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# ERLICHMANITE ($OsS_2$), A NEW MINERAL

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## ABSTRACT

On the basis of electron probe and X-ray data, natural osmium disulfide, given the new name erlichmanite, is recognized in two occurrences, one of which is in grains of platinum-metal sand from California, the other in a platinum-metal nugget from Western Ethiopian laterites. California erlichmanite has Os 68.0, Ir 2.6, Rh 3.8, Ru 0.4, Pd 0.5, and S 25.2, summation of 100.5 weight percent, the number of metal atoms being 1.06 on the basis of 2.00 sulfurs. Ethiopian material has higher Rh and Ir and lower Os. Both examples are optically isotropic, and spotty X-ray reflections from a 15-micron particle of California erlichmanite give rise to *d* spacings which match those of synthetic cubic osmium disulfide. Erlichmanite is defined as a cubic disulfide in which osmium is the most abundant metal atom.

## INTRODUCTION

A few small (*ca.* 20 $\mu$m) grains with composition near $OsS_2$ were found by the writer in ferroplatinum from noble-metal placers collected at the MacIntosh Mine, Willow Creek, Trinity River, Humboldt County, California. For comparison with this mineral a sample from Western Ethiopia said to contain "roseite" (described as an osmium, iridium monosulfide) was obtained from Dr. J. Otteman (Otteman and Augustithis, 1967). The material provided by him did not contain osmium monosulfide, although this phase may be present in other specimens from the Ethiopian locality. It did, however, contain osmium disulfide, the Ethiopian and California occurrences being the first natural examples of this compound. The name erlichmanite is in appreciation of Mr. Jozef Erlichman, electron microprobe analyst for the Planetology Branch, NASA-Ames Research Center, employee of Applied Space Products, Palo Alto, California. Since 1964, Mr. Erlichman has been associated with determinations on, or has identified, a number of new minerals including sinoite, niningerite, brezinaite, yagiite, and armalcolite. Pronunciation is ər-lik-man-īt, accent being on the first syllable. Type material and some synthetic erlichmanite is, through the courtesy of Dr. C. O. Hutton, deposited in the Mineralogy Collections, Stanford university (Stanford Research Collection Number 51965).

The examples of erlichmanite described below are nearly-pure $OsS_2$, but the name also applies, more generally, to cubic disulfides in which osmium is the most abundant cation, on the basis of numbers of metals. This definition, and the name, have been approved in advance of publication by the Commission on New Minerals and Mineral Names, I.M.A.

## ANALYTICAL PROCEDURE

Erlichmanite analyses were made with an electron microprobe, the ARL-EMX model. Os, Rh, Ir, Pd, Ru, and S were determined. Three alloys, each containing 90 weight percent Pt and 10 percent each of Ir, Rh, or Ru were used as standards for the determination of these metals. Pure, synthetic $OsS_2$ was obtained from Prof. O. Knop for possible use as a standard for both S and Os. This material had been synthesized for a detailed X-ray diffraction study of the compound (Sutarno *et al.*, 1967), and was therefore a very fine (<200 mesh) powder. It could not be mounted or polished as received, and briquettes of the material suffered from charging under the beam, despite heavy carbon coating. Therefore, sulfur was measured with pure synthetic galena. And Os was done with a briquette consisting of thoroughly mixed, finely-divided pure Os and Pd in the following weight percents: Os 89.73, Pd 10.27. This same briquette had proven itself in previous analytical work on Os (Snetsinger, 1971). Another briquette, 70 percent Pd mixed with 30 percent KBr, was used as the standard for Pd.

Data were machine-corrected for background, drift, deadtime, mass absorption, fluorescence, and atomic number with a computer program format similar to that of J. Z. Frazer, R. W. Fitzgerald and A. M. Reid[1]. J. Z. Frazer's data[2] were used in the mass absorption calculations, while Wittry's (1964) formula, slightly modified, was applied to obtain secondary fluorescence corrections. Duncumb and Reed's (1968) backscatter-effect results were used in the atomic number calculations.

Measurements were done at 10 kV, and $L\alpha$ lines were used with the exception of S ($K\alpha$) and Os ($M\alpha$). The noble-metal alloy standards were obtained from Englehard Industries, Inc., finely divided pure Os and Pd were from Johnson, Matthey and Co., and synthetic galena was from Atomergic Chemetals, Inc.

## RESULTS

Analysis of California erlichmanite is given in column 4 of Table 1, together with the formula (column 5) derived from the analysis. Steps in the calculations (columns 2 and 3) are given in order to illustrate the extent to which the data are modified by matrix-effect corrections. Analysis and formula of Ethiopian erlichmanite is given at the bottom of Table 1. Ir and Rh are present in greater amounts than the California material, and Os is correspondingly lower. Matrix effect corrections are comparable to the California mineral, and are not listed. In each mineral Pt, Re, Ag, Au, Fe, As, S, and Te were looked for but not found; their detection limit

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[1] Scripps Inst. Oceanography No. 66–14 (1966)

[2] Scripps Inst. Oceanography No. 67–29 (1967)

TABLE 1. ANALYSES OF ERLICHMANITE

Correction Data and Analysis of California Erlichmanite

| (1) Element | (2) Data corrected for drift, background, & deadtime | (3) Data in (2) corrected for mass absorption, fluorescence | (4) Data in (2) corrected for mass absorption, fluorescence, & atomic number[1] | (5) Formula on basis 2 sulfurs per unit cell, calculated from data in (4) | |
|---|---|---|---|---|---|
| Os | 57.0 | 56.1 | 68.0 | 0.911 | |
| Ir | 2.0 | 2.0 | 2.6 | 0.036 | |
| Rh | 3.3 | 3.2 | 3.8 | 0.094 | 1.063 |
| Ru | 0.3 | 0.3 | 0.4 | 0.010 | |
| Pd | 0.4 | 0.5 | 0.5 | 0.012 | |
| S | 20.2 | 22.3 | 25.2 | 2.000 | |
| Total | 83.2 | 84.4 | 100.5 | | |

Analysis of Ethiopian Erlichmanite

Data corrected for all instrumental and matrix effects [as in column (4), above]:
Os 64.3, Ir 3.5, Rh 5.5, Ru 0.4, Pd 0.6, and S 25.5, summation 99.8
Structural formula: $(Os_{0.85}Ir_{0.05}Rh_{0.13}Ru_{0.01}Pd_{0.02})S_{2.00}$

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[1] Pure theoretical osmium disulfide has Os 74.8, S 25.2 weight percent.

is estimated to have been about 500 ppm under the conditions employed.

Both examples of erlichmanite are optically isotropic: careful inspection at high magnification with oil immersion of all grains available, presumably including grains of different crystallographic orientation, failed to reveal any reflection pleochroism or anisotropy under crossed polarized light. An X-ray film was obtained from a minute (15-micron) grain of California erlichmanite. Reflections were spotty, and could not in all instances be measured accurately. The *d*-spacings observed (Table 2), however, match those of $OsS_2$ synthesized by Sutarno *et al.* (1967). They found the phase to be cubic with space group *Pa*3 (pyrite structure). Despite the necessarily approximate nature of the *d*-spacing measurements of California erlichmanite, it is clear (Table 2) that the length of its cell edge cannot be greatly different from that of synthetic $OsS_2$: *a* 5.6196, ±0.0003 Å (Sutarno *et al.*, 1967). Using this value, the calculated density of the California mineral is (assuming $Os_4S_8$ in the unit cell) 9.59 g/cc, somewhat higher than what is obtained using the data of Sutarno *et al.* (1967; XRDF card 19–882): 9.518 gm/cc.

Oftedal (1928) and Meisel (1934) had previously synthesized $OsS_2$ and found it to be cubic with cell edge similar to the above value.

TABLE 2. X-RAY DATA FOR SYNTHETIC $OsS_2$ AND FOR ERLICHMANITE

| SYNTHETIC OSMIUM DISULFIDE | | | | ERLICHMANITE[2] |
|---|---|---|---|---|
| Diffractometer data of Sutarno et al. (1967), as listed in ASTM card 19-882 | | | Film data, obtained in present study[1] | Film data, natural material |
| hkl | $I/I_0$ | d(meas.)Å | d(meas.)Å | d(meas.)Å |
| 111 | 100 | 3.24 | 3.23 | 3.22 |
| 200 | 85 | 2.810 | 2.81 | 2.80 |
| 210 | 8 | 2.513 | 2.51 | 2.50 |
| 211 | 6 | 2.294 | 2.29 | 2.28 |
| 220 | 55 | 1.987 | 1.99 | 1.98 |
| 221 | <2 | 1.873 | 1.87 | ---[3] |
| 311 | 85 | 1.694 | 1.69 | 1.70 |
| 222 | 20 | 1.622 | 1.62 | 1.62 |
| 320 | 2 | 1.559 | 1.555 | 1.55 |
| 321 | 4 | 1.502 | 1.50 | 1.50 |
| 400 | 4 | 1.405 | 1.404 | 1.39 |
| 410, 322 | <2 | 1.363 | 1.36 | --- |
| 411 | <2 | 1.325 | --- | --- |
| 331 | 25 | 1.289 | 1.287 | 1.29 |
| 420 | 25 | 1.257 | 1.256 | 1.25 |
| 421 | 2 | 1.226 | 1.225 | 1.23 |
| 332 | <2 | 1.198 | 1.196 | 1.20 |
| 422 | 20 | 1.147 | 1.146 | 1.15 |
| 430 | <2 | 1.124 | --- | --- |
| 431 | <2 | 1.102 | --- | --- |
| 511, 333 | 30 | 1.081 | 1.079 | 1.08 |
| 520, 432 | 2? | 1.044 | 1.042 | 1.045 |
| 521 | <2 | 1.026 | 1.024 | --- |
| 440 | 12 | 0.993 | 0.992 | 0.996 |
| 522, 441 | <2 | 0.978 | --- | --- |
| 531 | 20 | 0.950 | 0.949 | 0.950 |
| 600, 442 | 20 | 0.937 | 0.935 | 0.934 |
| 610 | <2 | 0.924 | 0.922 | --- |
| 611, 532 | 2 | 0.912 | 0.910 | --- |
| 620 | 16 | 0.889 | 0.887 | 0.888 |
| 621, 540 | <2 | 0.878 | 0.877 | --- |
| 541 | <2 | 0.867 | 0.869 | --- |
| 533 | 20 | 0.857 | 0.856 | 0.857 |
| 622 | 20 | 0.847 | 0.846 | 0.845 |
| 630, 542 | 2 | 0.838 | 0.837 | 0.835 |
| 631 | 2 | 0.829 | 0.828 | --- |
| 444 | 4 | 0.811 | 0.810 | 0.810 |
| 632 | <2 | 0.803 | 0.802 | --- |
| 543 | <2 | 0.795 | --- | --- |
| 711, 551 | 55 | 0.787 | 0.787 | 0.787 |
| 640 | 65 | 0.780 | 0.779 | 0.780 |

[1] The same $OsS_2$ synthesized by Sutarno et al. (1967), obtained through the courtesy of Dr. O. Knop, was used here. The already finely-divided material was mounted in the usual way, in a camera having a 114.59 mm diameter. Exposure was six hours using Ni-filtered Cu radiation. Intensities are similar to those listed in the second column. A film correction was made.

[2] Data taken from a single 15-micron grain. Ni-filtered Cu radiation, 57.3 mm camera, 40 hours exposure. Intensities appear similar to synthetic $OsS_2$, but as the pattern obtained was spotty, no attempt is made to quantify this further. A film-shrinkage correction was made.

[3] Horizontal lines indicate missing (weak) reflections.

## DISCUSSION

Also associated with erlichmanite in the California occurrence are laurite ($RuS_2$) containing 3.3 percent Os, and an intermediate, optically cubic compound having a formula close to $(Os_{0.46}Ru_{0.42}Rh_{0.10})S_{2.00}$. Stumpfl and Clark (1965a) have analyzed a disulfide which, on the basis of data which they themselves describe as far from satisfactory, gave Ru 33.0, Os 20.9, Ir 11.4, and S 21.4, summation 86.7 weight percent. This is roughly comparable to the above intermediate compound—but Stumpfl and Clark (1965a) note their mineral is optically anisotropic and even shows twinning; they state that "partial replacement of ruthenium in a laurite-type mineral by osmium and iridium obviously resulted in a loss of cubic symmetry" (Stumpfl and Clark, 1965a, p. 938). This would be unusual in view of the cubic state of erlichmanite and the intermediate compound associated with it. Stumpfl and Clark's material may not, however, be a single phase. Knop (1965) thinks it may be a mixture of laurite and siserskite. For more discussion of this, see Stumpfl and Clark (1965b) and Leonard *et al.* (1969, 1330–1331).

Otteman and Augustithis (1967) named "roseite" and assigned to it the formula (Os, Ir)S on the basis of limited electron probe data. They observed "roseite" was cubic optically. No analytical data were given for Os or Ir, and S was estimated at 15 percent with the comment that "an accurate correction for the measured values of S was not possible due to lack of dependable mass absorption coefficients." Fleischer (1967) has suggested that "data on 'roseite' are inadequate to justify a name, especially in the absence of X-ray data. In addition, the name roseite (Dana, 6th Ed., p. 668) has been in use since 1879 for a vermiculite-like pseudomorph." In 1968 "roseite" was disapproved by the I.M.A. Commission on New Minerals and Mineral Names. The supposedly "roseite"-bearing platinum specimen sent to the present writer by Dr. Otteman did not contain osmium monosulfide; it is difficult to be sure from their data that Otteman and Augustithis (1967) were not in fact analyzing erlichmanite. The monosulfide may, however, have been present in the osmiridium samples studied by Otteman and Augustithis, where it apparently occurs more typically; the example sent to the writer was of "roseite" in ferroplatinum.

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Yubdo-Birbir area, was loaned to the writer by Dr. J. Otteman, Mineralogical-Petrographical Institute, University of Heidelberg, Heidelberg, West Germany. Efforts of Messrs. H. Shade, G. Cunningham and T. Palmer in extracting, manipulating, mounting, and X-raying a grain no larger than 15 microns in size are appreciated.

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