

On pink epsomites and fauserite.

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IN 1865 A. Breithaupt¹ described a new mineral from Herregrund, Hungary, to which he gave the name of fauserite. It formed very pale pink crystalline aggregates and prismatic crystals, with prism angle near $88^{\circ} 42'$ (over a), apparently orthorhombic, and cleavage $b(010)$. Two other prisms with angles (over a) $54^{\circ} 39'$ and $107^{\circ} 50'$ were observed, and a pyramid p , giving $mp = 52^{\circ}$; these would correspond to forms (210), (340), and (111), and the angles are near those of epsomite. An analysis by Mollnár² gave the figures shown under I below—a magnesium and manganese sulphate hexahydrate, with the molecular ratio $\text{MgSO}_4/(\text{Mn,Mg})\text{SO}_4 = 31.62\%$. There is no evidence that the analysed material (stated to be crystalline) was homogeneous.

Some years later, J. Loczka³ studied material of similar appearance from Hodrusbánya, Hungary, which (evidently going by the similarity in appearance) he also styled fauserite; but his analysis (II below) showed a very striking difference from Mollnár's. His material was clearly a pink epsomite, the colour being due to traces of cobalt; manganese was present in only small quantity, and there were also traces of zinc and iron.

After referring to these two descriptions, Dana⁴ remarks that Loczka's work throws some doubt on the real existence of a fauserite corresponding to Breithaupt's original description and analysis. In the hope of at once obtaining evidence on this point and allocating the specimens to the proper species without question, the author

¹ A. Breithaupt, *Berg- und Hüttenmännische Zeitung*, 1865, vol. 24, p. 301.

² The second analysis quoted by Dana is Mollnár's theoretical figures.

³ J. Loczka, *Math. Természett. Közlem.* Budapest, 1891, vol. 24, p. 350; *Math. Naturwiss. Ber. aus Ungarn*, 1891, vol. 8 (for 1889-1890), p. 108.

⁴ J. D. Dana, *Syst. Min.*, 6th edit., 1892, p. 941.

TABLE I.

Analyses of pink epsomites and fauserite.

		I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Percentages.	SO ₃	34.49	32.52	32.90	34.15	32.53	32.33	31.54	32.62	32.92
	MnO	19.61	0.25	0.56	0.20	0.38	0.40	4.28	0.32	0.33
	MgO	5.15	15.47	15.98	17.24	16.93	15.24	12.76	14.58	15.59
	CoO	—	0.08	0.31	1.06	0.23	0.11	0.068	nil	0.11
	NiO	—	—	0.13	0.07	trace	trace	trace	nil	0.002
	FeO	—	0.04	0.024	trace	0.006	0.049	0.015	0.051	0.023
	ZnO	—	0.54	0.15	0.17	0.19	0.53	2.82	0.94	0.25
	H ₂ O	42.66	50.73	50.20	47.44	49.59	51.10	48.41	50.21	49.36
	Insol.	—	—	0.05	0.20	trace	trace	trace	1.02	1.00
Total ...	101.91	99.63	100.30	100.53	99.86	99.75	99.89	99.74	99.58	
Molecular parts (total bases = 100).	SO ₃	106.70	102.62	99.11	95.26	94.28	102.90	95.30	107.60	103.75
	MnO	68.38	0.89	1.93	0.64	1.26	1.45	14.78	1.21	1.19
	MgO	31.62	96.98	96.04	95.53	97.47	96.34	76.57	95.55	97.58
	CoO	—	0.28	1.00	3.16	0.71	0.37	0.22	nil	0.37
	NiO	—	—	0.53	0.21	trace	trace	trace	nil	0.01
	FeO	—	0.14	0.08	trace	0.02	0.17	0.05	0.19	0.08
	ZnO	—	1.68	0.42	0.46	0.56	1.67	8.38	3.05	0.77
(Total bases = 1).	H ₂ O	5.86	7.114	6.72	5.88	6.39	7.23	6.50	7.36	6.91
	Sp. gr.	1.888	1.670	1.68	1.68-9	1.73-5	1.68	1.70	1.70	1.68

- I. Herregrund, Hungary (now Španá Dolina, Czechoslovakia). A. Breithaupt, 1865 (loc. cit.).
- II. Hodrusbánya, Hungary (now Hodruša, Czechoslovakia). J. Loczka, 1891 (loc. cit.).
- III. Neusohl, Hungary (now Baňská Bystrica, Czechoslovakia). B.M. 33179. Extinction straight, 2E ca. 80°.
- IV. Neusohl, Hungary (now Baňská Bystrica, Czechoslovakia). B.M. 60538. 2E ca. 80°, negative.
- V. Locality unknown. B.M. 61317. 2E medium large, negative.
- VI. Herregrund, Hungary (now Španá Dolina, Czechoslovakia). B.M. 42916. Extinction straight, 2E ca. 83°. Bx_a ⊥ cleavage.
- VII. Schemnitz, Hungary (now Štiavnica, Czechoslovakia). B.M. 44274. Extinction straight, 2E 76-80°, negative, Bx_a ⊥ cleavage.
- VIII. Hodrusbánya, Hungary (now Hodruša, Czechoslovakia). B.M. 1907,878. Extinction straight, 2E ca. 83°, negative, Bx_a ⊥ cleavage.
- IX. Hodrusbánya, Hungary (now Hodruša, Czechoslovakia). B.M. 55371. Extinction straight, 2E medium large, negative. Epsomite has extinction straight, 2E 78°, negative, Bx_a ⊥ cleavage.

analysed all the 'fauserites' and pink 'epsomites' in the British Museum collection, with the results set out above (III-IX). Attention to these specimens had been drawn by Miss J. M. Sweet, who while preparing the slip-catalogue of the sulphates had been unable to identify any of the specimens as fauserite. It will be noticed that

TABLE II.
Synthetic study of the system $\text{MgSO}_4\text{-MnSO}_4\text{-H}_2\text{O}$.

Experiment No.	Moist Crystals			Solution		
	MgSO_4 .	MnSO_4 .	H_2O .	MgSO_4 .	MnSO_4 .	H_2O .
1	—	—	—	—	39.1	60.9
2	3.2	59.9	36.9	10.9	34.0	65.8
3	5.1	50.9	44.0	7.7	30.3	62.0
4	15.1	36.8	48.1	7.0	35.2	57.8
5	27.9	21.8	50.3	9.2	26.6	64.2
6	28.5	19.2	52.3	8.1	28.0	63.9
7	31.5	15.9	52.6	9.7	27.3	63.0
8	33.1	12.4	55.5	9.6	25.5	64.9
9	36.8	11.3	51.9	10.5	22.7	66.8
10	36.2	10.3	53.5	11.1	22.5	66.4
11	37.5	9.5	53.0	10.8	21.2	68.0
12	32.2	14.6	53.2	8.2	27.6	64.2
13	43.0	6.9	50.1	11.7	21.2	67.1
14	32.1	11.8	56.1	12.0	19.1	68.9
15	31.5	16.4	52.1	14.9	16.6	68.5
16	42.1	6.0	51.9	13.9	15.1	71.0
17	42.7	3.1	54.2	17.6	9.3	73.1
18	42.8	2.3	54.9	20.1	5.7	74.2
19	—	—	—	25.6	—	74.4

Microscopic examination of the crystals in experiments 1, 2, and 3 showed them to be anorthic, giving extinction-angles up to 15° ; they are accordingly the pentahydrate, isomorphous with chalcantite. Experiments 6 to 19 gave orthorhombic crystals with optic axial angles $2V\ 50^\circ$ approximately, negative. From the constancy of this figure it is clear that the admixture of as much as 30 molecules per cent. of $\text{MnSO}_4 \cdot 7\text{H}_2\text{O}$ has little if any effect on the optic axial angle of epsomite. Experiments 4 and 5 gave mixtures of the anorthic and orthorhombic crystals.

the water content in several cases falls considerably below seven molecules; the specimens in question were definitely somewhat effloresced, and an optical examination showed that the main part of the material was truly an epsomite, the low water being due to the presence of a small portion of kieserite produced by efflorescence. All the specimens correspond more or less to Loczka's in composition, containing cobalt as colouring agent, together with traces of nickel, iron, and zinc, and a variable but small proportion of manganese. In optical properties and specific gravity they agree with epsomite, all showing straight extinction and medium birefringence and having a refractive index in the neighbourhood of 1.45.

While satisfactory in other respects, these analyses throw no light on the real existence or otherwise of Breithaupt's fauserite, with the

TABLE III.

Recalculation of the data on the system $\text{MgSO}_4\text{-MnSO}_4\text{-H}_2\text{O}$,
in molecular proportions.

Experiment No.	Molecular percentage composition of the									Molecular ratio $\frac{\text{MgSO}_4}{(\text{Mn,Mg})\text{SO}_4} \times 100$ for the Solution. Crystals.	
	Moist crystals			Solution			Dry crystals				
	MgSO_4	MnSO_4	H_2O	MgSO_4	MnSO_4	H_2O	MgSO_4	MnSO_4	H_2O		
1	—	—	—	—	7.1	92.9	—	16.7	83.3	0.0	0.0
2	1.1	16.8	82.8	1.9	5.1	93.0	0.6	16.1	83.3	26.7	3.6
3	1.5	12.0	86.5	1.7	5.4	92.9	1.4	15.3	83.3	24.3	7.8
4	4.1	8.0	87.9	1.6	6.8	91.6	—	—	—	19.3	—
5	7.3	4.6	88.1	2.0	4.6	93.4	—	—	—	30.2	—
6	7.3	3.9	88.8	1.8	4.9	93.3	8.9	3.6	87.5	26.5	71.2
7	8.0	3.2	88.8	2.2	4.8	93.0	9.8	2.7	87.5	30.8	78.4
8	8.1	2.4	89.5	2.1	4.4	93.5	10.9	1.6	87.5	32.0	87.2
9	9.4	2.3	88.3	2.2	3.8	94.0	10.4	2.1	87.5	36.2	83.2
10	9.0	2.1	88.9	2.4	3.8	93.8	11.0	1.5	87.5	38.2	88.0
11	9.4	1.9	88.7	2.2	3.5	94.3	10.7	1.8	87.5	39.1	85.6
12	8.1	2.9	89.0	1.8	4.6	93.6	10.1	2.4	87.5	39.2	80.8
13	11.2	1.4	87.4	2.5	3.6	93.9	11.1	1.4	87.5	40.9	89.2
14	7.7	2.3	90.0	2.5	3.1	94.4	10.9	1.6	87.5	44.2	87.2
15	8.0	3.3	88.7	3.1	2.7	94.2	9.0	3.5	87.5	52.9	72.4
16	10.7	1.2	88.1	2.8	2.4	94.8	11.4	1.1	87.5	53.8	91.2
17	10.5	0.6	88.9	3.4	1.5	95.1	12.2	0.3	87.5	69.9	97.6
18	10.4	0.5	89.1	3.9	0.9	95.2	12.3	0.2	87.5	81.4	98.0
19	—	—	—	4.9	—	95.1	12.5	—	87.5	100.0	100.0

ratio $\text{MgSO}_4/(\text{Mn,Mg})\text{SO}_4$ about 33 %. Recourse was therefore had to synthetic experiments, in the hope of finding conditions under which such material could crystallize. If these conditions were such as might reasonably be expected in nature, it would appear reasonable to conclude that Breithaupt's results were correct, and fauserite would stand as a reasonably well-established, but rare species. Unfortunately, the results were not quite so definite as had been hoped; although the evidence is very strong for the view that Mollnár's analysis was made on a mixture, and that Breithaupt's crystals did not contain more than 30 to 40 % of $\text{MnSO}_4 \cdot 7\text{H}_2\text{O}$, the matter is still open to some doubt.

The synthetic experiments were of a very simple nature but gave fairly satisfactory results. A number of mixtures of magnesium and manganese sulphates were dissolved in a little water at a gentle heat and allowed to stand in corked tubes in a cool corner of the laboratory for five months to attain equilibrium; the temperature was about

17–19° C. throughout. Then the crystals were filtered off, and the mother-liquor analysed; to avoid errors introduced by attempts at drying, the moist crystals were analysed,¹ after pressing out most of the mother-liquor between filter-paper. The composition of the crystals without the adherent mother-liquor is then arrived at by a slight modification of Schreinemaker's method. In fig. 1, *L* is the composition of the mother-liquor in one experiment and *M* the composition of the moist crystals deposited therefrom. The composition of the crystals themselves must lie somewhere along the line *LM* extended. Since microscopic examination showed that the crystals were homogeneous and isomorphous with epsomite, we are justified in assuming that their composition must also be represented by a point along the line *El*, which represents $(\text{Mn,Mg})\text{SO}_4 \cdot 7\text{H}_2\text{O}$. Therefore the composition of the crystals is given by the point *C*, at the intersection of *LM* and *El*. This method cannot, of course, be directly applied to the eutectic *P*, the precise composition of the heterogeneous mixture of crystals deposited here remaining uncertain; but this is of no importance, as the composition of the mixture is of no interest.²

In this way we are able to plot the solubility curves of the system $\text{MnSO}_4\text{--MgSO}_4\text{--H}_2\text{O}$ at 17–19° C. (fig. 1), from the analytical data of table II. We see that manganous sulphate solutions containing up to about 25 % of magnesium sulphate (in molecular parts, $\text{MgSO}_4 \times 100 / (\text{Mn,Mg})\text{SO}_4$) deposit at this temperature crystals of $(\text{Mn,Mg})\text{SO}_4 \cdot 5\text{H}_2\text{O}$, isomorphous with chalcantite, and containing a much smaller proportion of magnesium than the solution (about 6 % in the maximum). More magnesium-rich solutions deposit

¹ The analyses were performed by Mr. S. E. Ellis of the Mineral Department, the method used being as follows: a portion of the solution or moist crystals was weighed out, diluted to 250 c.c., and an aliquot part taken for the estimation of sulphate as BaSO_4 . In a second portion $(\text{MnO} + \text{MgO})$ was estimated as the mixed pyrophosphates, while a third served for the manganese estimation. In the manganese-rich solutions and crystals this was carried out gravimetrically, the manganese being precipitated as sulphide and converted to pyrophosphate, but when more magnesium was present, the volumetric determination of manganese by Volhard's method, with KMnO_4 and zinc acetate, was employed. Water was obtained by difference.

² The composition of the eutectic mixture could be found if desired, but is of no value. If in fig. 1 *l* and *l'* (derived from fig. 2) be the compositions of the two mixed crystals involved in the eutectic, the composition of the mixture must lie along *ll'*, and is given by the point at which the tie-line joining the compositions of solution and moist crystals cuts *ll'*.

$(\text{Mg},\text{Mn})\text{SO}_4 \cdot 7\text{H}_2\text{O}$, isomorphous with epsomite, and containing a much higher proportion of magnesium than the solution (70% in the minimum). The eutectic solution has a composition about H_2O 92.6 mols., MgSO_4 1.85 mols., MnSO_4 5.55 mols.; or H_2O 61.1%, MgSO_4 8.2%, MnSO_4 30.7%. Fig. 1 really gives a com-

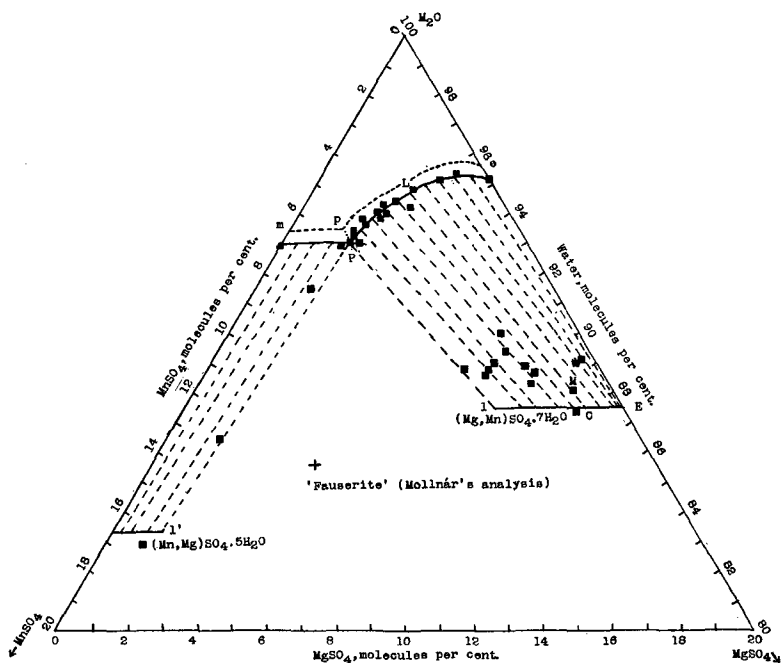


FIG. 1.

plete account of the system,¹ but the relation between the proportion of the two salts in the solution and in the crystals will be better understood from fig. 2, where they are directly plotted.

We now see that a homogeneous crystalline phase of the composition of Breithaupt's fauserite could not be deposited from a solution of magnesium and manganese sulphates at 17–19° C. Two possibilities now arise. Either Mollnár's analysis was made on heterogeneous material, consisting of a mixture of $(\text{Mn},\text{Mg})\text{SO}_4 \cdot 7\text{H}_2\text{O}$,

¹ The dotted tie-lines (e.g. LMC) in fig. 1 are drawn in by the aid of the smoothed curve of fig. 2, the actual tie-lines between the analyses of liquid and crystals being omitted for clarity.

and $(\text{Mn,Mg})\text{SO}_4 \cdot 5\text{H}_2\text{O}$ —a possibility supported by the low water content, or the deposition may have occurred at a different temperature, at which the relations might be different.¹ Let us consider this second possibility. The dotted curves *ep* and *mp* in fig. 1 trace the probable course of the solubility curves at 9° C., being based on the known solubilities (*e* and *m*) of $\text{MnSO}_4 \cdot 5\text{H}_2\text{O}$ and $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ at that temperature and the fact that the curves usually tend to move parallel with themselves on change of temperature. The line *Pp* will then trace the probable change of the eutectic with temperature from 17° to 9° C. Now change of temperature does not usually affect the relation between the proportions of the two salts in the mixed crystal and in the solution very much; therefore, we may reasonably extend the $(\text{Mg,Mn})\text{SO}_4 \cdot 7\text{H}_2\text{O}$ curve of fig. 2, to about *u* for a temperature of 9° C., or perhaps to about *u'* for 0° C. But even then there is no sign of any approach to the point *F*, which would correspond to deposition of crystals of the composition given by Mollnár's analysis (apart from the water content).

Thus we are led to conclude that Mollnár's analysis was made on a heterogeneous eutectic mixture of $(\text{Mn,Mg})\text{SO}_4 \cdot 5\text{H}_2\text{O}$, and $(\text{Mg,Mn})\text{SO}_4 \cdot 7\text{H}_2\text{O}$; while Breithaupt's orthorhombic crystals (which were undoubtedly isomorphous with epsomite² and hence had $7\text{H}_2\text{O}$) were probably not richer in manganese than between 30 and 40 mols. % $\text{MnSO}_4 \cdot 7\text{H}_2\text{O}$. It is perhaps additional confirmation to note that if we assume Mollnár's analysis to be accurate and the pentahydrate to have contained 5 mols. % of $\text{MgSO}_4 \cdot 5\text{H}_2\text{O}$, the mixture works out at 57 parts of this hydrate to 43 parts of $(\text{Mg,Mn})\text{SO}_4 \cdot 7\text{H}_2\text{O}$, containing 33 mols. % $\text{MnSO}_4 \cdot 7\text{H}_2\text{O}$ —a eutectic which might clearly have been deposited at a temperature a little lower than 17–19° C.

It may be noted that the system $\text{MgSO}_4\text{--MnSO}_4\text{--H}_2\text{O}$ was studied

¹ The analysis is stated to have been made on clear crystals, which makes it improbable that the low water was due to efflorescence. On the other hand, the crystals might well have been a mixture, since it is unlikely that the best developed material would be used, and the author has observed that crystals of $(\text{Mg,Mn})\text{SO}_4 \cdot 7\text{H}_2\text{O}$ and $(\text{Mn,Mg})\text{SO}_4 \cdot 5\text{H}_2\text{O}$ are not readily distinguished unless well developed or unless optical examination is resorted to. There is a third but unlikely possibility; the analysed crystals may have really been a hexahydrate, since monoclinic and tetragonal series of hexahydrates are known among the vitriols. But Breithaupt's measurements cannot be reconciled with either series.

² Epsomite is orthorhombic and has the *b*-cleavage, $mm''' = 89^\circ 26'$ (fauserite $88^\circ 42'$).

by C. F. Rammelsberg,¹ who found that crystals deposited at the ordinary temperature containing up to 43 mols. % MnSO_4 had the epsomite form, in fair agreement with the present results. But

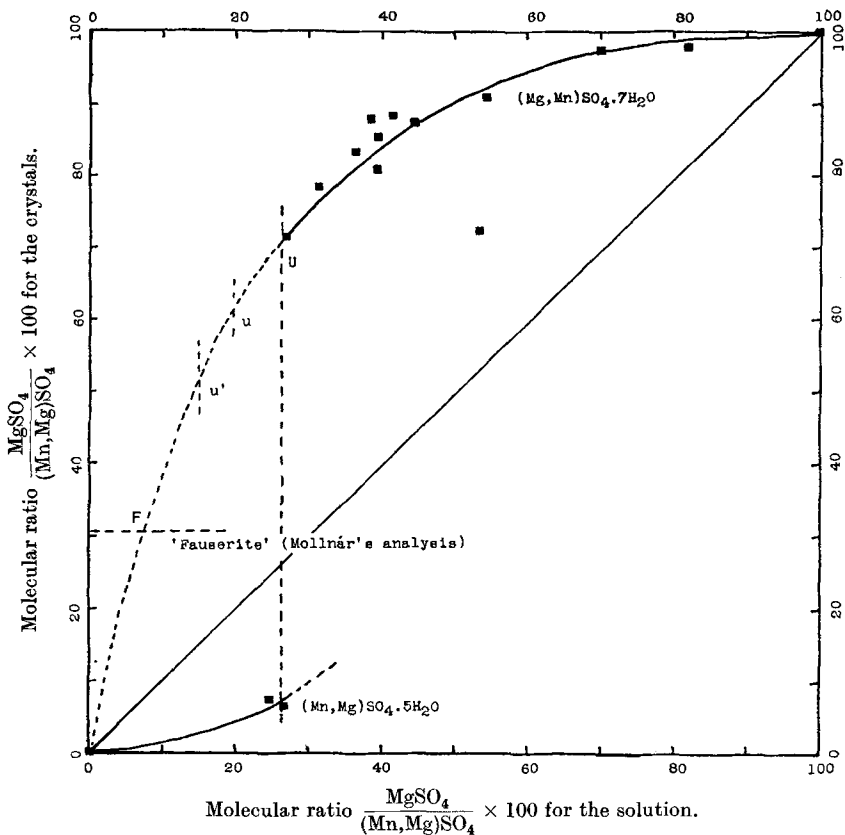


FIG. 2.

the more manganese-rich crystals he found to be a heptahydrate isomorphous with melanterite and containing up to 34 mols. % MgSO_4 ; this was perhaps a metastable equilibrium, which readily occurs with manganous sulphate; moreover, below 9°C . manganous sulphate heptahydrate is stable and is monoclinic and isomorphous with melanterite. R. Hollmann,² on the other hand, found a well-

¹ C. F. Rammelsberg, *Ann. Phys. Chem. (Poggendorff)*, 1854, vol. 91, p. 342.

² R. Hollmann, *Zeits. Physik. Chem.*, 1901, vol. 37, p. 209 (footnote 4).

defined series of triclinic mixed crystals, 'probably a pentahydrate', but he gives no quantitative data. R. Balló¹ does not appear to have examined his solid phases for homogeneity, and believed he had discovered a series of mixed crystals of $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ and $\text{MnSO}_4 \cdot 5\text{H}_2\text{O}$, so that his results are practically useless. However, the supposed solubility minimum, at which crystals and solution contain the two salts in the same proportion, and to which continued evaporation led, must have been the eutectic; he found it to lie at 19.5 mols. % MgSO_4 , at 18–21° C., in moderately good agreement with the present result. His conclusions with regard to fauserite are, of course, worthless.

With regard to the application of the name fauserite, it seems undesirable to associate it with the mixture analysed by Mollnár, and it is suggested that it be retained for manganiferous epsomites containing a considerable proportion of manganese, such as the crystals studied by Breithaupt which would be the richest possible in manganese. On the high magnesium side, no precise limit to the variety can be suggested, but it appears reasonable to regard analysis VII (B.M. 44274) with 15 mols. % MnSO_4 as a fauserite. The case is parallel to that of melanterite, pisanite, and chalcantinite studied by H. F. Collins²; melanterite corresponds to epsomite, fauserite to pisanite, and $\text{MnSO}_4 \cdot 5\text{H}_2\text{O}$ (not known in nature) to chalcantinite. The stalactitic 'fauserite' analysed by Mollnár would correspond to a 'pisanite' containing over 19% CuO and really consisting of a mixture of pisanite and chalcantinite (compare H. F. Collins, loc. cit., p. 37).

If the above interpretation of the data of Breithaupt and Mollnár is correct, the material analysed by the latter must have contained about 57% of $(\text{Mn}, \text{Mg})\text{SO}_4 \cdot 5\text{H}_2\text{O}$, hitherto unrecorded as a mineral. The selection of a name for this new member of the chalcantinite group had, however, best await the definite confirmation of its occurrence and physical properties.

¹ R. Balló [Magyar Chem. Folyóirat, 1907, vol. 13, pp. 17, 33, 49, 65, 81, and 97]; abstr. in Zeits. Kryst. Min., 1910, vol. 47, p. 298.

² H. F. Collins, Min. Mag., 1923, vol. 20, p. 32.