

The crystallographical constants of variscite are then: Orthorhombic,  $a:b:c=0.8729:1:0.9788$ .  $p_0=1.1225$ . Habit octahedral. Eight forms:  $c$  (001),  $a$  (100),  $d$  (120),  $e$  (012),  $r$  (113),  $i$  (112),  $p$  (111),  $s$  (121).

The optical properties of variscite from Arkansas are: optically negative,  $2V$  moderately large,  $Z$  is parallel to the elongation.  $\alpha=1.562$ ,  $\beta=1.583$ ,  $\gamma=1.590$ ,  $\gamma-\alpha=0.028$ . The intermediate index of refraction,  $\beta$ , of specimens from other localities varies from 1.560 to 1.588 and the birefringence from 0.020 to 0.030. The axial angle of the variscite from Striegis is  $53^\circ$ , that from Lucin is  $57^\circ$ . The dispersion of the optic axis is perceptible and  $\rho < \nu$ .

Variscite has the same composition as metavariscite,  $\text{Al}_2\text{O}_3 \cdot \text{P}_2\text{O}_5 \cdot 4\text{H}_2\text{O}$ , as evidenced by analyses of material from Utah (lucinite), Arkansas, Messbach, Striegis, Sardinia, etc. Its density is nearly the same as that of metavariscite.

## RADIO-DETECTOR MINERALS

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In the paper by Roberts and Adams<sup>1</sup> on radio-detector minerals only thirteen species were listed. The writer has tested a considerable number of additional ones, using a copper "cat's whisker" and a simple crystal set, and has found about 75 to possess detector properties. These are listed in table 1, arranged in the order of their chief metallic constituents in the periodic system. As is well known, radio-detector properties are not constant for a given mineral, but vary from one specimen to another, and even from one form to another on a single crystal; in general, the maximum effect obtained with each mineral is here recorded.

The relation of detector properties to the composition of the minerals is very interesting. In most cases sulfides detect better than oxides, but occasionally the oxides may be superior, as with manganese and zinc. Replacement of sulfur by selenium may improve the detector properties, as in argentite-aguilarite-naumannite, but the reverse holds in stromeyerite-eucairite. The effects of introducing tellurium or arsenic are likewise variable.

On comparing the list of detecting minerals with the table of low-voltage conductors prepared by Davy and Farnham,<sup>2</sup> a certain

<sup>1</sup> *Am. Min.*, 7, 131-136, (1922).

<sup>2</sup> Microscopic examination of the ore minerals. N. Y., 1920, p. 123.

amount of correlation appears. With few exceptions, species which might be expected to detect, but prove not to do so, were found by them to be non-conductors. Tetrahedrite occupies an anomalous position, being classed as non-conducting, yet detecting well; but the gradation into tennantite is a sufficient explanation. In general the better detectors are found in the list of moderate conductors, ranging from pyrite with about 5% conductivity to galena with 80% (compared with metallic copper as standard).

TABLE 1

RADIO-DETECTOR PROPERTIES OF MINERALS

ELEMENTS	GOOD	FAIR	POOR
C		graphite	C anthracite
Si	(artificial)	Si carborundum	SiC
Ti		octahedrite	TiO <sub>2</sub> (artificial)
Ti		brookite	TiO <sub>2</sub> ilmenite
Mo		molybdenite	MoS <sub>2</sub>
Mn		pyrolusite	MnO <sub>2</sub> psilomelane
Fe	pyrite, impure. FeS <sub>2</sub> +X	pyrrhotite	FeS <sub>1-1.5</sub> (artificial)
Fe		loellingite	FeAs <sub>2</sub> arsenopyrite
Fe		hematite	Fe <sub>2</sub> O <sub>3</sub> magnetite
Fe+Ni		taenite	Fe, Ni pentlandite
Fe+Cu	tennantite* Fe <sub>2</sub> Cu <sub>10</sub> As <sub>4</sub> S <sub>13</sub>	chalcopyrite*	Fe Cu <sub>2</sub> S <sub>2</sub> bornite
Fe+Cu		tetrahedrite*	Fe <sub>2</sub> Cu <sub>10</sub> Sb <sub>4</sub> S <sub>11</sub> stannite*
Co		linneite	CoS <sub>2</sub> smaltite, safflorite
Co		glaucodotite	CoSAs cobaltite*
Ni		polydymite	Ni <sub>2</sub> S <sub>4</sub> (artificial)
Ni		rammelsbergite	NiAs <sub>2</sub> ullmannite*
Cu	enargite	Cu <sub>3</sub> As <sub>2</sub> chalcocite	Cu <sub>2</sub> S domeykite
Cu		berzelianite	Cu <sub>2</sub> Se covellite
Cu		lamafinite	Cu <sub>2</sub> SbS <sub>4</sub> rickardite
Cu+Ag		stromeyerite	CuAgS eucairite
Cu+Pb			aikinite
Ag		aguilarite	Ag <sub>2</sub> (S, Se) argentite
Ag		naumannite	Ag <sub>2</sub> Se empressite
Ag		hessite	Ag <sub>2</sub> Te argyrodite*
Ag+Au		sylvanite	AgAuTe <sub>2</sub> petzite
Ag+Pb			alaskinite
Au		calaverite	AuTe <sub>2</sub>
Au+Pb			nagyagite
Zn	zinc oxide, art.*	ZnO zincite*	(Zn, Mn)O
Hg		tiemannite*	HgSe metacinnabarite*
Hg		coloradoite	HgTe onofrite*
Pb	galena, impure. PbS+X	clausthalite	PbSe altaite
Pb		chiviatite	PbBi <sub>2</sub> S <sub>7</sub> bismutoplagonite
Pb		guitermanite	Pb <sub>2</sub> As <sub>2</sub> S <sub>5</sub> galenobismutite
Pb		beegerite	Pb <sub>2</sub> Bi <sub>2</sub> S <sub>5</sub> lillianite
As			arsenic
Sb			antimony
Bi		guanajuatite	Bi <sub>2</sub> SS <sub>2</sub> bismuth
Bi			tetradymite
Te			tellurium

Noteworthy non-detectors (might be expected to detect, but do not)

Ti	rutile.....	TiO <sub>2</sub>	Mn alabandite.....	MnS	Zn+Fe marmatite.....	(Zn, Fe)S
Zr	zircon.....	ZrSiO <sub>4</sub>	Fe troilite.....	FeS	Cd greenockite.....	CdS
Cb+Fe	columbite.....	FeCb <sub>2</sub> O <sub>4</sub>	Fe+Zn franklinite.....	ZnFe <sub>2</sub> O <sub>4</sub>	Hg cinnabarite.....	HgS
Ta+Fe	tantalite.....	FeTa <sub>2</sub> O <sub>6</sub>	Ni millerite.....	NiS	Sn cassiterite.....	SnO <sub>2</sub>
Cr+Fe	chromite.....	FeCr <sub>2</sub> O <sub>4</sub>	Cu cuprite.....	Cu <sub>2</sub> O	Sb stibnite.....	Sb <sub>2</sub> S <sub>3</sub>
W+Fe	ferberite.....	FeWO <sub>4</sub>	Cu, etc. sulfo-salts, except as noted above.		Bi bismuthinite.....	Bi <sub>2</sub> S <sub>3</sub>
U+X	uraninite.....	UO <sub>2</sub> +X			Se selenium, cryst.....	Se

\* Possessing polar (hemimorphic) axes.

In the paper cited Roberts and Adams suggested that the sensitive spots of radio-detecting crystals are points where layers composed wholly of one kind of atom occur; and in accordance with this theory, the spots on galena would be octahedral planes, bevelling the corners of the usual cubic cleavage. The octahedrally cleavable galena (containing bismuth as an impurity) mentioned in the mineralogy texts, should, then, be an unusually good detector, and small samples of this material<sup>3</sup> were obtained through the kindness of Professor Ford of Yale University and Professor Palache of Harvard University. It proved, however, not to detect at all, indicating the insufficiency of the simple one-kind-of-atom-layer theory.

A modification of that theory is accordingly here suggested, namely, that the layers (or groups) of like atoms must exhibit one-sided attraction for assemblages of electrons. There are two cases to be considered, the one in which the purer the crystal the better the results, as exemplified by zincite, the other in which the radio-detector properties are clearly connected with the presence of definite impurities, as in galena, pyrite,<sup>4</sup> and apparently most of the other minerals in the table.

In zincite the layers of one kind of atom are arranged perpendicular to the singular axis (crystallographic axis *c*) in such a manner that this axis is polar (or as it is often rather inaptly termed, hemimorphic). Perhaps the corresponding one-sided attractive force holding the electrons to such an atom layer permits these electrons to move more readily in one direction than in the other and so renders the substance a radio-detector. About ten other minerals, starred in table 1, also show polar axes, and may owe their detector properties to this structural peculiarity.

<sup>3</sup> Dr. E. G. Zies of the Geophysical Laboratory kindly tested some fragments from Lancaster County, Pa., with the spectroscope, and found several per cent of bismuth to be present, but no other impurities in more than slight traces.

<sup>4</sup> Qualitative tests of unusually good pyrite from Leadville, Colo., indicated the presence of a little arsenic and selenium (?), although to which of these, if either, the detector properties are to be assigned can not be decided.

That the presence of certain impurities, with the corresponding irregularity in the crystal structure, increases the radio-detector properties of many minerals is evident. The relatively pure galenas from the Joplin district and elsewhere in the Mississippi Basin, for instance, are poor, while on the other hand the argentiferous galenas from many of the Rocky Mountain deposits are excellent detectors. Examination of the cleavages of the latter specimens with a lens almost always shows the existence of a wavy-striated surface, indicating some distortion in the crystal structure, no doubt connected with the presence of the silver compound. It seems probable that such distortion of the layers of atoms may shift electrons out of their normal positions, so that groups of them are held by one-sided attractive forces, and may thus give rise to the radio-detector properties exhibited.

SUMMARY. About 75 minerals which have been found to possess more or less radio-detector properties are tabulated with respect to their compositions. Sulfides are usually better than oxides of the same metals, selenides sometimes better than sulfides. Most of these minerals are moderate conductors of low-voltage electricity. The theory of Roberts and Adams that sensitive spots on crystals are merely layers composed wholly of one kind of atom is shown to be insufficient, and a modification is suggested. In some cases such layers are perpendicular to "hemimorphic" or polar axes, and the detector properties may be due to the corresponding one-sided attraction of the electron layers. In most minerals the presence of certain impurities improves the detector properties, which may be due to resulting irregularities in the crystal structure, with corresponding one-sided attractive forces holding groups of electrons.

### A REEXAMINATION OF BEAUMONTITE FROM BALTIMORE<sup>1</sup>

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Beaumontite, described as a new mineral from Baltimore in 1839 by Levy and named after Elie de Beaumont,<sup>2</sup> was the subject

<sup>1</sup> Published by permission of the Secretary of the Smithsonian Institution. This paper is the fourth preliminary paper on subjects of interest developed in the course of an investigation of the minerals of Maryland undertaken in cooperation with the Maryland State Geological Survey.

<sup>2</sup> F. Michel Levy: L'institut, No. 313, p. 455; Berzelius Jahrsbericht, 20, 217, (1840); London & Edinb. *Phil. Mag.*, Feb. 1840.