerals will be found entirely absent.

It may be mentioned that this type of ore deposit does not usually develop pitchblende, but uraniferous titanates, niobates, and tantatates, and thorium minerals may be expected.

Monazite is found in the same district, in the lode at the King's Bluff gold-mine, 28 miles north-west, which fact should stimulate local interest in quest of thorium minerals, and reinforce the possibilities of the thorium content of the Radium Hill ore.

This body of radio-active ore is, in the matter of quantity, much the most important yet discovered in Australasia. Its low grade, however, introduces serious difficulties to commercial enterprise in this direction. The high value of vanadium for hardening steel, and the fact that the titanium,

* See "The Nature of Ore Deposits," by Dr. R. Beck, trans. by W. H. Weed, p. 21, vol. i.

chromium, and uranium contents are utilized for the same purpose should induce a demand for the heavy black minerals for the manufacture of special steels.

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Preliminary Analytical Notes on the Minerals Described in the Preceding Paper.

By E. H. Rennie, M.A., D.Sc., and W. T. Cooke, D.Sc.

[Read September 4, 1906.]

At Mr. Mawson's suggestion, we have examined two of the minerals referred to by him in the previous paper. As regards the carnotite, we are so far able to confirm Mr. Chapman's results as to the presence in it of potassium, uranium, and vanadium, and we hope later to furnish quantitative details. As regards the dark-coloured mineral (No. 2 in previous paper), of which the carnotite appears to be a decomposition product, we have examined it qualitatively up to a certain point; but the difficulties of analysis are considerable, owing to the complex nature of the mineral. We have, however, ascertained that, in addition to titanic and ferric oxides, which are the chief constituents, there are present uranium, vanadium, cerium, and almost certainly thorium and other rare earths, traces of lime, and, we believe, also chromium and traces of manganese. The quantities of vanadium and chromium, however, if present, are very small, and in presence of uranium difficult to detect with certainty. As a result of this, and by reason of other matters which have occupied our time, we send these imperfect preliminary notes in the hope of being able at a future date to offer to the Society a more complete analysis.