

*On a group of minerals formed by the combustion of
pyritous shales in Midlothian.*

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AT the Emily coal pit, Arniston, Midlothian, a heap of shaly refuse from the workings became spontaneously ignited some time ago, the cause being presumably the evolution of heat by atmospheric oxidation of iron-pyrites. As a result of the slow combustion of the shale, accompanied as it is by liberation of sulphuric vapours, a number of uncommon mineral-species have been formed and deposited as sublimates in the cooler parts of the heap. The credit of discovering these minerals and recognizing their unusual character belongs to Mr. A. Craig Christie, F.L.S., from whom the specimens in the Royal Scottish Museum were obtained.

So far, five species have been distinguished, of which one may be doubtfully described as new, while three are new to Scotland. These five are the following:—

Native sulphur

Ammonium chloride (sal-ammoniac)

? Ammonia-alum (tschermigite)

Ammonium sulphate (mascagnite)

Aluminium sulphate (? new species).

Sulphur appears as a powdery encrustation and also in minute crystals which do not exceed one-tenth of a millimetre in greatest diameter. The commonest form is the simple pyramid p {111}, many crystals of this form lying on their sides in parallel position and often joined together in stacks. The combination pc (111, 001) is also commonly seen, while either n {011} or e {101} may be present in addition. The pyramid-faces almost invariably show triangular pittings and depressions or 'sunk panels'.

Ammonium chloride occurs in fibrous crusts, much less commonly in crystals. The latter are either simple rhombic-dodecahedra or complete

penetration twins of two dodecahedra with o (111) as twin-plane (fig. 2). In the former case they are usually elongated along a trigonal axis (fig. 1). The largest crystals measure only about one millimetre in diameter. Groth,¹ and more recently Goldschmidt and Schröder,² have described a similar occurrence of sal-ammoniac in the burning dump of a coal pit at Burgk, Dresden. The crystals from that locality, however, are generally rough and skeletal, while the Arniston crystals are well

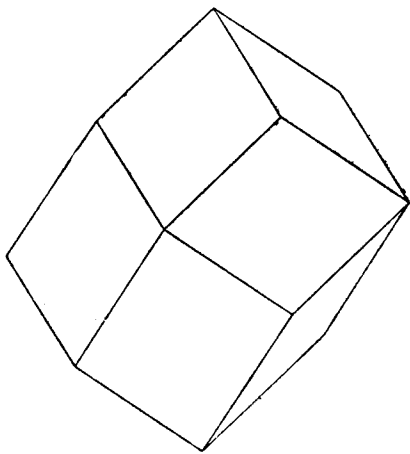


Fig. 1.

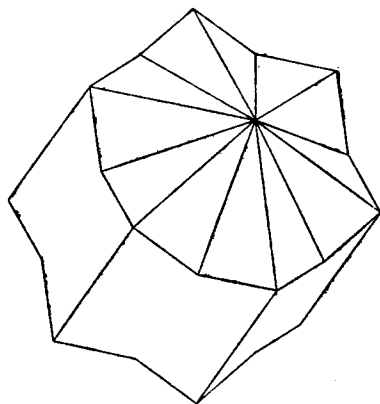


Fig. 2.

Crystals of Sal-ammoniac from Arniston, Midlothian.

developed and highly lustrous. Vesuvian crystals of the same mineral show rather complex combinations.³ Greg and Lettsom⁴ record the occurrence of sal-ammoniac 'in the vicinity of ignited coal-seams, as near Newcastle in Northumberland, and at Bradley in Staffordshire; also at Hurler, near Paisley'.

Ammonia-alum (tschermigite) was detected by Mr. Christie by qualitative tests. I have examined all the specimens in the Museum with particular care but fail to find anything which I can refer to this species.

¹ P. Groth, 'Ueber neu gebildete Mineralproducte auf einem brennenden Steinkohlenfelde bei Dresden.' Sitzungs-Ber. naturw. Ges. Isis, Dresden, 1867, pp. 68-70.

² V. Goldschmidt and R. Schröder, Zeits. Kryst. Min., 1908, vol. xlv, p. 220.

³ V. Goldschmidt and R. Schröder, loc. cit., p. 221.

⁴ R. P. Greg and W. G. Lettsom, 'Manual of the Mineralogy of Great Britain and Ireland,' 1858, p. 23.

It is, however, quite probable that the alum really occurs, since the necessary ammonium and aluminium sulphates are present.

Ammonium sulphate (mascagnite) is found only in fibrous and mealy encrustations which show no peculiar characters. Greg and Lettsom¹ note the occurrence of mascagnite 'at Bradley in Staffordshire, in ignited coal-beds'.

Aluminium sulphate occurs in porous, highly vesicular masses cementing bits of cinder and burnt shale together into a kind of conglomerate. The portions which seem to be purest are quite white, but the material is more commonly stained yellow or brown by ferric sulphate. Since their arrival in the Museum the specimens have shown a tendency to deliquescence, accompanied by formation of basic iron salts and liberation of sulphuric acid. These changes make it somewhat difficult to determine the original composition of the aluminium salt. The substance in its present state contains a good deal of water, but some of this certainly is, and therefore all may be, due to deliquescence. Mr. Christie informs me that the specimens were taken by him from a part of the dump which was red-hot and in active combustion, and since the appearance of the material is that of a fused product, it seems that at the time of its removal it must have been practically anhydrous. For the purpose of analysis an undetermined weight of the cinder with adhering sulphate was treated with cold water, and all insoluble matter was filtered off and rejected. The solution was then analysed in two portions, with the results shown in the following table. Columns I and II give the actual quantities found, in grams, while column III gives the percentages of the oxides as calculated from these quantities:—

	I	II	III
Al ₂ O ₃ ...	0.0924 ...	0.0925 ...	20.44
Fe ₂ O ₃ ...	0.0478 ...	0.0477 ...	10.57
CaO ...	not determined ...	0.0049 ...	1.08
SO ₃ ...	0.8071 ...	not determined ...	67.91
			100.00

Ammonia, magnesia, and alkalis were absent or inappreciable. By calculating the oxides into sulphates, the following proportions are obtained for the latter:—

¹ R. P. Greg and W. G. Lettsom, loc. cit., p. 70.

$\text{Al}_2(\text{SO}_4)_3$...	68.13
$\text{Fe}_2(\text{SO}_4)_3$...	26.28
CaSO_4	...	2.62
H_2SO_4	...	2.97
		100.00

The presence of the above excess of acid over bases makes it practically certain that the aluminium is present in the form of the normal sulphate; this view is supported by the solubility of the material, most basic salts of aluminium and iron being insoluble in water. Of the known sulphates of aluminium, alunogen, halotrichite, aluminite, felsöbanyite, and paraluminite are hydrous sulphates containing from nine to twenty-four molecules of water of crystallization, while aluminite, felsöbanyite, and alumian are basic salts and are insoluble in water. On the whole, the composition indicated above seems to have its nearest parallel in that of halotrichite, and it is suggested that the substance may have originated as a 'berg-butter' or impure halotrichite, that it was subsequently dehydrated by heat, and that it is now returning by absorption of moisture to its former condition. If this suggestion is correct, the pure, white substance, in its dehydrated condition as anhydrous aluminium sulphate, would represent a new mineral-species.

In conclusion, I wish to anticipate an objection that may be raised to the inclusion of these substances among minerals. It is true that the shale heap in which they originated is an artificial creation. Since, however, the materials of which the heap is composed are entirely natural, and the combustion has from the first been spontaneous, it is obvious that the process might be paralleled at any place where pyritous and carbonaceous shales are exposed to atmospheric oxidation (e.g. the 'burning cliffs' of Lyme Regis, Charmouth, &c.; see *Geol. Mag.*, 1908, pp. 561-563). In this respect these substances have certainly a more solid claim to recognition as minerals than the laurionite and other minerals of Laurion, Greece, which have been formed from a purely artificial lead-slag. As the latter are accepted and described by all writers on mineralogy, I see no reason for refusing to recognize as minerals the substances which are discussed in the foregoing pages.