ACICULAR OPALINE SPELEOTHEMS FROM MT. HAMILTON LAVA CAVE, WESTERN VICTORIA

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ABSTRACT

Clusters of radiating needles (anthodites) on the wall of Mt. Hamilton lava cave are composed of opal-A, and probably represent pseudomorphs after a fibrous zeolite. Post-eruption hot spring activity on Mt. Hamilton might have supplied the acid solutions that leached the zeolites to silica, and could also have been responsible for the sulphate-rich solutions that have deposited gypsum within the cave.

INTRODUCTION

Speleothems (secondary mineral deposits formed in caves) have been recorded from many lava caves, where they occur either within the sediment on the cave floor, or growing on the walls and roof as coralloids, stalactites or flowstone. Phosphates and clays are the most common minerals in the sediment or rubble on the floor (Hill, 1976) whereas the speleothems on the walls and roof are usually composed of opal (Finlayson and Webb, in press).

There are over 50 lava caves in western Victoria, but few of them contain speleothems (Webb et al., in press). Skipton lava cave is world famous for the rare and unusual phosphate minerals that have been collected from within the sediments on the cave floor; two of these, newberyite and hannayite, were first described from this locality (McIvor, 1887, 1902; Pilkington and Segnit, 1980). Skipton lava cave also contains small opaline coralloids on the walls, and thin layers of opal coat lava stalactites in a cave at Byaduk (Webb et al., in press).

Mt. Hamilton cave is unusual in that it contains abundant speleothems, and some of these are of a shape and composition rarely encountered in lava caves.

MT. HAMILTON LAVA CAVE

The lava cave is located on the southern flank of an extinct volcano, Mt. Hamilton, about 85km WSW of Ballarat, in western Victoria. Mt. Hamilton is one of nearly 400 points of eruption in the large volcanic province that occupies much of western Victoria; the basalts of this province are collectively known as the Newer Volcanics (Joyce, 1975). Although the precise age of Mt. Hamilton and its associated lava flows has not been determined, it probably lies within the last 4 million years, as this is the time period when most of the Newer Volcanics were erupted (McDougall et al., 1966).

Mt. Hamilton lava cave lies less than 13m below the ground surface, and probably formed in one of the last flows from this vent. It is the largest of three caves in the area, and is in fact the longest and most compex lava cave in Victoria, with over 1,200m of bifurcating and anastomosing passages (Ollier, 1963), The cave passages are semi-circular in cross-section, being up to 8m wide and 4m high, and there are abundant lava stalactites. Subfossil mammal bones have been collected from several parts of the cave, and include three prehistoric species (Wakefield, 1963, 1964).

Laminated clay deposits are present throughout the cave, both on the floor and in cavities in the walls. Gypsum crusts coat the walls and roof, particularly in the central part of the cave, and small coralloids and stalactites can be seen on the roofs of some passages. Most of the stalactites are opaline, but a few are composed of gypsum. In the eastern part of the cave are small stalactites identified by Ollier (1963) as calcite; however, XRD analysis has shown that these are composed of banded opal.

At the southernmost (downslope) end of the cave is a medium-sized chamber with a pool of water occupying a large part of the floor. The size of the pool varies, and during periods of drought it may almost disappear. On the eastern wall of this chamber are abundant rosettes of acicular crystals (Fig. 1), and these unusual speleothems are the subject of this study.

SPELEOTHEM DESCRIPTION AND ANALYSIS

The rosettes are best termed "anthodites" (from the Greek *anthos*=flower), following Hill (1976) who defined anthodites as "speleothems which are composed of clusters of needle - or quill-like crystals."

The Mt. Hamilton anthodites are white in colour, although some have a faint orange tint. They occur in clusters on the cave wall (Fig. 1) and each rosette is composed of a number of sheaves of acicular crystals, all radiating from a common base. Individual sheaves are up to 2.5cm long and 1.5cm wide, and some are compound, consisting of a series of two or more crystal fans, one succeeding the other down the length of the sheaf (Fig. 2). Each sheaf is made up of numerous radiating needles, which are up to 2cm long but less than 1mm wide.

During moist periods the anthodites may have water droplets on their tips (Fig. 1). However, given their composition (Table 1), they are unlikely to be actively growing.

Isolated sheaves lie scattered on the floor of the cave and these were collected for thin section study and analysis.

Thin section examination show that the anthodites are composed of an isotropic mineral. In long section individual needles have an irregularly botryoidal surface (Fig. 3) and in cross-section they are circular or oval in shape with a central canal of varying size (Fig. 4). The thinnest needles are less than 0.1 mm in diameter and generally circular in cross-section. The material comprising the needles is consistently 0.05 mm thick or less, irrespective of the shape or diameter of the needles (Fig. 4).

X-ray diffraction showed that the anthodite mineral is amorphous and has a prominent but very broad peak centred at about 4.1 A. This is typical of opal A, one of the three structural groups into which natural hydrous silicas (opals) are subdivided (Jones and Segnit, 1971). Opal-A shows the least degree of structural organization of the three.

Electron microprobe analysis of the anthodites shows that they consist almost entirely of silica; other elements total less than 0.4% (Table 1). The balance of the analyses (7-8%) is undoubtedly water, as opals typically contain 3-11% water (Segnit et al., 1965).

COMPARISON WITH PREVIOUSLY DESCRIBED SPELEOTHEMS

Although Hill (1976) used the term "anthodite" exclusively for $CaCO_3$ speleothems, it would appear reasonable to apply the name to any speleothems with the characteristic needle - or quill-like morphology, no matter what their composition.

Aragonite and calcite anthodites are relatively common in limestone caves (Hill, 1976; White, 1976; Webb and Brush, 1978), but opaline speleothems with this morphology appear to have been described only once before. Webb (1979) noted radiating masses of white acicular crystals on the wall of a lava cave in southeast Queensland. These anthodites are shorter than the Mt. Hamilton examples, and composed of either opal-CT or chalcedony (Webb, 1979).

The basalt flows enclosing the Queensland cave are 22-23 m.y. old (Webb, 1979), whereas the Mt. Hamilton lavas are probably less than 5 m.y. old. Thus the Queensland anthodites are likely to be much older than the Victorian ones, and this probably explains the difference in mineral composition between the two.

Under atmospheric conditions amorphous silica precipitates more readily than crystalline silica from supersaturated solutions. Thus groundwater supersaturated with respect to silica will initially precipitate opal (Eitel, 1954), which will gradually transform from opal-A to opal-CT to chalcedony to quartz (Markova, 1978). A fairly long time period (millions of years) is believed to be necessary for this conversion (Mizutani, 1970).

Table 1.
Electron microprobe analyses (in wt%) of two anthodite samples.

SiO_2	92.51	91.56
TiO_2	0.09	0.14
Fe_2O_3	0.00	0.00
MnO	0.05	0.05
MgO	0.07	0.01
Al_2O_3	0.00	0.00
CaO	0.04	0.03
BaO	0.00	0.03
Na_2O	0.01	0.03
K_2O	0.02	0.03
Total	92.77	91.75

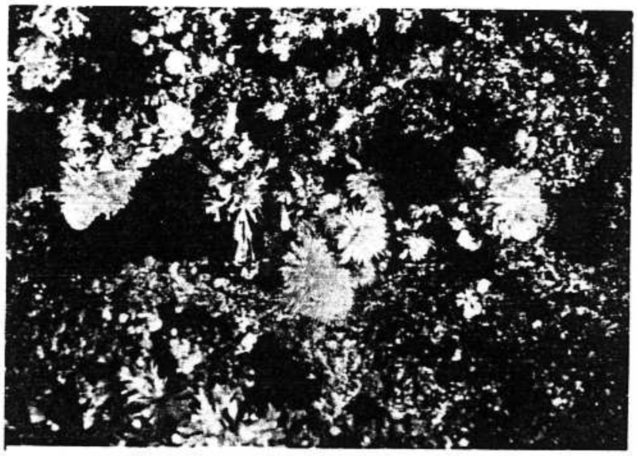

Fig. 1

Opaline anthodites on the wall of Mt. Hamilton lava cave, some with water droplets on their tips. About one third natural size.

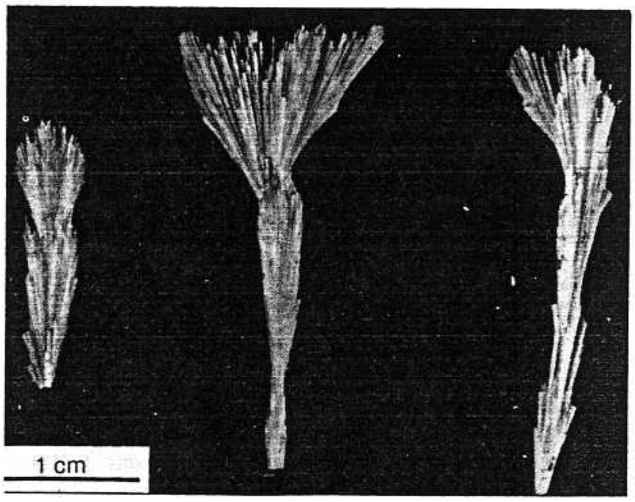

Fig. 2

Isolated sheaves from the anthodites, showing their compound nature and the radiating needles.

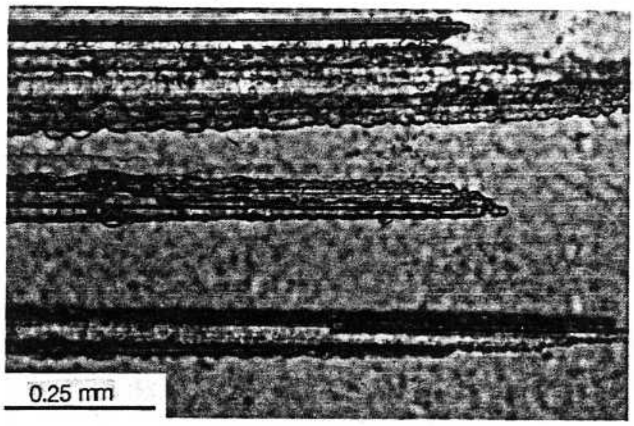

Fig. 3

Close-up of the anthodite needles, showing botryoidal surfaces.

Thus the Queensland anthodites were probably initially opal-A, which has transformed to opal-CT and chalcedony. The Victorian speleothems are too young for the conversion to have begun.

FORMATION OF THE ANTHODITES

As opal-A is amorphous, it cannot form crystals, and the opaline anthodites must represent pseudomorphs of silica after another mineral. The radiating acicular nature of the anthodites resembles the common crystal habit of fibrous zeolites and aragonite, and Webb (1979) suggested either of these as the pseudomorphed mineral in the case of the Queensland lava cave anthodites.

Zeolites are common in vesicles within the Cainozoic basalts of central and western Victoria, both in the older mid-Tertiary flows (Coulsell, 1980) and in the Pliocene and Quaternary Newer Volcanic lavas (e.g. Vince, 1980). The fibrous zeolites mesolite and natrolite have been recorded at several localities, and typically occur as hemispherical rosettes of radiating needles, which can be up to 2.5-3cm long (W. Birch, pers. comm.). Aragonite is often associated with the Victorian zeolites, as acicular radiating crystals (e.g. Hollis, 1979).

Neither zeolites nor aragonite have been recorded in any Victorian lava caves, although zeolites occur occasionally in U.S.A. lava caves (Hill, 1976). However, a zeolite is more likely as the precursor mineral of the Mt. Hamilton anthodites, because the crystallographic-chemical destruction of a zeolite to give a silica gel is well documented (Eitel, 1954). Dilute acids will completely remove all components of the zeolite except the silica and the water, leaving a pseudomorph which retains the outline of the original mineral. Some zeolites, e.g. the heulandite group, form pseudomorphs which may partially retain the optical orientation of the parent crystals, whereas the natrolite group of fibrous zeolites gives pseudomorphs which show only broad crystal outlines (Eitel, 1954). The Mt. Hamilton speleothems have a needle-like shape but lack crystal faces, so they probably represent pseudomorphs after a fibrous zeolite.

Removal of the non-silica components from a zeolite involves considerable volume reduction (e.g. natrolite consists of less than 60% silica + water), and even zeolites which pseudomorph as well-formed crystals show fine microscopic cracking (Eitel, 1954). Thus the central canals in the Mt. Hamilton anthodites could be a shrinkage effect developed during replacement, and the jagged edges of the canals (Fig. 4) would tend to support this conclusion.

Pseudomorphing of a zeolite by silica has not been recorded previously in Victoria, and its occurrence in Mt. Hamilton lava cave indicates something of the chemical conditions that have prevailed there. Zeolites in veins and cavities in basalt flows are believed to crystallize deuterically (in the final stages of lava cooling), or somewhat later at low temperatures, when meteoric waters react with the lava (Hay, 1977). Thus the zeolites at Mt. Hamilton probably crystallized soon after emplacement of the lava, and were later leached by acid solutions to form the silica pseudomorphs. Present day groundwater in the Mt. Hamilton area would be incapable of this leaching action, as it has a pH of 7-8 (unpublished records, Groundwater Division, Victorian Department of Mines). However, thermal waters associated with hot springs or fumarolic activity are frequently acidic; most fumarole condensates are dilute solutions of HCl (Barnes, 1984), and hot spring waters may have pH values as low as 1 (Kiyosu and Kurahashi, 1984). Thus it seems likely that fumaroles or hot springs were active on the flanks of Mt. Hamilton after the basalt eruptions had ceased, and supplied the acid solutions to leach the zeolites. Other Newer Volcanic volcanoes, e.g. Mt. Noorat and Red Rock Volcano, show patches of bleaching and staining in their pyroclastic deposits, apparently due to fumarolic activity (E.B. Joyce, pers. comm.). Direct evidence of this nature is lacking at Mt. Hamilton.

The occurrence of gypsum in Mt. Hamilton lava cave may also be related to hot spring activity. Gypsum speleothems apparently form as a result of evaporation (White, 1976), so the solutions depositing them must have high sulphate concentrations. Groundwater throughout the Newer Volcanics is undersaturated with respect to gypsum (Komarower and Wall, 1981); in the Mt. Hamilton region the groundwater contains less than 450ppm sulphate (unpubl. records, Groundwater Division), and in general groundwater in the basalts of western and central Victoria averages 600ppm sulphate or less, except in areas of agricultural or industrial contamination (Murphy, 1983). By contrast, acid thermal waters may be highly enriched in sulphate. Hot springs on Zao volcano in central Japan contain up to 5500ppm sulphate, which is magmatic in origin (Kiyosu and Kurahashi, 1984). Thus hot springs on Mt. Hamilton could have supplied the sulphate-enriched solutions necessary for the formation of gypsum in the cave. If the gypsum speleothems had precipitated from normal groundwater, then other lava caves in the Western District besides Mt. Hamilton might be expected to contain gypsum. However, this is not the case.

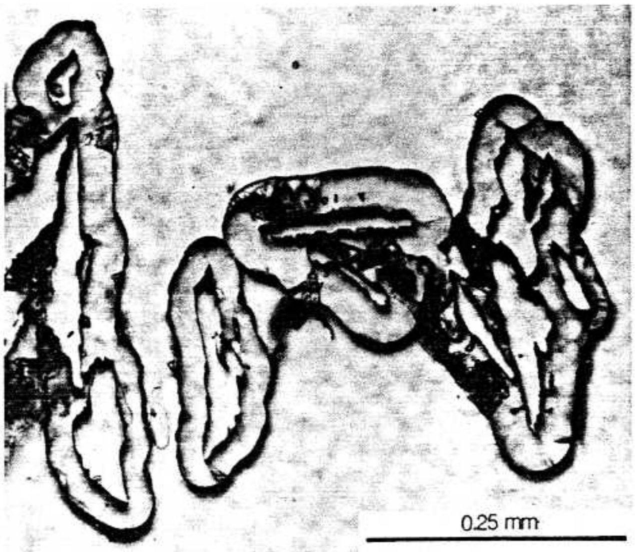

Fig. 4

Cross-section of anthodite needles, showing irregular oval shape and central canals.

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INTERNATIONAL MINERALOGICAL ASSOCIATION 14th GENERAL MEETING July, 1986

The 14th General Meeting of the International Mineralogical Association will be held on the campus of Stanford University, 50 km south of San Francisco, California, from 13th-18th July, 1986. It is being held under the auspices of The Mineralogical Society of America and the United States Geological Survey.

The meeting will attract mineralogists from all over the world; past meetings have been attended by about 500 delegates. Accommodation will be mainly in twin rooms in the hostels of the University, and will be reasonably priced, probably in the region of US$40-$45 per day including all meals. Alternate accommodation for the more affluent is plentifully available in motels and hotels in the close neighbourhood of the campus.

The programme during the main week of the meeting will cover all aspects of mineralogical science, ranging from crystal structures to gemmology. The scientific standard will be high. Also during this week there will be numerous social functions, including a reception at the Californian Academy of Science in Golden Gate Park, an evening of music, and an outdoor banquet. Several special tours and social functions will also be arranged for "accompanying members".

There will also be an exhibition of equipment and minerals, and exhibits are invited.

The meeting will be preceded and followed by field excursions to areas famous for their mineralogy and petrology. Pre-meeting tours being planned are:

1. Colorado-Rocky Mountain ore deposits (about 5 days).
2. New Mexico pegmatites and volcanic rocks (about 4 days).
3. Franciscan blueschist and eclogite in northern California (2 days).
4. Alaska (6 days).

Post-meeting field trips are:

1. Black Hills, South Dakota (about 3 days).
2. New Idria region, California (3 days).
3. Mineral deposits of the Great Basin, Nevada (7 days).
4. Hawaiian Island Volcanics (5 days).
5. New England metamorphics (about 5 days).

Estimated costs for the tours are expected to be about US$80 a day inclusive.

Further information may be obtained from Dr. E.R. Segnit, CSIRO Division of Mineral Chemistry, Port Melbourne 3207 (Telephone 03 - 647 0293) or Dr. W.D. Birch, Museum of Victoria, Russell Street, Melbourne (Telephone 03 - 669 9878).