Siliceous sinter from Lustleigh, Devon.

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THE district round Lustleigh, near Bovey Tracey, is mined on a small scale for a very fine quality of micaceous haematite, which occurs there in well-defined lodes traversing the granite. This soft and powdery variety of haematite, known both locally and in the trade as 'shining ore', is used for a variety of purposes, but principally as the basis of a rust-proof paint. The ore and its mode of occurrence have been briefly described by J. S. Martin,[1] and for the purpose of this short paper no further description of the mines in general will be necessary.

The sinter was found at the Plumley mine, and as far as could be ascertained occurs in only one of the several lodes that have been worked there. Unfortunately, this particular lode was considered unsatisfactory owing to the hardness of the ore, and the trial pits were filled in and the lode abandoned. It is from an examination of the material found in the dumps, and from information obtained from Mr. W. H. Hosking of Newton Abbot (the mining engineer who examined the lode when the trial pits were sunk) that the following information has been obtained.

The lode is completely cemented by colloidal silica, and the micaceous haematite, which in the other lodes occurs as a soft powder, is here of a coarse nature, and is bound by the silica into a hard stony mass in which occur well-developed crystals of white fluor-apatite, masses of acicular, brown tourmaline, and cavities containing quartz crystals coated with chalcedony. The lode contains thick layers of almost pure sinter, very like lithomarge in appearance, and until analysed it was considered to be a variety of that mineral.

The material is hard and compact, but extremely fragile, and is liable to splinter and break up conchoidally even when most carefully handled. It is opaque, and while some specimens are almost pure white, the majority are delicately banded in light shades of red according to the quantity of haematite included. Interbanded with the sinter are occasional thin layers composed of fragments of quartz and tourmaline.

[1] J. S. Martin, Trans. Manchester Geol. Soc., 1895, vol. 23, p. 162.

In many cases the layers of sinter are rippled and folded in an interesting manner (well shown on polished surfaces), and it appears evident that the material as a whole has been deposited from solution, layer by layer, on the walls of the lode in the form of a siliceous jelly, and that a gradual stiffening and ultimate solidification of the jelly has taken place by loss of water. The shrinkage caused by this loss of water together with the position of the gelatinous material on the hanging-wall of the lode would account for ridges and sagging folds on the surface of the jelly, and these would in turn become covered by later deposits, giving rise to the rippled banding observed in the solidified material. The extremely fragile nature of the sinter can be accounted for by the strains set up throughout the material by the shrinkage.

Thin sections of the sinter showed a few flakes of haematite, and small fragments of quartz and tourmaline, enclosed in a finely granular, isotropic groundmass.

The following analysis was made on a carefully selected specimen of a pale-red colour, perfectly fresh and unaltered, and free from visible inclusions:

SiO_2	69·76 per cent.
Al_2O_3	2·68
Fe_2O_3	5·38
CaO	trace
Na_2O	0·36
K_2O	0·76
P_2O	trace
H_2O (at 105° C.)	18·62
H_2O ($>$ 105° C.)	2·38
	99·94
Sp. gr.	1·73

The proportion of water (21 per cent.) is remarkable, and appears to be abnormally high for a sinter or opal of compact (non-porous) texture. The values for iron were found to vary greatly in a number of analyses made on other specimens of different colour. The ratio of silica to water, however, was remarkably constant in those specimens which were free from signs of alteration.

On examining the large masses of sinter which have suffered exposure at the surface of the dumps for many years, it was found that they were covered with a thin layer (in no case more than half an inch in thickness) of soft, white material which adheres strongly to the tongue, and which is merely a zone of partial dehydration. Below this layer the sinter is hard and unaltered, and has its characteristic brittle and almost porcellaneous appearance. In most cases the soft crust has lost the usual red colour and become distinctly yellow, presumably by hydration of the haematite inclusions.

A fragment of the fresh sinter of almost blood-red colour was placed in a desiccator over sulphuric acid. After three months the specimen was found to have lost 0·23 per cent. of its water, and the red colour had almost completely disappeared, the material then having a pinkish-white appearance throughout. By soaking in water for a few minutes the red colour reappeared.

The origin of this sinter and its associated minerals (tourmaline, apatite, and micaceous haematite) is of considerable interest, though perhaps rather beyond the scope of this paper. The iron appears to have been carried up fissures in the granite by water-vapour perhaps at a temperature above its critical point. On cooling, liquefaction would be followed sooner or later by the copious precipitation of the iron in the form of finely divided flakes of micaceous haematite. There do not seem to be any grounds for suggesting that the haematite may have separated out above the critical point of water. The fact that haematite can be prepared artificially from aqueous solutions at a temperature of 210° (Wibel)[1] suggests that the ferric oxide probably remained in solution at temperatures above this figure.

It is quite possible that these bodies of haematite may be the result of segregation of the materials into zones, according to their solubilities, under the varying conditions which must have existed at different levels. That the sinter has been found in only one out of the many lodes which exist in this neighbourhood seems to suggest that this particular lode was formed under special conditions. It may have been formed in a lateral fissure which had no outlet at a higher level, but which had a circulation of mineral-bearing solutions derived from one of the larger lodes which run close to it. Solutions circulating in a fissure of this type would cool at a slower rate than those in the main lodes passing upwards. Crystallization would in consequence also take place at a slower rate and would account for the unusually large size of the flakes of haematite, and for the presence of the well-developed crystals of apatite which are not found in the main lodes. Although the sinter is only preserved in this special case, there is little doubt that it existed in all of the lodes during the period of activity, and that it separated from solution after the haematite, and usually at a much higher level in the

[1] Roscoe and Schorlemmer, A Treatise on Chemistry, 1907, vol. 2, p. 197.

fissures. Possibly some or all of it may have reached the surface and been deposited as sinter in the ordinary way.

That this separation of the sinter from the haematite took place at different levels is of importance from the mining standpoint, as in the special case where the two occur together the sinter cements the flakes of haematite into a valueless stony mass.

In conclusion, it may be said that the reason for using the term sinter for this particular form of silica is that the material appears to have been formed under conditions which approximate more to those under which a normal sinter is deposited than to those under which an opal is formed, although in appearance the material has a greater resemblance to the latter substance.