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*On Carnotite and an associated mineral complex
from South Australia.*¹

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THIS paper gives the results of an investigation at the Imperial Institute of a carnotite-bearing specimen received from South Australia.

The material represented by the specimen is described by Mr. H. Y. L. Brown,² Government Geologist of South Australia, as occurring about 2 miles SSW. of Teesdale's dam and about 20 miles ESE. of Olary railway station.³ He remarks: 'The ore occurs as yellow and greenish-yellow incrustations and powder on the faces, joints, and cavities of a lode formation, which consists of magnetic titaniferous iron, magnetite, &c., and quartz in association with black mica (biotite) The outcrops traverse metamorphic gneissic micaceous granite and granite schist, into which dykes of granite and diorite have been intruded.'

During 1906, Mr. W. S. Chapman, analyst at the South Australian School of Mines, analysed a bulk sample of the lode-stuff and found that it contained 0.28 per cent. of uranium oxide (U_3O_8). The amount of the yellow incrustation collected is stated to have been insufficient for a complete analysis; but it was found to contain 60 per cent. of

¹ Communicated by permission of the Director of the Imperial Institute.

² H. Y. L. Brown, 'Record of the Mines of South Australia.' 4th Edition, Adelaide, 1908, p. 361.

³ The exact locality is referred to by Mr. Mawson (see below) as Radium Hill.

uranium oxide and a considerable amount of vanadic oxide, and it was inferred that the yellow incrustation consisted of the substance known as carnotite.

The material was subsequently examined by Mr. D. Mawson, Professor E. H. Rennie, and Dr. W. T. Cooke, of the Adelaide University. After a mineralogical examination of the lode-stuff, Mr. Mawson concluded that it contained several new minerals.¹ To one of these he gave the name 'davidite', after Professor T. W. Edgeworth David; the others he left unnamed pending the completion of the chemical analyses by Drs. Rennie and Cooke. The latter confirmed the identity of the carnotite, but were unable at the time to give quantitative analytical results for the supposed new minerals, though they hoped to do so at a later date.² The results stated by Mr. Mawson are quite inadequate for the purpose of establishing the existence of any new mineral in the lode-stuff; and no further results appear to have been published either by him or by Drs. Rennie and Cooke.

A massive block of the lode-stuff, weighing about 16 lb., has been examined by us. In a general way, it corresponds very closely with the Government Geologist's description already quoted. The bulk of the material consists of the ingredient referred to by him as 'magnetic titaniferous iron, magnetite, &c.', which on superficial examination gives one the impression that it is homogeneous, though here and there patches of rutile can be seen on its broken surfaces by examining closely with a pocket-lens. In lustre it is much duller than ilmenite, and in general appearance it approaches massive varieties of titaniferous magnetite; but certain small portions of the mass were observed to have the brilliant lustre of ordinary ilmenite. Coarse, irregular plates of biotite were present in scattered patches, and the block was bordered on one side by a layer of coarsely granular quartz.

The constituent described as carnotite was present in the small cracks and cavities of the block, but the total amount was very small. Ferruginous and earthy-looking decomposition products were also present, and the whole block had a brownish-red, much-weathered exterior.

The portions of the specimen specially examined by us were:—

(1) The carnotite.

¹ D. Mawson, 'On certain new mineral species associated with carnotite in the radio-active ore body near Olary.' *Trans. and Proc. Royal Society of South Australia*, 1906, vol. xxx, p. 188.

² E. H. Rennie and W. T. Cooke, 'Preliminary analytical notes on the minerals described in the preceding paper.' *Ibid.*, p. 193.

(2) The complex material which formed the bulk of the specimen, and which appeared from a preliminary mineralogical examination to consist essentially of an intimate admixture of ilmenite, rutile, and magnetite, the ilmenite predominating.

(1) THE CARNOTITE.

a. Chemical composition:—As no complete analysis had been made of the South Australian carnotite, it was considered advisable that this should be attempted, in order to ascertain if its identity could be fully established. For this purpose about 12 lb. of the lode-stuff was broken into coarse fragments, and as much as possible of the yellow powder collected. It was found impossible to collect sufficient in a clean state to carry out an analysis. The yellow crust was therefore scraped from the fragments, in order to obtain as much as possible. The amount thus obtained weighed about 0.9 gram; but it was very impure, containing a considerable amount of biotite, and other ingredients from the general mass, as well as some of the ferruginous and earthy-looking decomposition products already referred to as occurring in the cracks and cavities of the specimen. It was gently ignited, re-weighed, and then digested with dilute nitric acid, to dissolve the yellow powder. The amount thus dissolved was 0.22 gram, and it was on this that the analysis had to be made. The analysis of this soluble portion of the ignited yellow powder, &c., gave the following result:—

U_3O_8	...	47.8 per cent.
V_2O_5	...	16.8
P_2O_5	...	trace
Al_2O_3	...	5.7
Fe_2O_3	...	19.4
CaO	...	1.0
MgO	...	trace
K_2O	...	5.2
Na_2O	...	1.8
PbO	...	1.3

99.0

It may be assumed that the ferric oxide and alumina represent impurity scraped from the specimen along with the yellow crust. If we re-calculate on this assumption, allowing 5 per cent. of water, we get the following result; beside which is placed, for the purpose of com-

parison, a re-calculated analysis by Dr. W. F. Hillebrand on carnotite from Copper Prince claim, Roc Creek, Montrose Co., Colorado.¹

	South Australia.			Colorado.		
U ₃ O ₈	60.8	...	...	61.53 (UO ₃).
V ₂ O ₅	21.4	...	...	20.72
P ₂ O ₅	trace	...	...	0.90
CaO	1.3	...	...	3.03
BaO (SrO)	—	1.03
MgO	trace	...	...	0.25
K ₂ O	6.6	...	...	7.31
Na ₂ O	2.3	...	...	0.15
PbO	1.7	...	...	—
H ₂ O	5.0	...	...	5.08
			99.1			100.00

It is unfortunate that there was not sufficient of the South Australian yellow powder to enable a more complete and satisfactory analysis to be made. The analysis here given is an obviously imperfect one, but it is perhaps permissible to infer that a comparison of results such as that given above, establishes the chemical identity of the South Australian and Colorado carnotites. This inference is strengthened by the fact that Mr. Chapman, working on a fairly clean specimen of the South Australian yellow powder, found 60 per cent. of uranoso-uranic oxide (U₃O₈).

b. Physical characters.—The South Australian carnotite has in part a powdery consistency, and when clean appears to have a canary-yellow colour. When highly magnified under the microscope, the powder is seen to consist of innumerable, very small, four-sided crystal-plates and platy aggregates, which are more or less transparent, and of a fine yellow colour. The platy crystals forming the loose yellow powder observed in the cavities were of variable size, some of them being about 0.03 mm. across; but the average length and width observed was well below 0.01 mm. These plates are rhombic in shape, and have well-defined edges. Some have grown irregularly, but even when irregular in shape they usually show serrated edges, the angles of the serrations having the same values as those of the regular plates. The averages of numerous readings give 78° for the acute angles, and 102° for the obtuse angles of

¹ W. F. Hillebrand and F. L. Ransome, 'On carnotite and associated vanadiferous minerals in western Colorado.' Amer. Journ. Sci., 1900, ser. 4, vol. x, pp. 120-144; and Bull. United States Geol. Survey, 1905, No. 262, pp. 9-31.

the rhombic plates. The readings were made with a microscope having a fixed stage and rotating cross-wires, a $\frac{1}{12}$ inch oil-immersion objective being used. The plates show symmetrical extinction, the cross-wires bisecting the angles in the extinction position. (Fig. 1.)

In order to obtain if possible crystals large enough to give optical interference-figures in convergent light, a lump of the lode-stuff was partially crushed and treated magnetically to extract the ilmenite, biotite, magnetite, &c., which made up the bulk of the specimen. In this way a comparatively small portion of relatively non-magnetic residue was obtained; it consisted largely of rutile, but contained also

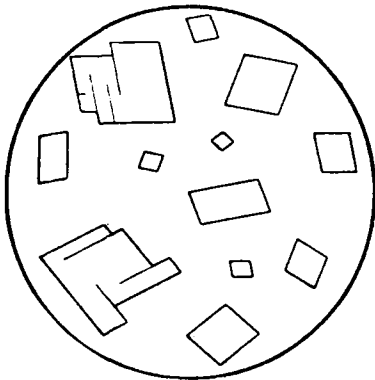


Fig. 1.

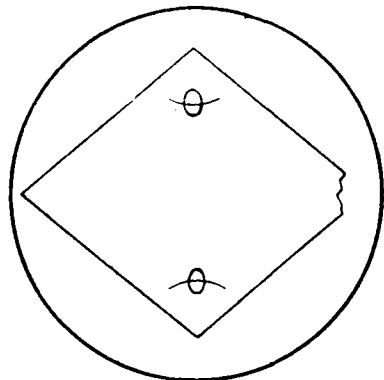


Fig. 2.

Tabular crystals of South Australian carnotite.

FIG. 1.—A portion of the yellow powder from one of the cavities. Magnified 800 diameters.

FIG. 2.—One of the larger crystals obtained by magnetic separation. Magnified 180 diameters.

a number of comparatively large rhombic plates (about 0.25 mm. across); the angles of these had the same average value as those of the smaller plates already described. When examined in convergent polarized light these show very good biaxial figures; the acute bisectrix emerging normal to the surfaces of the plates. The sign of the acute bisectrix, and therefore that of the crystal, is negative. The optic axial plane bisects the obtuse angles; and the value for $2E$, as indicated on a graduated eye-piece micrometer, appears to be approximately 90° . The plates show no appreciable pleochroism. Their birefringence effects are to some extent irregular, due to the presence of patches having an isotropic tendency. (Fig. 2.)

c. *Conclusions suggested by the chemical and physical characters of South Australian carnotite.*—A consideration of the above-mentioned facts concerning the South Australian carnotite leads to the conclusion that carnotite is essentially a definite mineral, as originally inferred by Messrs. C. Friedel and E. Cumenge,¹ and not to any serious extent a mixture of different minerals, as later inferred by Dr. Hillebrand.² Such a statement is perhaps rather sweeping, in face of the fact that the chemical evidence in the case of the South Australian carnotite is not very strong, while that adduced by Dr. Hillebrand with regard to the Colorado carnotite is of a high order of exactitude. Indeed it would not be justifiable apart from the fact that, in the Australian occurrence, we have for the first time carnotite which is wholly and definitely crystalline, and which permits of an examination of its physical characters. These physical characters are such as to indicate that carnotite is an orthorhombic mineral, probably with a basal cleavage,³ and that it belongs to the uranite group of minerals. Its chemical composition indicates that it is essentially a hydrous vanadate of uranium and potassium, as originally shown by Messrs. Friedel and Cumenge; and it may reasonably be regarded as the vanadium analogue of autunite (hydrous phosphate of uranium and calcium), the lime being in part or altogether replaced by alkali. The probability of the existence of a mineral vanadate corresponding to autunite, and the close correspondence in physical characters between autunite and South Australian carnotite, give strong support to this conclusion, notwithstanding the fact that the exact chemical composition of carnotite remains uncertain.

In this connexion it is worthy of note that a variation in the percentage of water, as proved by Dr. Hillebrand, is not peculiar to carnotite, but is also characteristic of autunite. The analyses of the latter mineral quoted by Dana show percentages of water varying from 16 to 22; and Sir A. H. Church⁴ has shown that as much as 14 per cent. of this water may be given off in dry air and *in vacuo*. Hence it may be inferred that these minerals are unstable as regards their degree of hydration, and that in them the water plays an uncertain rôle. In the same connexion, it may be noted that both autunite and

¹ C. Friedel and E. Cumenge, *Compt. Rend. Acad. Sci. Paris*, 1899, vol. cxxviii, p. 532; and *Bull. Soc. franç. Min.*, 1899, vol. xxii, pp. 26 and 26 *bis*.

² W. F. Hillebrand, *loc. cit.*

³ The birefringence effects at the margin of the splintered plates indicates abrupt stepping due to basal cleavage.

⁴ A. H. Church, 'On the composition of autunite.' *Journ. Chem. Soc. London*, 1875, vol. xxviii, pp. 109-112.

carnotite exhibit irregular birefringence effects, due to the fact that certain portions tend to become isotropic; and this tendency is not improbably connected with the instability of these minerals as regards their state of hydration.

d. Comparison of Australian and Colorado carnotites.—The physical condition of the Colorado carnotite has been described by Drs. F. L. Ransome and G. P. Merrill, in connexion with Dr. Hillebrand's paper.¹ Dr. Ransome examined it in sections of the sandstone, and found it 'very minutely crystalline, and too indistinct for successful optical study'. Dr. Merrill examined the carnotite by the fragmental method, and found that it consisted chiefly of minute dust-like particles, with occasional well-defined fragments. Working over a considerable amount of the powder he also observed occasional clusters which he describes as 'having the form of flattened radiating crystals with pyramidal terminations, which give extinctions always parallel to the axis of elongation. These are so minute (not over 0.25 mm. in length) and so thin that no crystal could be found so oriented as to give an opportunity of determining its exact character; and it can only be said that the general shape is such as to suggest a hexagonal mineral, though this is by no means certain'.

Still more recently, the carnotite of Colorado has been described occurring as crystals showing hexagonal form, but too minute to give interference-figures.²

These descriptions by the American authorities afforded no satisfactory means of comparison between the Colorado and South Australian carnotites. Consequently, a specimen of Colorado carnotite was examined. An examination of a few crumbs of the sandstone sufficed to provide crystals similar in habit to those described by Dr. Merrill. Like the Australian crystals, they are tabular in habit, and orthorhombic in symmetry. An isolated crystal plate, measuring not more than 0.05 mm. × 0.03 mm., when examined with a $\frac{1}{12}$ inch oil-immersion objective, gave a good biaxial figure. The acute bisectrix was normal to the surface of the plate, the optic axial plane being at right angles to the long edge or direction of elongation. As far as can be determined by an eye-piece micrometer, the optic axial angle appears to have about the same value as that of the Australian carnotite crystals. The optical sign is also negative.

¹ loc. cit., pp. 18 and 21.

² H. S. Gale, 'Carnotite in Rio Blanco County, Colorado.' Bull. United States Geol. Survey, 1907, No. 815, pp. 111, 112.

These Colorado crystals were observed in considerable numbers in the small fragments of sandstone examined, being apparently best developed, as one would expect, in the interstices of the coarser sandy portions. But though they appear to resemble the Australian crystals in their optical characters and in their tabular habit, they differ from them in form, as may be seen from the accompanying diagram (fig. 3).

Assuming that the acute angles of the Australian crystals is 78° , and treating the form enclosing them as $\{110\}$, the value for the obtuse angle enclosed by the form $\{120\}$ should be about 116° . The observed angle between the prism-edges of the Colorado plates gives an average reading of 114° . The observed values of angles here given are somewhat uncertain, owing to the small size of the crystals; and the limits of

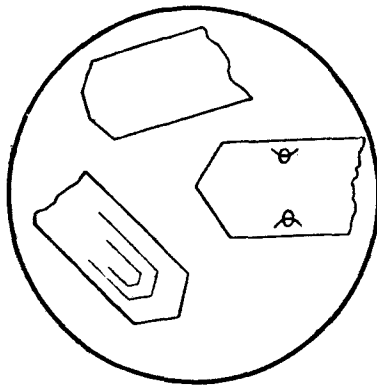


FIG. 3.—Tabular crystals from Colorado carnotite. Magnified 500 diameters.

error are probably wide enough to embrace the difference between the values observed. Nevertheless, it is perhaps inadvisable to draw any positive conclusion from this result as to the actual mineralogical identity of these Colorado crystals with those from South Australia. Before this can be safely done, it is desirable that larger crystals should be examined and more uniform readings obtained than those from which the average values of angles here given have been determined.

But far more numerous than these crystals in the Colorado material, and apparently constituting the greater part of it in some cases, are the irregular crystalline 'granules' referred to by Dr. Merrill. Though these are for the most part shapeless, some of them take on a rhombic appearance decidedly suggesting the form of the smaller Australian plates. While, therefore, pending the establishment of more exact data, it would be hazardous to draw definite conclusions based on a comparison

of the Colorado and Australian carnotites, it appears not improbable that they are essentially identical. It should be possible to collect sufficient of the Australian carnotite to get an analysis of the pure orthorhombic crystals. The Colorado material, on the other hand, is very variable in character, even in the same hand-specimen, and it is not at all surprising that the results of analyses should vary considerably, unless the selection of material for analysis is made very carefully and controlled by examination with the microscope. It seems quite probable that a careful selection of material would yield more consistent results than those recorded by Dr. Hillebrand.

(2) EXAMINATION OF THE COMPLEX MATERIAL ASSOCIATED WITH
THE CARNOTITE.

A mineralogical examination of a portion of the massive black ingredient which has been already referred to as constituting the bulk of the specimen, indicated that it was made up of an intimate mixture of ilmenite, rutile, and magnetite, with a variable but small amount of other material. A piece of the freshest-looking part of the specimen was selected for analysis. It had a specific gravity 4.33. To the naked eye it appeared homogeneous, though it seemed unlikely from a previous microscopical examination of the crushed material that such could be the case. It was broken into two parts; one of these was crushed and analysed; from the other part a section was cut for examination with the microscope. This section shows that the homogeneous-looking, black material is really heterogeneous and very complex. The slice is made up chiefly of the opaque, black constituent, which is perhaps best described as titaniferous magnetite (ilmenite + magnetite), the ilmenite predominating. This is impregnated with numerous irregular, small patches of material which is translucent and brownish in colour; these consist in part of rutile, but rutile is also present in patches of considerable size.

In addition to the rutile, there is a certain amount of less transparent material lining or filling cracks and cavities, and in some places wrapping round the rutile, from which it can be clearly distinguished. It is optically heterogeneous, but mainly isotropic, and its colour suggests the presence of cerium-bearing decomposition products, but its identity is optically indeterminable. This constituent entirely fills some of the small cavities, and lines others. Some of the cavities which contain it as an outer lining show growing out from it towards the centres of the

cavities, numerous fibrous-looking crystalline growths which are yellow in colour and decidedly pleochroic.

There can be little doubt that this constituent, seen as fibrous growths in section, is carnotite. Its habit of growth in platy aggregates explains its appearance in section, and one is not surprised to find that it shows a decided pleochroism in sections transverse to the plates.¹ The pleochroism is yellow to practically colourless, and may be stated thus:—

$$c = b \text{ (yellow) } > a \text{ (colourless).}$$

The optical behaviour of these fibrous growths resembles that of the micas in sections normal to the basal cleavage. They compensate across the fibres with a positive quartz-wedge, in accordance with the negative character of the crystals. The birefringence is apparently high, suggesting an approach to that of muscovite.

No constituent identifiable as roscoelite was seen in the section, or indeed in any part of the whole specimen described in this paper.

The portion analysed was found to have the following composition:—

TiO ₂	...	51.85 per cent.
Fe ₂ O ₃	...	17.87
FeO	...	17.37
SiO ₂	...	1.21
U ₃ O ₈	...	2.25
V ₂ O ₅	...	0.98
Cr ₂ O ₃	...	1.60
CaO	...	0.25
MgO	...	trace
MnO	...	0.24
PbO	...	0.40
ThO ₂	...	0.13
Ce ₂ O ₃	...	1.26
La ₂ O ₃	}	2.13
Di ₂ O ₃		
Y ₂ O ₃	...	1.15
H ₂ O	...	1.21
		99.85

This analysis² is consistent with the mineralogical description which

¹ The occurrence of the carnotite as platy growths in these cavities accounts for the good crystals obtained by partial crushing and magnetic separation.

² In making the above analysis, the estimation of alkalis was inadvertently omitted; an examination of a separate fragment showed that alkalis were present, perhaps to the extent of a few tenths per cent.

has just been given. The titanic oxide is clearly in excess of the amount required to form ilmenite, the excess being due to the presence of rutile. The uranium and vanadium oxides are present in roughly the same proportions as those of carnotite, though an examination of the slice would not lead one to expect 3.5 per cent. of this constituent.

The rare earths may be accounted for by the brownish, optically heterogeneous but mainly isotropic constituent, referred to in describing the slice. It may be inferred as highly probable that the rare earths are combined with titanic oxide and silica. On this assumption, they would be present in the form of a mineral consisting essentially of a silico-titanate of cerium earths. Apparently the only known mineral which fits in with these requirements is tscheffkinite, all the constituents of which are present; the cerium, lanthanum, didymium, and thorium oxides being in practically the required proportions, whilst yttria is in excess. The optical characters displayed by the brown translucent constituent seen in the slice are quite consistent with the view that the mineral is tscheffkinite.

Tscheffkinite is a decidedly rare mineral, and there is little or no information recorded as to its associates. But, according to Dana, it usually leaves a black residue of ilmenite grains when dissolved in nitric acid; and from this we may infer that it occurs in association and intimately mixed with ilmenite. This fact lends support to the view that the mineral in question is tscheffkinite, a view which seems warrantable on the basis of evidence here presented.

It is perhaps important to state that, as far as one can judge from an examination of the slice, there appears to be quite enough of the brownish constituent infilling the cavities, to account for the small percentages of rare earths recorded in the analysis. From this and the presence of carnotite, it seems unnecessary to allocate any of the uranium, vanadium, and rare earths to the opaque constituents.

(3) THE SUPPOSED NEW MINERALS OF THE SOUTH AUSTRALIAN CARNOTITE-BEARING COMPLEX.

The specimens of the supposed new minerals 'davidite' and 'seffstromite'¹ now on sale by mineral dealers, appear to be identical with the mineral complex described in this paper. The evidence presented by Messrs. Mawson, Rennie, and Cooke in no way conflicts with that

¹ If this is named after Sefström, the discoverer of vanadium, as is presumably the case, the supposed new mineral should have been called sefströmite.

here presented. Mr. Mawson's supposed new mineral 'davidite', which he describes as a lustrous black mineral containing over 50 per cent. of titanic oxide, a large amount of iron, together with some uranium, vanadium, and rare earths, may be regarded as ilmenite impregnated with rare-earth titanates, carnotite, and possibly a little rutile.

The South Australian workers have apparently not identified the rutile which forms such an important constituent of the complex. This rutile is black in the mass and brownish when powdered. It has a specific gravity about 4.2. An analysis by Mr. S. J. Johnstone, of the Imperial Institute, shows that it contains about 3 per cent. of iron oxide and about $1\frac{1}{2}$ per cent. of vanadic oxide. It may therefore be described as a vanadiferous nigrine.

There is every reason to believe that the specimen described in this paper was fairly representative of the Radium Hill lode-stuff, as it answered closely to the description given by both the Government Geologist and Mr. Mawson. Its condition indicates that the minerals of the lode-stuff are of a very mixed description. With the possible exception of the carnotite, none of them appears to be free from admixture with the associated minerals. Under such circumstances the existence of new minerals should only be inferred as a last resource to meet difficulties which are otherwise unmanageable. In the present instance, the evidence to be handled undoubtedly presents serious difficulties, but it seems less objectionable to cover this evidence by an appeal to known minerals than by an invention of new ones.

(4) PROBABLE GENESIS OF THE CARNOTITE.

The association of this carnotite-bearing complex with eruptive rocks suggests that the complex owes its condition to the impregnation and metamorphism of a mass of ilmenite during a late phase of eruptive activity. The rutile and magnetite are probably of secondary origin, resulting from the disintegration of original ilmenite. Contemporaneous with this change, and due to the same agencies, new material in the form of uranium, vanadium, and rare-earth compounds was probably added; and it is to this impregnation, directly or indirectly, that the formation of the carnotite is probably to be attributed.

(5) SUMMARY.

1. The radio-active lode-stuff of Radium Hill, near Olary, South Australia, is a mineral complex consisting of an intimate admixture of ilmenite, magnetite, rutile, carnotite, and a mineral which is probably

a titanate or silico-titanate of rare earths, &c., and which may possibly prove to be tscheffkinite or some allied mineral. The predominant constituent is ilmenite, the other minerals being present as impregnations.

2. The carnotite, which occurs sparingly in cracks and cavities, partly as a yellow powder and partly in the form of minute, tabular crystals and platy aggregates, is entirely and definitely crystalline, the crystals belonging to the orthorhombic system. The physical characters, taken in conjunction with the chemical composition, indicate that carnotite is a definite mineral, belonging to the uranite group, and that it may be regarded as the vanadium analogue of autunite.

3. The Colorado carnotite, though not so definite in its crystalline condition as the Australian mineral, contains tabular crystals and platy aggregates which are orthorhombic in symmetry; and it is probable that these are mineralogically identical with those of the Australian carnotite.

4. The supposed new minerals 'davidite' and 'sefströmite' are apparently identical with the complex above referred to.

The authors' thanks are due to Mr. L. J. Spencer, of the British Museum, for generous assistance in a variety of ways during the elaboration of this paper; also to Dr. J. W. Evans for kindly confirming the optical observations.

POSTSCRIPT by T. Crook (February 14, 1910).—On February 9, 1910, at a meeting of the Geological Society of London, Dr. D. Mawson exhibited specimens of 'davidite' from the Olary lode-stuff. He had seen the proof-sheets of the above paper, and with a knowledge of the results which we had obtained, he stated that 'davidite' is a homogeneous mineral, and that we had not seen it. Two days later Dr. Mawson kindly gave me one of the indistinct, cuboidal crystals of davidite, and I thereby had an opportunity of comparing it with the materials contained in the specimen of lode-stuff which we examined. After having examined an authorized specimen of 'davidite', it seems desirable that this opportunity should be taken to make a brief statement so as to prevent, if possible, any misunderstanding and confusion which might otherwise arise.

Dr. Mawson's 'davidite' is identical with that particular ingredient of our original specimen which we describe as occurring in small patches and having the lustre of ordinary ilmenite (see p. 272). This particular ingredient was not analysed by us, as there was not enough of it; but

Dr. Mawson informs me that full details of chemical analyses by Drs. Rennie and Cooke will be published shortly; and mineralogists will then be in a position to judge more correctly whether 'davidite' is to be regarded as a new and distinct mineral species rather than as an impure ilmenite.

An examination of the genuine 'davidite' has led me to the conclusion that, like the main ingredient of the lode-stuff, it is not homogeneous. The 'davidite' of our specimen occurred in small pieces having an irregular shape, and some of these could be clearly seen to merge insensibly into the main mass of the complex. It is perhaps necessary to remark that the mere uniformity of appearance and continuity of a fracture-surface is not sufficient to prove that the material is homogeneous; and the fragments of the 'davidite' which we examined show unmistakable signs of heterogeneity.

For the present, therefore, and pending the publication of proof to the contrary, one may reasonably continue to regard 'davidite' as a mineral complex which is essentially similar to that which we have described in the above paper.
