

Eggonite (kolbeckite, sterrettite), $\text{ScPO}_4 \cdot 2\text{H}_2\text{O}$

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SYNOPSIS

THE curious history of the mineral eggonite is reviewed, and two new occurrences are described. The original specimens, for which Schrauf gave good morphological and optical data in 1879, with a tentative suggestion that it was a cadmium silicate, were fakes; the tiny crystals of the new mineral were glued on to hemimorphite specimens from Altenberg, Belgium. In 1929, Zimanyi edited and published observations by Krenner, who found the mineral on silver ores from Felsőbánya, Hungary, added to Schrauf's physical data, and identified it as an aluminium phosphate. It was not until 1959 that Mrose and Wappner showed that it is scandium phosphate, $\text{ScPO}_4 \cdot 2\text{H}_2\text{O}$, and essentially identical with kolbeckite, described by Edelman in 1926 as a phosphate and silicate of beryllium, aluminium, and calcium from Saxony,

and with sterrettite, described by Larsen and Montgomery in 1940 as an aluminium phosphate from Fairfield, Utah.

In 1980 the IMA Commission on New Minerals and Mineral Names, while accepting the identity of the three minerals and rejecting the name sterrettite, were almost equally divided over the names eggonite and kolbeckite, which are thus both acceptable; since eggonite has 47 years priority, we suggest that it should have preference.

The available physical and chemical data on eggonite are summarized and added to, and two new occurrences, at Potash Sulfur Springs, Arkansas, and at Sakpur, Gujarat, India, are described.

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Historical. The mineral eggonite has had a bizarre history: its original or type locality was long doubtful, its chemistry was not established till 80 years after its first description, and the full story of the original specimens will probably remain unknown.

Eggonite was described by Schrauf (1879); his material "hat Herr A. Gentsch unter seinen Vorräthen von Zinkmineralien des Fundortes Altenberg [Belgium] aufgefunden", and it consisted of a few small (½ to 1 mm) crystals perched on hemimorphite crystals, which in turn occur in small cavities of the smithsonite; he named the mineral from the Greek ἔγγονος a grandson, in allusion to its being the third in a paragenesis.

Schrauf noted that the crystals resemble a baryte figured (fig. 505) in the 5th (1868) edn of Dana's Syst. Mineral., but his observed forms do not correspond to any of the known forms of baryte. He described the mineral as anorthic, with forms {100}, {010}, {320}, {320}, {023}, and {023}, and elements $a:b:c:: 1.3360:1.0.7989, \alpha 90^\circ 23', \beta 90^\circ 50', \gamma 91^\circ 0'$, with twinning on {010}; no cleavage. This morphological description has been generally accepted, but crystallographers who have had occasion to use Schrauf's data for other crystals (e.g. in connection with the Barker Index) are well aware that he assigned crystals to the anorthic system on very flimsy evidence, and a review of his actual measurements on three crystals (Table I) shows that eggonite is really monoclinic, with $\beta 90^\circ 42'$ (Schrauf himself notes "Constant ist eine Differenz vorhanden zwischen den Winkeln des Doma zu vorderen oder rückwärtigen Prismflächchen"). Refractive index measurements by the prism method, using the 56° prism {023}:(023), gave $n^o 1.571$ (L1), 1.575 (Na), 1.577 (T1), and $\gamma^o 1.593$ (L1), 1.598 (Na), 1.601 (T1), with $n^o \perp (100)$ and $\gamma^o \parallel [010]$.

With the small amount of material available, chemical analysis was impossible, but Schrauf tried blowpipe tests, and observed an evanescent brown sublimate on charcoal and a silica "skeleton" in a microcosmic salt bead; he concluded "Nach diesen Reaktionen zu urtheilen, ist Eggonit im Wesentlichen ein Cadmium enthaltenden Silicat", but clearly had misgivings as to his tests (with hindsight, we may suspect that the brown sublimate was carbon compounds from heated gum and the silica skeleton from hemimorphite contamination).

But soon after publishing his work, with correct morphological and optical data adequately characterizing his eggonite, Schrauf lost all confidence in his work, and informed E.S. Dana that the crystals (which he now termed baryte) had been "implanted in crystallized calamine" from Altenberg in Belgium. Disregarding the wide discrepancy between Schrauf's optics and those of baryte, which has $\gamma 1.648 \parallel [100], \beta 1.637 \parallel [010]$, Dana also dismissed eggonite as merely baryte, and with publication of Schrauf's retraction, eggonite could only be considered as discredited, a synonym for baryte.

By then, specimens of the mineral had been acquired by many collectors, dealers, and museums. In 1884 Andor von Semsey purchased for the Hungarian National Museum part of the Fauser collection, containing the faked mineral (Krenner, 1908, unpublished data, posthumously reported by K. Zimanyi, 1929); in 1885 the British Museum purchased two specimens from the well-known dealer A. Krantz, and Krenner himself bought three from J. Böhm.

The possible legitimacy of eggonite was not raised until Zimanyi published Krenner's laboratory notes, verbatim (1929). Krenner had found in the Hungarian National Museum the counterpart of Schrauf's eggonite ("Welches da Pendant war desjenigen"), and

also had the three purchased from Böhm. He noted particularly that the forged paragenesis could only be detected by close examination and painstaking scrutiny ("bei sorgfältiger Augenscheinahme und einiger Übung"). He established with certainty the true source of the crystals implanted on the Belgian zinc ore as Felsőbánya, Hungary, by finding identical crystals on Felsőbánya miargyrite and diaphorite; and he observed that these minerals had never been seen in any Belgian zinc ore. Although insufficient material precluded quantitative analysis, his qualitative tests assured him that eggonite was a hydrous aluminium phosphate, and from goniometric study he referred it to the metavariscite group. Later, L. Tokody (1954) again found eggonite on Felsőbánya diaphorite. Having thus brilliantly improved Schrauf's description of eggonite (with allowance for his misidentification of scandium as aluminium), Krenner was content to observe that it seldom happens in the history of a mineral species that after careful and complete reexamination nothing remains unchanged but the name. Unfortunately, Krenner's specimens in the Magyar Menzeti Museum have been lost, or destroyed in the 1956 fire.

Three years before publication of Krenner's data, F. Edelmann (1926) described a new mineral, kolbeckite, as bright blue-grey crystals, found sparingly in 1908 in the Sadišdorf copper mine, near Schmiedeberg, Saxony; the name was in honour of the mineralogist F. Kolbeck (1860-1943), for whom R. Herzenberg later named another mineral kolbeckine. Apart from the density, 2.39, only qualitative data were available; Prof. Böhring determined it as a phosphate and silicate of Be, with some Al and Mg.

In 1932 Hilde Thurnwald and A.A. Benedetti-Pichler¹ published

1. Benedetti-Pichler was perhaps the foremost microanalyst of his time; Hilde Thurnwald was a promising young microchemist fated to perish with so many other Jews (Mary E. Mrose, pers. comm.).

a full quantitative analysis of kolbeckite; unfortunately, this suffered from a misidentification of the elements present, but, as we shall see, it was nevertheless a conscientious and creditable analysis for its date, considering the minute size of the sample (a few milligrams). Its reinterpretation is not difficult. In the 7th edn of Dana's System (Palache *et al.*, 1951) their data for kolbeckite are given: "apparently a hydrated silicate phosphate of beryllium, aluminum and calcium". Had they (or indeed many others involved in the history of the mineral) made use of the spectroscopy, much confusion would have been avoided.

Larsen and Montgomery (1940) described a new mineral from Utah, sterrettite, with composition $\text{Al}_2(\text{PO}_4)_2(\text{OH}) \cdot 5\text{H}_2\text{O}$, based on an analysis by F.A. Gonyer. There were unexplained discrepancies in their account, all arising from Gonyer's failure to realize that his aluminium was actually scandium. Indeed, Larsen and Montgomery themselves noted the difference between their calculated and measured densities (2.45 against 2.36), and stated that "an X-ray powder photograph of sterrettite is completely different from those of variscite and metavariscite"; misled by the analysis, they may have stressed the differences rather than the similarities - eggonite and metavariscite are isostructural.

In 1940, then, there were three distinct mineral species recognized: Schrauf's once-discredited eggonite, since validated by Krenner as $\text{ScPO}_4 \cdot 2\text{H}_2\text{O}$, Edelmann's kolbeckite, a hydrated silicophosphate of beryllium, aluminium, and calcium, and Larsen and Montgomery's sterrettite, $\text{Al}_2(\text{PO}_4)_2(\text{OH}) \cdot 5\text{H}_2\text{O}$. The following year, Bannister (1941) established the identity of eggonite and sterrettite by X-ray diffraction, using the "Altenberg" fakes in the British Museum (Natural History) collection and cotype sterrettite for comparison.

Then, as now, Krenner's material was not available, and a careful search failed to reveal any eggonite on the British Museum's Felsobánya material. Bannister seems to have accepted Larsen and Montgomery's description, with Conyer's analysis, as the most satisfactory to date, and recommended adoption of the name sterrettite in place of eggonite. There seems little doubt that the unexplained circumstances of the faking of the "Altenberg" specimens, by an unknown hand, led him to disregard Dana's rule: "when ... a badly described but well known old mineral is re-described correctly, there is no propriety in the new describer changing the old name" (Syst.Min., 6th edn, p. xliii (1892)).

Several contemporary mineralogists strongly dissented from Bannister's rejection of eggonite for sterrettite. First to protest was M.Fleischer, then, as now, mentor to American mineralogists; he wrote: "According to the rules of priority, Krenner would have been justified in giving a new name to the mineral, but did not do so. Eggonite is listed in both Dana-Ford and Larsen-Berman [Bull.U.S.Geol.Surv. 848, 164] as hydrous aluminum phosphate and the optical data given are correct. It would seem, therefore, to be a violation of the generally accepted rules of priority to drop the name eggonite for sterrettite Dr.Larsen (private communication) feels eggonite has preference. Incidentally, the material from Fairfield seems to be a third generation mineral". (Dr.Esper S.Larsen, 3d (1912-1961) was the son of the famous mineralogist of the same name. His ready and cheerful acknowledgement of the priority of Schrauf's eggonite over his own sterrettite was characteristically generous. But in 1951 the compiler of the phosphate section of the new (7th) edition of Dana's System followed Bannister, as did Hey (1950).

L.Tokody (1954) was outraged, declaring Bannister's rejection of eggonite "überraschender und ungewohnterweise" and concluding that "natürlich [muss] des ursprüngliche Name Eggonit beibehalten werden"; he noted that Larsen and Montgomery had been unaware of Krenner's work, and, therefore, of the identity of eggonite and sterrettite. He further recorded his own finding (in 1944) of eggonite on Felsöbánya silver ore.

Meanwhile, Schroeder and Borchert (1947) has obtained X-ray data for kolbeckite, showing it to be monoclinic, with β $90^{\circ}40'$ and cell-dimensions close to those of eggonite and sterrettite; but as these were believed to be orthorhombic aluminium phosphates and kolbeckite a monoclinic beryllium phosphate their identity was not suspected.

A few years later M.E.Mrose and B.Wappner (1959) found almost identical X-ray data for the Utah sterrettite, the Saxony kolbeckite, the "Altenberg" eggonite, and synthetic $\text{ScPO}_4 \cdot 2\text{H}_2\text{O}$, also finding scandium as the major or only cation in all three minerals. Following Bannister and the new Dana, they designated the $\text{ScPO}_4 \cdot 2\text{H}_2\text{O}$ mineral sterrettite. The name kolbeckite they reserved for the Saxony (Sc,Be,Ca)(SiO₄,PO₄)₂·2H₂O, regarding it as a species distinct from sterrettite, the similarity of the X-ray patterns notwithstanding. But an unpublished analysis made in 1964 by Robert Meyrowitz of the

Table I. Morphological data for eggonite from Schrauf (1879), Tokody (1954), and Miers (1894, see text), with calculated angles from the X-ray data for Mrose and Wappner (1959); Schrauf's {320} and {023} are $\underline{m}\{110\}$ and $\underline{q}\{011\}$ of the X-ray cell.

Schrauf (obs.and mean)	Tokody	Miers	Calc.
\underline{bm} $48^{\circ}19' - 48^{\circ}55'$ (6) $48^{\circ}34'$	-	-	-
\underline{bq} $61^{\circ}35' - 62^{\circ}17'$ (13) $61^{\circ}56'$	$62^{\circ}22'$	$61^{\circ}52'$	$62^{\circ}0'$
\underline{mq} $70^{\circ}36' - 71^{\circ}53'$ (6) $71^{\circ}26'$	$71^{\circ}49'$	-	$71^{\circ}51'$
$\underline{m'q}$ $72^{\circ}10' - 72^{\circ}40'$ (7) $72^{\circ}24'$	-	-	$72^{\circ}33'$

β calc. from Schrauf's \underline{bm} , \underline{bq} , \underline{mq} , $90^{\circ}36'$; from \underline{bm} , \underline{bq} , $\underline{m'q}$, $90^{\circ}46'$, from X-ray data, $90^{\circ}45'$.

U.S.Geological Survey showed that Edlmann's Saxony kolbeckite was also $\text{ScPO}_4 \cdot 2\text{H}_2\text{O}$ (Mrose, 1965). And in 1965 the Commission on New Minerals and Mineral Names of the I.M.A. was asked to decide between kolbeckite and sterrettite as the specific name and voted for kolbeckite; the name eggonite was not considered on this occasion. This omission has been remedied by a recent vote on the three names eggonite,

kolbeckite, and sterrettite, which resulted in almost equal votes for eggonite and kolbeckite, and none for sterrettite; thus both eggonite and kolbeckite are currently acceptable names. But we feel that eggonite, with 47 years priority, should take precedence.

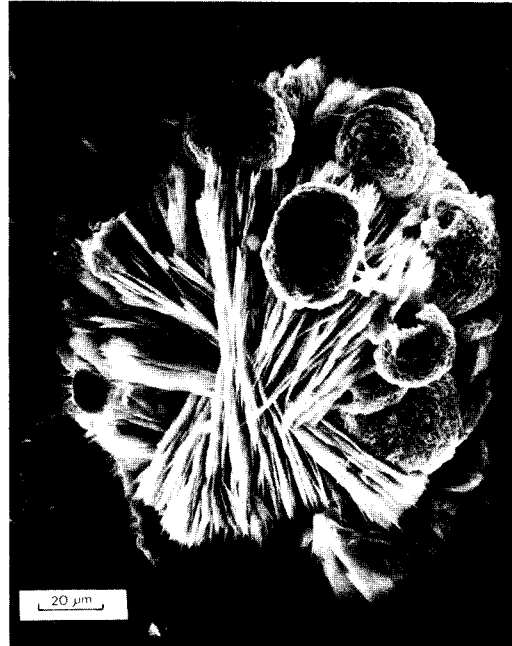


Fig. 1. Radiating platy crystals of eggonite associated with crystalline spherules of a new Fe-Zr-Sc phosphate; from Potash Sulphur Springs, Garland County, Arkansas. SEM photograph.

Two new occurrences of eggonite

Potash Sulphur Springs, Garland County, Arkansas. Here eggonite occurs in the Union Carbide Vanadium Mine ore, associated with an extraordinary assemblage of vanadium, scandium, zirconium, uranium, and niobium minerals. The ore is thought to have resulted from post-Cretaceous weathering of hydrothermally altered basic alkalic intrusives, which originally contained vanadinite pyroxene. Repeated cycles of solution and precipitation have concentrated specific elements into these various minerals. A similar and doubtless related mineralogy is known from the classical Magnet Cove region of alkalic intrusives only a few miles east, where kizimeyite, zirconium garnet, with minor yet significant scandium, is found.

In the vanadium ore, eggonite occurs in vugs, usually on black diopside-hedenbergite, on which frequently is also found a new zirconium mineral, $\text{FeZr}(\text{PO}_4)_2 \cdot 4\text{H}_2\text{O}$ - again an association of scandium and zirconium (fig.1).

The Arkansas eggonite differs from the others in the presence of much ferric iron replacing scandium (Table III). Since eggonite and phosphosiderite are isostructural and the ionic radii of Sc^{3+} and Fe^{3+} only differ by 0.09 Å (Sc^{3+} 0.732, Fe^{3+} 0.64 Å, Handb. Chem.Phys., 31st edn, 1970, F-152), this replacement is not surprising. Ito and Prondel (1968) noted a complete replacement of ferric iron by scandium in the synthetic compositions $\text{NaFeSi}_2\text{O}_6$ and $\text{NaScSi}_2\text{O}_6$. As would be expected from the smaller ionic radius of Fe^{3+} , the ferric eggonite has a smaller unit cell (Table III).

Sakpur, India. A specimen, BM 76791, presented to the British Museum (Natural History) in 1894 by Mr R.B.Foote of Junagadh, India, was originally registered as unidentified "small green crystals from a drusy cavity in a trap dyke from Sakpur, Dammagar Taluq, Baroda, Territory, Kathiawar". Sakpur, $21^{\circ}34' \text{N}$, $71^{\circ}31' \text{E}$, is on the Kathiawar peninsula, formerly in Baroda State, now in Gujarat. This specimen, now identified as eggonite by X-ray diffraction, (X8961) and by an electron-probe analysis (Table II), was examined in 1894 by

Table II. Chemical data for eggonite. Atomic ratios calculated to $\Sigma(P, V, Si) = 4$, except for analysis 8.


	1	2	3	4	5	6	7	8
P ₂ O ₅	40.8	40.3	41.0	40.5	40.10	40	40.34	33.8
V ₂ O ₅	0.04	0.4 [†]	0.02	0.01	-	-	-	-
SiO ₂	0.16	0.07	0.07	0.05	-	-	-	9.2
Sc ₂ O ₃	40.9	41.1	40.3	41.3	39.07	27	39.19	34.7
Al ₂ O ₃	0.3	0.24	0.4	0.4	-	-	-	-
Fe ₂ O ₃ *	0.02	0.07	0.05	0.03	-	12	-	0.3
CaO	0.01	-	0.15	-	-	-	-	3.2
H ₂ O	[17.7]	[17.8]	[18.0]	[17.7]	20.36	20	20.47	23.4
Sum	100	100	100.1	100	99.53	99	100.00	104.6
PO ₄ ³⁻	3.98	3.96	3.99	3.99	4	4	4	3.27
VO ₄ ³⁻	0.003	0.03	0.002	0.001	-	-	-	-
SiO ₄ ⁴⁻	0.02	0.01	0.005	0.006	-	-	-	1.05
Sc ³⁺	4.10	4.14	4.04	4.19	3.99	3.0	4	3.45
Al ³⁺	0.04	0.03	0.05	0.05	-	-	-	-
Fe ³⁺	0.002	0.006	0.004	0.003	-	1.1	-	0.03
Ca ²⁺	0.001	-	0.02	-	-	-	-	0.39
OH ⁻	0.4	0.5	0.3	0.7	-	-	-	-
H ₂ O	[6.6]	[6.6]	[6.7]	[6.5]	7.99	7.9	8	8.9

- "Altenberg", BM 56282
- Sakpur, BM 76791 Electron-probe analyses by A.M.Clark; means of 5 to 7 points.†
- Fairfield, Utah BM 1941,9 A.M.Clark; means of 5 to 7 points.†
- Fairfield, Utah BM 1965,433
- Sterretite, Fairfield, Utah; F.A.Gonyer in Larsen and Montgomery (1940), assuming "Al₂O₃" was all Sc₂O₃.
- Potash Sulfur Springs, Arkansas. Robert G.Johnson, U.S.Geol.Surv., analyst.
- Theory for ScPO₄.2H₂O.
- Kolbeckite, Saxony, after Thurnwald and Benedetti-Pichler (see text). Mean of two analyses on 3.5 and 3.0 mg.

* Total iron as Fe₂O₃.

† Varies from 0.1 to 1.0% at different points.

‡ Standards: P₂O₅, apatite; Sc₂O₃, V₂O₅, and Fe₂O₃, metal; Al₂O₃, jadeite; CaO and SiO₂, wollastonite.

A beryllium phosphate.

 mm = 5-6.16' about
 Biaxial negative, large
 axial angle.
 cleavage c imperfect.
 S.G. = 2.32 about

Lab. 564.
 H.M.
 76791.

76791.
 Small green crystals from
 a drusy cavity in a trap
 dyke from Sakpur
 Dammagar Taluk
 Beroda Territory
 N.A. M. Kathiawan

FIG. 2. H.A. Miers' sketch (top) of the Sakpur, India, eggonite crystal and (below) R.B. Foote's original label.

Table III. Physical data for eggonite.

	1a	1b	2a	2b	3a	3b	4	5
a	8.92	8.93	8.46	8.93	8.92	8.93	8.88 Å	-
b	10.26	10.25	10.09	10.25	10.22	10.25	10.08	-
c	5.41	5.447	5.34	5.44	5.44	5.445	5.42	-
β	90°	90°45'	90°40'	90°40'	90°	90°45'	90°51'	-
D	2.44	2.35	2.39	2.39	2.36	2.366	-	2.32
H	4-5	3-4	3-4	-	5	-	-	-
α _D	1.575	-	-	-	1.572	-	-	-
β _D	1.590	-	-	-	1.590	-	-	-
γ _D	1.598	-	-	-	1.601	-	-	-
2V _a	60°34'	-	-	-	60°±10°	-	-	-
Ax.pl.	(010)	-	-	-	(010)	-	-	(010)
Bx _a	(100)	-	-	-	(100)	-	-	(100)

1a. "Altenberg", data from Schrauf (1879), Krenner (1929), and Bannister (1941).

1b. "Altenberg", data from Mrose and Wappner (1959).

2a. Saxony, data from Edelmann (1926) and Schroeder and Borchert (1947).

2b. Saxony, data from Mrose and Wappner (1959).

3a. Fairfield, Utah, data from Larsen and Montgomery (1940).

3b. Fairfield, Utah, data from Mrose and Wappner (1959).

4. Potash Sulfur Springs, Arkansas.

5. Sakpur, India (BM 76791). H.A.Miers and G.T.Prior, see text.

Note: Komissarova *et al.*, 1965 [Z.Chem. 2, 429], cited by J.D.H.Donnan and H.M.Ondik, 1973 (Crystal Data, 3rd edn, 2, H-166) report a hexagonal cell for ScPO₄.2H₂O, with a 5.108, c 8.024 Å, so it may possibly be dimorphous.

H.A.Miers and by G.T.Prior (fig.2). Miers sketched a prismatic crystal, with prism angle 56°16', clearly the (011) of Larsen's sterretite, with an imperfect cleavage (Larsen's (100) normal or nearly normal to the prism. His optical observations are included in Table III; it has not been possible to complete them for lack of material.

Prior determined the density (2.32) by flotation in cadmium borotungstate solution, and made a partial qualitative analysis, finding a little H₂O, much phosphate, and after removal of the phosphate ammonia gave a gelatinous precipitate freely soluble in ammonium carbonate; he concluded that the mineral was probably a hydrated beryllium phosphate. In 1894 little was known of the chemistry of scandium, whose hydroxide, like that of beryllium, is soluble in ammonium carbonate, a fact that was almost certainly unknown to Prof.Dörfling in 1911 and led to his identifying kolbeckite as a beryllium phosphate.

A summary of the chemistry and physical properties of eggonite

No quantitative analysis of eggonite (or sterretite) has been published since the recognition of scandium as a major constituent; accordingly, a series of electron-probe analyses have been made and are included in Table II, along with the reinterpreted analyses of Gonyer and of Thurnwald and Benedetti-Pichler. The former is simple; if the presumed alumina is wholly scandia, the analysis is a sound one. The latter requires more detailed consideration.

The preliminary qualitative analysis was apparently directed to ascertaining what minor constituents were present, and no specific tests for Al or Be were made; the presence of Si and Ca and the absence of appreciable Mg and Na were demonstrated. In the quantitative analysis, the precipitation with 8-hydroxyquinoline at pH 5 to 6, intended to separate Al and Be, would result in an incomplete precipitation of Sc as Sc(C₉H₆ON)₃.C₉H₆ON; the scandium in the filtrate, after destruction of the excess reagent, would be precipitated by ammonia, and duly weighed as sulphate. The analysis has therefore been recalculated on these lines and is included in Table II; the Sc₂O₃ figure may be somewhat low, since the sulphate may have been slightly basic. Kolbeckite would thus appear to be a calcian silicatian eggonite.

REFERENCES

- 1879 A. Schrauf, *Z. Krystallogr. Mineral.* 3, 352-6
- 1892 E. S. Dana, *syst. Mineral.*, 6th edn, 905
- 1926 F. Edelmann, *Jahrb. Berg.-Hüttenwes. Sachsen*, 100, A10 [M.A. 3, 472]
- 1929 J. Krenner (K. Zimanyi, ed.), *Centralbl. Mineral.* 34-8 [M.A. 4, 332]
- 1932 Hilde Thurnwald and A. A. Benedetti-Pichler, *Mikrochemie*, 11, 200-20 [M.A. 5, 295]
- 1934 E. S. Larsen and H. Berman, *Bull. U.S. Geol. Surv.* 848, 164
- 1940 E. S. Larsen, 3rd, and A. Montgomery, *Am. Mineral.* 22, 513-8 [M.A. 8, 3]
- 1941 F. A. Bannister, *Mineral. Mag.* 26, 131-3
- 1942 M. Fleischer, *Am. Mineral.* 27, 653
- 1947 R. Schroeder and W. Borchert, *Heidelberg. Beitr. Mineral. Petrogr.* 1, 110-1 [M.A. 10, 386]
- 1950 M. H. Hey, *Index of Mineral Species and Varieties*, 408. *Brit. Mus. (Nat. Hist.)*
- 1951 C. Palache, H. Berman, and C. Frondel, *Dana's Syst. Mineral.*, 7th edn, 2, 965 and 1015
- 1954 L. Tokody, *Neues Jahrb. Mineral., Monatsh.* 204-7 [M.A. 12, 474]
- 1959 M. E. Mrose and B. Wappner, *Bull. Geol. Soc. Am.* 70, 1648-9 (abstr.)
- 1965 M. E. Mrose, *Am. Mineral.* 50, 288 (abstr.)
- 1968 C. Frondel and J. Ito, *Am. Mineral.* 53, 943-53 [M.A. 69-307]

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