

The identity of minervite and palmerite with taranakite.

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THE abundance of the well-known potassium aluminium silicate minerals, orthoclase, microcline, and muscovite, stands in striking contrast with the rarity of the little-known potassium aluminium phosphate minerals. The only one of these which occurs as distinct crystals and which has yielded a satisfactory formula is minyulite, $\text{KAl}_2(\text{PO}_4)_2(\text{OH},\text{F})\cdot 4\text{H}_2\text{O}$. This mineral was first described by E. S. Simpson and LeMesurier¹ from Western Australia in 1933 and an examination of well-crystallized specimens from South Australia by L. J. Spencer et alii² was published in 1943. Spencer's paper included X-ray single-crystal and powder data for minyulite. X-ray, optical, and specific gravity data were also determined at that time for a few other hydrous potassium aluminium phosphate minerals from the British Museum collections. These included palmerite from guano deposits in a large cavern, Monte Alburno, near Controne in Salerno, Italy, presented by E. Casoria³ who described the mineral in 1904, and taranakite from the Sugarloaves, near New Plymouth, Taranaki, New Zealand. A specimen labelled minervite from Oran proved to be whitlockite $\beta\text{-Ca}_3(\text{PO}_4)_2$ and is the subject of the work described in the preceding paper. Only recently did one of the authors (G. E. H.) present a specimen of minervite to the British Museum which is part of a gift he received from Professor P. F. Kerr of Columbia University; this like the original minervite described by A. Carnot⁴ is from Minerva grotto, Fauzan,

¹ E. S. Simpson and C. R. LeMesurier, Journ. Roy. Soc. Western Australia, 1933, vol. 19 (for 1932-33), pp. 13-16. [M.A. 5-293.]

² L. J. Spencer, F. A. Bannister, M. H. Hey, and Miss H. Bennett, Min. Mag., 1943, vol. 26, pp. 309-314.

³ E. Casoria, Atti R. Accad. Geogofili, Firenze, 1904, ser. 5, vol. 1, p. 293; Ann. R. Scuola Sup. Agric. Portici, 1904, vol. 6.

⁴ A. Carnot, Ann. des Mines, 1895, ser. 9, vol. 8, p. 319.

dép. Hérault, France. These specimens are the principal ones which we have studied and upon which we base our identification.

Despite the differences in the published chemical analyses of these minerals, all three yield the same X-ray powder photographs and have almost identical refractive indices and specific gravities. Taranakite is a pale-cream-compact mineral occurring as thin seams in the trachytic rocks of the Sugarloaves. Prior to chemical analysis it was thought to be wavellite, but it is softer and more readily fusible.¹ Hector and Skey observed a few thin seams of a dark yellowish-brown coloured substance traversing the taranakite in various directions. They reported these seams to be wavellite and said they avoided them in selecting a sample of taranakite for chemical analysis. We have detected the same inclusions and have shown by X-ray powder photographs that they are identical with vashegyite, not wavellite.

Both palmerite and minervite are soft, powdery minerals like kaolin in appearance and to the touch. Like taranakite they are very fine-grained, but when immersed in a liquid and viewed with an inch objective they reveal minute birefringent laths. Their refractive indices obtained by the Becke line method are given in table I. Molecular proportions calculated from published chemical analyses are also listed

TABLE I. Chemical analyses and molecular ratios.

	I.	II.	III.		I.	II.	III.
P ₂ O ₅	35.05	37.28	37.10	...	3.0	3.0	3.0
Al ₂ O ₃	21.43	18.59	22.89	}	...	2.89	2.14
Fe ₂ O ₃	4.45	0.83	1.17				
CaO	0.55	1.40	trace				
K ₂ O	4.20	8.28	8.04	...	0.54	1.00	0.98
(NH ₄) ₂ O	—	0.52	0.90				
H ₂ O	33.06	28.20	29.16	...	22.29	17.88	18.59
Insol.	0.80	4.35	0.36				
	<u>100.00</u>	<u>99.78</u>	<u>99.64</u>				
Sp.gr.	2.15	—	2.15	}	(F.A.B.)		
n	1.502	1.50	1.507				

I. Taranakite, Sugarloaves, Taranaki, New Zealand. Also Na₂O trace, Cl 0.46, SO₂ trace, iron as FeO. (Hector and Skey, 1865.) Specific gravity and optical data on B.M. 1936,51.

II. Minervite, Minerva grotto, France. Also MgO 0.33. F, Cl, SO₂ traces. (A. Carnot, 1895.) Optical data on B.M. 1947,1.

III. Palmerite, Monte Alburno, Italy. Also Na₂O 0.02, MgO trace. (E. Casoria, 1904.) Specific gravity and optical data on B.M. 1909,370.

¹ J. Hector and W. Skey, Reports of the Jurors, New Zealand Exhibition, 1865, Dunedin, 1866, p. 423. S. H. Cox, Trans. New Zealand Inst., 1882, vol. 15, p. 385.

in the same table. Palmerite and minervite have yielded analyses not incompatible with their identity if one admits the possibility of admixture of small quantities of other undetected minerals. Taranakite, however, apparently possesses only half the potash content of the other two and, if we attribute this to admixture with vashegyite, then we must conclude that despite their care in selecting material for analysis Hector and Skey actually analysed a mixture of taranakite and vashegyite in about equal proportions. There is, however, too little vashegyite present in the specimen of taranakite that we have examined to support this assumption. It would be more reasonable to assume that their figure for potash is low owing to their failure to separate all the enclosed vashegyite, and that the differences in composition between taranakite, minervite, and palmerite, particularly their variation in content of potash, remain for the present unexplained. The X-ray powder data (table II) and optical data do, however, show that the

TABLE II. Spacings in kX units and estimated intensities of the lines observed on X-ray powder photographs of taranakite, B.M. 1936,51, taken with filtered copper radiation, 1.539 kX, in a cylindrical camera, 5.98 cm. diameter.

15.5 vs	3.34 mw	2.19 w	1.68 vw	1.396*vw	1.209 w
7.6 s	3.15 s	2.07 ms	1.65 vw	1.354 vw	1.172 w
5.8 m	2.84 s	1.97 mw	1.61 mw	1.338 vw	1.146 vw
5.1 vw	2.73 vw	1.91 w	1.569 vw	1.316 vw	1.133 vw
4.39 m	2.63 ms	1.88 vw	1.542 vw	1.281 w	1.115 vw
3.82 s	2.40 m	1.84 } mw	1.502 mw	1.262 vw	1.097*vw
3.58 m	2.26 w	1.77 } mw	1.466 vw	1.246 w	1.073 vw
		1.73 mw	1.427 mw	1.237 vw	1.056 vw

Bracketed lines are unresolved bands consisting of several lines, and the diameters and intensities of the limits are given.

* Doublets.

main component of the three specimens we have examined is the same, and on grounds of priority we consider that all three should be named taranakite. Only an approximate formula can be given, and this we base on Casoria's analysis of palmerite rather than on the much earlier analysis of taranakite itself. Casoria's analysis yields approximately $3P_2O_5 \cdot 3(Al,Fe)_2O_3 \cdot K_2O \cdot 18H_2O$. Our choice is arbitrary and assumes a comparatively simple formula and a constant composition.

THE GEOCHEMISTRY OF TARANAKITE (G. E. Hutchinson).

A qualitative spectrographic examination of the specimen of minervite showed strong lines of K, Al, and Fe, as would be expected from the published analyses; Na, a small amount of Ca, and a trace of Mg were

also present. Rb is definitely present in more than minute traces, the concentration being possibly of the order of 1% of the K-content; this may be of some interest as suggesting that the potassium as well as the aluminium of the mineral came from the rock undergoing alteration rather than from the guano solution. Li, Sr, Ba, Mn, and Zn appear to be absent, though the conditions for recognizing the last element were poor. Pb is definitely present, but in view of the fact that the powdery mineral had been lying for many years in a drawer in New York City, the lead may be a contaminant. The material appears to contain no exchangeable hydrogen or exchangeable bases.

The name *minervite* has been given to material from various localities similar to that from *Minerva grotto*, Fauzan, France. Published analyses suggest that many of these are also identical with *taranakite* and the known and probable occurrences of the mineral may be grouped as those of:

(1) Caves, probably due to phosphatizing solutions from bat guano, which, however, may have disappeared.—*Grotte de Minerve*, France (*minervite*, A. Carnot, 1895); *Monte Alburno*, Italy (*palmerite*, E. Casoria, 1904); *Misserghin*, Algeria ('*minervite*', A. Carnot, 1895);¹ *Jenolan*, New South Wales ('*minervite*', J. C. H. Mingaye, 1898);² *Réunion*, Indian Ocean ('*minervite*', A. Lacroix, 1910).³

(2) Coastal localities, probably due to phosphatizing solutions from bird guano.—*Sugarloaves*, Taranaki, New Zealand (*taranakite*, Hector and Skey, 1866); *Islas Leones*, Patagonia (L. R. Catalano).⁴

It will be observed that both the coastal localities are in relatively high latitudes. In tropical latitudes in which the phosphatization of the igneous rocks of bird-islands has occurred, the resulting minerals appear to be *variscite* and *metavariscite* ($\text{AlPO}_4 \cdot 2\text{H}_2\text{O}$), *barrandite* ($(\text{Al,Fe})\text{PO}_4 \cdot 2\text{H}_2\text{O}$), *strengite* and *phosphosiderite* ($\text{FePO}_4 \cdot 2\text{H}_2\text{O}$). Such occurrences have been described by Lacroix⁵ and by McConnell⁶ and less critically by many other authors. A full discussion of all localities will appear in a later publication on the biogeochemistry of guano deposits (Hutchinson, forthcoming). Meanwhile it is desirable to point out that the known

¹ A. Carnot, *Compt. Rend. Acad. Sci. Paris*, 1895, vol. 121, p. 153.

² J. C. H. Mingaye, *Rep. Australasian Assoc. Adv. Sci.*, 1898, vol. 7, p. 327; *Rec. Geol. Surv. New South Wales*, 1899, vol. 6, p. 113.

³ A Lacroix, *Bull. Soc. Franç. Min.*, 1910, vol. 33, p. 34; 1912, vol. 35, p. 114.

⁴ L. R. Catalano, *Argentina Direc. Minas y Geol. Pub.*, 1933, no. 100, p. 1. Analysis of nodular phosphate from *Islas Leones* yielded a formula near to that of *palmerite*.

⁵ A. Lacroix, *Compt. Rend. Acad. Sci. Paris*, 1906, vol. 143, p. 661.

⁶ D. McConnell, *Rev. Colegio Ing. Venezuela*, 1941, vol. 19 (no. 140), p. 115; *Bull. Geol. Soc. Amer.*, 1943, vol. 54, p. 707. [M.A. 9-182.]

distribution of the $(Al,Fe)PO_4 \cdot 2H_2O$ minerals confirms the suggestion of Lacroix that they occur in regions of markedly seasonal rainfall. Such regions are characterized on land by 'la latérisation, cette autre maladie tropicale des roches silicatées' (Lacroix, 1906, loc. cit.). In contrast to this it is reasonable to suppose that the two exposed and all the hypogean sites of formation of taranakite are perennially damp. The Sugarloaves, as illustrated in the *New Zealand Pilot* (U.S. Hydrogr. Office no. 171, 1929, view 20), appear to be ideal sites for bird colonies. Though it seems improbable that the islands are at present occupied by large numbers of birds, Morgan¹ indicates that the phosphorus of the taranakite and the wavellite found on these islands is undoubtedly of avian origin. The *Islas Leones* material which is chemically similar, but otherwise little known, is associated with a penguin colony. In view of the considerable climatic differences between the west coast of New Zealand, off which the Sugarloaves lie, and the drier east coast, a critical examination of the so-called Redonda phosphate of Green Island and White Island, Otago, would be interesting. The supposed titanium phosphate (Morgan),¹ apparently found as the result of phosphatization by guano solutions at Antipodes Island, also requires investigation.

Finally, it may be pointed out that if one is justified in supposing that taranakite is the typical product of phosphatic alteration in perennially damp conditions, small amounts may well be present dispersed in wet soils, and that the possible formation of such a mineral should be considered by investigators interested in the fate of soluble phosphates added to soils.

¹ P. G. Morgan, *Réserves mondiales en Phosphates*. Congrès Géol. Internat. 1926, Madrid, 1928, vol. 2, p. 823.