Spangolite.

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In the year 1890 Mr. S. L. Penfield described a new copper mineral, to which he gave the name of Spangolite in honour of Mr. Norman Spang, by whom it was first brought to his notice. Of this beautiful mineral only a single specimen was found, and the exact locality has never been ascertained; it belonged to a man living near Tombstone in Arizona, who had gathered together a collection of minerals within a radius of about 200 miles, and it is described by Mr. Penfield as "a rounded mass of impure cuprite which was mostly covered with hexagonal crystals of Spangolite associated with a few crystals of azurite and some slender prismatic crystals of a copper mineral containing chlorine, probably atacamite."

The Spangolite itself occurs in large hexagonal tables or short prisms of a magnificent deep green colour, as may be seen from a portion of the original specimen presented by Mr. Penfield to the British Museum. A full description of the mineral is to be found in Dana's *System of Mineralogy*, Sixth Edition, p. 919, taken from the original paper by Penfield in the *American Journal of Science*, Vol. XXXIX. p. 370.

In June 1893 I was engaged in company with Mr. Fletcher in making a selection from the fine old collection of minerals (mostly Cornish) belonging to Mr. J. C. Williams, of Caerhays, Cornwall—a portion of which he desired to present to the British Museum. Among the specimens selected was one which presented an unusual appearance; it consisted of granular quartz (slightly gossany), upon both sides of which was a little massive cuprite covered and partly replaced by various green copper minerals; chrysocolla, malachite, liroconite and clinoclase, and a little chessylite. In the midst of these, and upon both sides of the specimen, are groups of brilliant translucent crystals of a deep emerald green colour inclined to indigo; these present the aspect of an acute hexagonal pyramid having the apex truncated by a bright basal plane; they are about 2½ mm. in length and ¾ mm. in breadth (see *Nature*, 48 (1893), p. 426).

The examination of a minute group of crystals by Mr Prior and myself showed the mineral to be a hydrated sulphate and chloride of copper and aluminium, insoluble in water but readily soluble in acids.

In these and all other respects it was found to be identical with the Spangolite of Penfield; the mineral belongs to the rhombohedral system; the pyramid angle is 53°7′ (Penfield 53°11½′); it has a perfect basal cleavage; it is uniaxial with strong negative birefringence; the specific gravity determined by suspending a fragment in solution of cadmium borotungstate is 3·07 (Penfield 3·141); the basal plane or a cleavage plate subjected to the action of very dilute acids becomes immediately covered with beautiful etched triangles identical with those described by Penfield.

It will be seen that the only difference between the American and the English specimen is the habit, but the faces present are the same, with the exception that the latter is less rich in forms; closer examination of a crystal isolated from a small group shows that the acute pyramid terminates a combination of two hexagonal prisms, as shown in the accompanying figure; both the prisms and pyramid are striated horizontally.

Information regarding locality which is dubious for the American mineral is totally lacking in the case of the English specimen; but the associated minerals are those characteristic of the mines of the St. Day district, near Redruth, Cornwall, from which, moreover, most of the Williams collection was obtained. The character and appearance of the clinoclase and liroconite leave absolutely no doubt that this is the locality at which the Spangolite must have been found.

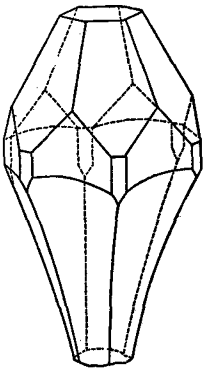
The St. Day district formerly produced a number of rare copper minerals, many of which are almost unknown elsewhere. The only locality which presents the same associated minerals is the Tintic district in Utah, more especially the Mammoth mine; among the minerals which occur both at this mine and in the St. Day mines are brochantite, pharmacosiderite, olivenite, cornwallite, chalcophyllite, clinoclase, and possibly erinite; among the St. Day minerals almost the only species which are not recorded from the Mammoth mine are liroconite and the rare sulphato-chloride connellite; further, the resemblance between the associated minerals at the two localities is most striking. Considering the doubtful nature of the evidence, it seems quite possible that the American specimen of Spangolite may have been brought from the Tintic district.

The St. Day mines have been closed for more than 30 years, and my endeavour to get information on the spot regarding the exact mine from which the rare arsenates of copper were raised has been unavailing, in spite of the kind assistance of Mr. Letcher of St. Day. Attempts to find another specimen of the mineral in any English collection have also been fruitless; all available specimens of connellite in particular were examined, since the two minerals might be expected to occur together; but no Spangolite was found.

In August 1893, however, I happened to visit Professor Liebisch at Göttingen University, and my attention was then attracted by a small example of Cornish connellite, which was obtained for the Göttingen Museum by Sartorius von Waltershausen in 1868. On this specimen associated with connellite are isolated crystals of Spangolite very closely resembling those described above both in colour and habit; they occur with the connellite upon a light green scaly arsenate of copper, which overlies a thin coating of chrysocolla upon a matrix consisting of vein quartz and cuprite; there is also chalcophyllite upon the quartz and a little stalactitic malachite. Some of the minerals have undergone considerable change, the connellite having been at one point transformed into a light green and the chalcophyllite into a light brown substance.

This specimen possesses a special interest in the association of the two sulphato-chlorides, Spangolite and connellite; they appear to be contemporaneous, and to have been produced under the same conditions. (See *Neues Jahrb. f. Mineralogie*, 1893 (2), p. 174).

On the Göttingen example the Spangolite occurs, not in groups, but in isolated crystals, which have perfectly brilliant terminations and large basal planes, but taper down in an uneven manner towards the attached end. This gives the crystals the peculiar appearance represented in the figure, and the habit at once suggests a hemimorphic development; whether the crystals are really hemimorphic could not be decided by goniometric measurement on account of the curved and uneven nature of the attached ends, and it appeared hopeless to search for a pyro-electric character upon crystals of so small a size, less than ¾ mm. in length.



The attempt was, however, made by the Kundt process of dusting with a mixture of red lead and sulphur, and to my great surprise was perfectly successful; the character is so pronounced that the crystals separate the red lead and the sulphur in a very marked manner, and may be easily lifted with the grains adhering. During cooling the crystal becomes negatively electrified at the pyramidal unattached end, and positively electrified at the tapering attached end. Both specimens of Cornish Spangolite behaved alike in this respect. Simultaneous experiments performed on crystals of connellite of the same size showed no indications of pyro-electricity.

Twinning occasionally takes place, as was proved by a crystal from the Göttingen specimen which consisted of two individuals united by their tapering ends in the fashion of an hour-glass. In this crystal the sulphur adhered in the form of a ring at the narrowest point where the two individuals meet.

In order to obtain independent evidence of the hemimorphic character of the mineral, experiments were next made upon the etched figures, it being thought that possibly some difference might be found between the etching upon the upper and under surface of a cleavage plate. This was found to be the case; cleavage flakes exposed to the action of dilute hydrochloric acid showed upon both sides the characteristic etched triangles figured by Penfield; these were identical in form, but very different in dimensions; the plates were invariably attacked with much greater rapidity upon the lower or attached end than upon the surface directed towards the unattached end of the crystal.

Finally, the relation between Spangolite and connellite is a matter of considerable interest; the two minerals have a similar composition; they resemble one another in habit, and also in symmetry, although the observations of Maskelyne indicate that connellite belongs to the hexagonal type, whereas the etched figures show Spangolite to be rhombohedral. Now if the hexagonal pyramid of connellite can be supposed to belong to the same vertical series as those of Spangolite, it will be found that its vertical axis would be 1·335 as compared with 2·0108 for Spangolite, *i.e.* exactly $\frac{2}{3}$ of the latter. It is possible, therefore, that there may be an additive relation between the two minerals as regards chemical composition which affects the length and polarity of the vertical axis.

The composition of Spangolite is established beyond any doubt by the analysis of Penfield, who was able to use three grams of the pure crystals for the purpose, and that the chlorine and alumina are essential is confirmed by their presence in the Cornish specimen.

On the other hand, Penfield's analysis of connellite was made on only 0·074 gram, and can scarcely be regarded as certain.

Although resembling one another in the above respects, the two minerals may be distinguished with perfect safety by their physical characters. Spangolite has a perfect basal cleavage and negative birefringence, and is pyro-electric; connellite has no basal cleavage, has positive birefringence, and does not exhibit pyro-electricity.