THE MINERALOGY AND PARAGENESIS OF SPEEDWELL MINE, CASTLETON, DERBYSHIRE

by

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Summary

A paragenetic study of the mineral veins in Speedwell Cavern and Mine, Castleton, is presented following field and microscopic examination and X-ray diffraction analysis.

It is suggested that the cavity-fills and veins can be divided into two areas recording a similar mineralization history depending principally on the order fluorite before barite or barite before fluorite. Calcite occurs as the earliest gangue mineral in the pipe and minor veins but is absent as an early phase in the two major fracture veins. Two late calcite phases are ubiquitous. Galena is a common but minor early mineral, whilst sphalerite is rare. The widespread occurrence of minor iron sulphides throughout the paragenesis is connected to periods when free growth of other minerals was limited. Wulfenite and an unusual blue fluorite variety are also recorded. Goethite/mud concretions on the cave walls are related to mineralized styolites and speleogenesis. The broadly east-west veins recognizable on the surface, some 150 metres above the mine and cave passages, are only partly recognizable underground.

Introduction

This report results from observations made in the far reaches of Speedwell Cavern and Mine, Castleton, North Derbyshire, and subsequent microscopic and XRD study.

The mineral deposits consist of vertical fissure veins and elongated bodies of variable dimensions known as pipes, consisting primarily of coarse calcite occupying solution cavities. Owing to problems of access, only one visit was permitted for fieldwork and to obtain material for a paragenetic study of the minerals present. Their sequence of deposition is presented in the following pages.

Other than Ford's (1956) brief note on "four feet of calcite in Faucet Rake" no previous description of the mineral deposits in Speedwell Mine has been traced. The minerals present in the veins near Winnats Pass have only been briefly noted in the Geological Survey Memoirs (Carruthers and Strahan, 1923; Stevenson and Gaunt, 1971).

Description of mineralization

The Main Canal

A major E-W vein, Faucet Rake, is encountered in the Bottomless Pit cavern at the end of Speedwell Main Canal (location 1, Fig. 17). The vertical rake is about 1.5 m wide and consists primarily of comb-textured white calcite ('7' to 'X' in Fig. 1).

In a fissure vein early minerals are usually marginal owing to a process of symmetric inward growth from the walls. Late crystals tend to occur in the centre, except where there has been asymmetric re-opening. In Faucet Rake the earliest mineral phases are seen on the north wall ('Ln', Fig. 1). Barite ('2') lies between two layers of purple fluorite ('ls') and ('ln') which occur on the unaltered limestone wall (Ln) and as a thinner surface on the

Mercian Geologist, vol. 10, no. 1,
1985, pp. 39-60, 17 figs., 23 tables

north side of the main part of the vein ('X'). The fluorite layer is also represented by a discontinuous coating on the south wall of the rake ('ls"). Therefore the initial opening of the fissure was followed by a few millimetres free growth of purple cubic fluorite ('ls' and 'ln') from the two planar limestone surfaces ('Ls' and 'Ln') and then precipitation of barite ('2'). Further opening was accommodated by a fracture along the south contact ('Ls/ls'). An inward growth of calcite ('3s' and '3n') was followed by purple fluorite ('4') in vugs at the centre. The beginning of the major opening phase was a limited dilation on the north side of the calcite at the early purple fluorite boundary ('3n/ls'). This was filled by fluorite ('5') and later barite ('6'), and sealed with a few calcite crystals. The north wall continued to part at this purple fluorite contact ('ls') with the deposition of thicker layers of calcite (eg. '7s' and '7n'). A minor influx of iron-rich fluoritizing solution caused fine brown fluorite replacement of layer '8' (Fig. 1). This was probably followed by splitting along this replacement suture and the fracture was healed with a thin layer of calcite (9). The main part of the vein is thick calcite formed during progressive fissure dilations. A late veinlet running irregularly through the massive calcite on the southern half is bordered by brown, turbid and stained calcite (see Fig. 1). Dissolution probably preceded the secondary growth of the vuggy scalenohedra and was caused by a fracture briefly introducing fluid that was initially undersaturated.

High level workings indicate that Faucet Rake was mined for galena, although none was seen in the accessible part. The mineral parageneses described later in this paper suggest galena in Faucet Rake was deposited early in the sequence. Table 1 represents the probable paragenesis, with time as a horizontal dimension. The latest phases are on the right, the earliest mineralization event is the line furthest to the left in the table.

The Near Bung Hole Passage

At the end of the Far Canal a mostly natural stream passage trends ENE downstream of the Bung Hole (see Fig. 17). On the east side of Block Hall (location 2, Fig. 17) a small ENE-WSW vein, that probably controlled development of the chamber, shows early sparry orange-coloured calcite followed inwards by barite and with late white calcite in the centre (see Table 2). The late calcite also shows some vuggy scalenohedral development in the orange calcite.

150 m further down Near Bung Hole Passage (location 3, Fig. 17), stopes above the stream can be followed upwards for 10 to 20 m to boulder chokes, although there is some evidence of higher inaccessible workings to the north-east. Location 3 is about 175 m directly beneath Hurdlow Barn (385 m O.D.), and therefore may be a deep extension of the NW-SE Nether Pipe recorded on the Oakden plan of 1779 (see Ford, 1982). A typical mineralized area is shown in Fig. 2 and consists of botryoidal barite, overgrowing large corroded calcite crystals. The barite in turn lies beneath columnar calcite and later pipe-type calcite which is similar in shape to the early calcite. The habit of the late calcite is to occur as large single scalenohedra, sometimes with the unit rhombohedron giving modified terminations to the blocky crystals. Twinning is common, sometimes multiple and parallel to the long C-axis, yielding doubly-terminated groups of scalenohedra. The final cavity filling produces a metre or so in thickness of calcite. Purple/pale blue fluorite appears only once in the paragenetic sequence. The fluorite often occurs as a mosaic of cubic crystals; to "support" this texture, host rock dissolution prior to and during fluorite growth must have occurred. Interstitial barite and micro-vugs filled with barite have a fine cockscomb surface with platy crystals about 1 mm long. Galena occurs between and with the fluorite and barite. The paragenesis in Table 3 is rarely seen complete in any one area.

Whirlpool Passage

Upstream of the Bung Hole, at the Whirlpool a tributary stream enters the Main Stream Passage from the north-west. After following this passage for 130 m, a NE-SW veinlet is encountered (location 4, Fig. 17), about 1 cm wide, with mud at its centre (see Fig. 3).

At the Whirlpool Stopes (location 11, Fig. 17) it is possible to see cockade-textured galena, about 1 cm thick, on top of corroded, early calcite, with an intervening thin layer of goethite. Presumably oxidation of pyrite produced enough sulphuric acid to cause slight dissolution of the underlying calcite. Coarse, white, massive and columnar calcite also occurs above the galena layer and is obviously a later phase.

On the SE side of the stream at location 5 (Fig. 17) mineral gravel lies on a stone-built ore-processing floor. Specimens from here were dissimilar to the mineralization seen in the rest of Whirlpool Passage: (i) A loose pebble showed barite and calcite lying beneath later fluorite containing iron sulphide inclusions; (ii) dark purple fluorite cubes (1 cm) were found with calcite imbedded and included in their surface (see Discussion, 1)); (iii) stubby, multi-faceted crystals of calcite on galena probably originate from the mined passage nearby at locality 11 (these show a combination of the unit rhombohedron and scalenohedron, and partial development of the hexagonal prism with sides parallel to the C-axis).

Fig. 8 (location 11) is a sketch of goethite pseudomorphs after marcasite but with a pyritic central core. Therefore it seems that pyrite was changed to, or encrusted by, late marcasite which in turn altered to goethite in oxidizing aqueous conditions.

Fig. 4 shows a cross-section of the WSW-ENE vein at location 6 (Fig. 17) and Table 6 is the inferred paragenesis. Several metres further up the passage on the north-west wall at location 7 there is a circular vug shown in Fig. 5. The minerals have grown concentrically into the cavity and therefore dissolution must have occurred before mineralization. Table 7 indicates the paragenesis. The same order of events is recorded in an intermittent pipe-type body that continues at least as far as location 8 (Fig. 17). Here, early calcite, pyrite and galena are not present presumably due to the absence of a pre-mineralization cavity (see Table 8). When these four events are excluded from the paragenesis it is interesting to notice how closely matched Table 7 and Table 8 are. Thus early dissolution at location 7 allowed a greater spread in the timing and number of mineral phases but broadly the paragenesis remains the same.

A stratiform mineral body occurs in the walls below the low passage roof around location 9 (Fig. 17). A field sketch is shown in Fig. 6 and the interpreted paragenesis in Table 9. Large quantities of late calcite are still observed. Relic calcite anhedra, rimmed and partially replaced by barite, may be the earliest mineral (near the base of the pipe), with cubic, coloured fluorite occurring in fractures and the flat surface beneath the calcite clasts. Therefore the calcite may have formed as coarse, bed-parallel crystals replacing the limestone along a bedding plane. Later dissolution started beneath and around their grain boundaries. The fluid responsible for this resorption may have been introduced by fracturing (with subsequent growth of fluorite). The fluorite was followed by barite as the pipe developed. Fine fluorite deposition (or metasomatism of the roof) above the horizon was followed and preceded by dissolution and galena crystallized on the exposed surfaces. Galena, followed above by manganese wad and goethite occur within three layers of the typical yellow chalky barite. This is overlain by columnar calcite and late blocky calcite. A 'muddy' base to the calcite probably represents a halt in precipitation between the barite and calcite phases.

At location 10 (Fig. 17) a veinlet about 1 cm wide and shown in Fig. 7 has a simple paragenesis (Table 10) of galena -› fluorite -› barite.

The passage continues NW to Whirlpool Rising where the stream rises from a deep flooded pothole. Beyond this, at location 12 (Fig. 17) a vein about 60 cm wide is found on the floor. Fig. 9 depicts the SW half and the paragenesis is shown in Table 11.

Several specimens were also collected here, and one boulder was found to have a small encrustation of wulfenite crystals (see Discussion, and Fig. 15). The paragenesis of the boulder is shown in Table 12. The specimen (Fig. 10) is also interesting for the reniform (convex up) fluorite which shows a replacement texture; however, cubic surfaces, which are often purple, are also present. These crescent-shaped vugs arise at culminations in the reniform layers. Probably partial dissolution occurred directly above a replacement front, followed by fluoritization (brown, purple and black) and the growth of free fluorite crystals as the metasomatism moved upwards. Finally galena partially infilled these spaces. This cycle happened again with more complete vug development, and was followed by further overhead dissolution and precipitation of barite on the upper fluorite surface. The third and last galena growth is within the barite and this shows goethite and tarnished pyrite inclusions with a goethite coating and a thin layer of purple fluorite on top. Another mineral specimen from location 12 (Fig. 17) shows a more restricted paragenesis (see Table 13), equivalent to only the middle portion of the stages in Table 12, and with no galena. Both Table 12 and Table 13 represent parts of the paragenesis of the Whirlpool Pipe that continues NW beyond the Whirlpool Rising. One finally reaches a WSW vein, shown in Fig. 11, at the end of the passage. The similarity to Faucet Rake (Fig. 1, Table 1) is striking and it is concluded that location 13 intersects a westerly branch off Faucet Rake. Location 13 on the underground survey appears to correlate with Quick Scrin on the surface according to Oakden's 1779 plan of the Speedwell area. This minor vein trends WSW but cannot be seen to join Faucet Rake on the surface. Table 14 shows the paragenesis. There are only minor differences compared to Table 1 (Faucet Rake), the chief being the presence of galena (with early fluorite and barite) and large pipe-type blocky calcite in the centre of a much reduced thickness (compared to location 1) of columnar and faintly pink calcite. It is puzzling why the galena layer (2 cm thick) adjacent to the limestone wall (see Fig. 11) was not exploited by the miners, as nowhere else in Speedwell Mine was ore of this thickness observed.

The Main Stream Passage

Rejoining the Main Stream Passage the next area of mineralization upstream is at the Boulder Piles, location 14 (Fig. 17). Early barite clasts are included in pinkish, columnar, polygonal calcite which in turn is traversed by discontinuous veinlets of barite. The suggested paragenesis is shown in Table 15. Mineral gravel, essentially fluorite, barite and galena (see Table 16), was also found and it is probable that these were derived from overhead stopes that are now blocked by large, unstable boulders.

After the Blackpool Sands a few small irregular veins of coarsely crystalline calcite were seen. At location 15 (Fig. 17) consolidated dark brown silt occurred interstitially between subhedral calcite crystals. The silt grains were mostly quartz although it is suspected that some fine goethite is also present. The quartz silt, rather than a specific mineral precipitate, was probably derived from the host limestone. Table 15 records the mineral order in these veinlets.

From after the Boulder Piles to the Main Rising curious botryoidal, mud-coated concretions were found along the passage walls. Internally they consist of banded mud and silt (manganese- and iron-rich) and goethite, with a hard central core of granular quartz and goethite. The formation of these recent speleothems probably occurred as follows: Areas of partial silicification along stylolites (see Fig. 12) and joints probably became porous later by dissolution of early calcite (formed contemporaneously with the quartz replacement) and permitted the flow of iron-rich water. Reniform goethite outgrowth from the limestone wall (after speleogenesis) was interrupted or supplemented by sediment coatings from the stream during periods of flood.

Cliff Passage

A vein trending 070/075° can be seen above the waterfall at the entrance into Cliff Passage (location 16 on Fig. 16). This is about 150 m directly beneath New Rake, with a similar ENE trend on the surface. In fact the whole Main Stream Passage is closely parallel to New Rake. Fig. 13 shows early tension gashes filled with barite then galena, found on the south side of the main fracture that mostly consists of calcite. The vein is displaced 25 cm to the south below a shale layer near the floor in Cliff Passage. A few metres back along the Main Stream Passage a simple veinlet consists of barite on the outside and central calcite. Vertically-layered goethitic mud lies on the NW side and partially fills the centre of the vein. A thin layer of flowstone coats the surface.

The calcite pipes seen in Cliff Passage are controlled by a shaley layer about 1 cm thick, with calcite crystals generally beneath and occurring as small bodies tapering downwards or lensatic in shape as lenses. A typical example (Fig. 14) has a cavity lining of fluorite followed by barite, and filled with blocky calcite. Around location 18 (Fig. 17), the second pipe encountered has late iron-rich cubic fluorite grown from the flat surfaces of the large modified calcite scalenohedra. A third pipe shows evidence of late intersertal fluoritization (or fine fluorite deposition) and galena growth along planar calcite compromise boundaries.

Near location 17 (Fig. 17) there are numerous thin goethite/fluorite veinlets (with perhaps barite) only a few millimetres thick. They often trend NW or sub-horizontally and crosscut calcite veinlets.

Higher up in Cliff Cavern (location 19, Fig. 17) a calcite pipe is disrupted by numerous stylolites but there are no clay layers at this upper level.

In conclusion Cliff Passage shows cavity-fill (palaeo-karst?) mineralization and some coarse metasomatic calcite replacement of the limestone.

Discussion

Blue Fluorite

In the Whirlpool Passage, at location 5 (Fig. 17), some loose mineral gravel was collected, including some dark purple interpenetrant fluorite cubes (>1 cm) with calcite grains imbedded on their surface. On later microscopic and chemical investigation it was found that apparently pure splinters of fluorite taken from the specimen were mainly colourless but "laced" and spotted with a blue coloration. In fluorite from other areas in Derbyshire a purple edge coloration often occurs adjacent to another mineral—usually barite, or calcite, or micro-inclusions of chalcopyrite, pyrite, arsenopyrite, bornite, bravoite, and goethite. Braithwaite et al (1973) maintained that purple coloration in fluorite from Derbyshire was due to colloidal calcium. However this would tend to produce a more diffuse and even colour than that observed. Although the splintrs had no apparent carbonate inclusions the fluorite effervesced with the addition of hydrochloric acid. The fluorite was investigated to reveal whether the purple/blue coloration could be explained by one of two theories: lattice distortion possibly due to radiation from or exsolution of another mineral, or the presence of blue-coloured microscopic inclusions.

No alpha, beta or gamma radiation was detected from the specimen.

XRD analysis showed that the crushed splinters contained about 5% calcite, and that the intensity ratio of the fluorite d-spacing peaks 3.15 and 1.93 is approximately 100:30 respectively compared with 93:100 for synthetic fluorite (Berry, 1974). Replacive and secondary fluorite from Matlock Bath also produces a more intense 3.15

lattice diffraction than the 1.93 spacing, whereas unequivocal primary fluorite has a ratio similar to the 93 to 100 of pure synthetic fluorite — both having an undistorted lattice. The specimens are all prepared in a similar way by hand crushing to a fine powder with pestle and mortar and making smear-slides with acetone. Two thin sections (see Fig. 15) under the microscope revealed hydrocarbon and glauconite concentrated along crystal boundaries and late fractures. Calcite, quartz, epidote and pyrite also occur as late inclusion zones in the fluorite associated with several purple bitumen-stained layers. Hydrocarbon occurs at the boundaries between the radiating columns of the interpenetrant twins, and the incorporation of other inclusions is preferentially along the locus of edge growth of the fluorite (see Fig. 15). Glauconite occurs in intimate association with the bitumen and occurs slightly lamellar and parallel to the fluorite walls. The hydrocarbon also shows lamination and cracks due to shrinkage and is opaque to brown translucent at some edges. It imparts a purple stain along some cleavage zones formed by strained growth in the fluorite. The external surface of the fluorite is rough but regular cubic, however, internally the structure consists of zoned growth with areas of polygonal and cubic sub-crystals (see Fig. 15). Calcite has a more broad distribution than the other inclusions that occur only in the final fluorite zones, although calcite too occurs *mainly* as a late inclusion. Some calcite crystals are embayed and partially replaced by fluorite, others are rounded calcite rhombs or occur as irregular crystals. The epidote prisms are colorless but characteristically highly birefringent. Partial replacement by quartz inclusions show slightly strained extinction in crossed polarizers and are probably detrital. It appears that most of the included crystals were released by dissolution of adjacent limestone and occur in greater concentration at the edges and final growth zones of the fluorite. However, many of the zones of elongate calcite inclusions (see Fig. 15) probably indicate competetive growth between the fluorite surface and coprecipitating calcite, and certainly the secondary calcite shown in Fig. 15 grew in fractures in the fluorite. The centre of the specimen is a cubic mosaic of turbid fluorite crystals which may indicate initial growth was by replacement. Probably the source of the hydrocarbon was also the limestone and this bitumen is the cause of the coloration in the fluorite.

Wulfenite

Minute (<1 mm) wax-yellow, twinned and striated, tetragonal prisms of the lead molybate, wulfenite ($PbMoO_4$), were found coating a fluorite surface at location 12 (Fig. 17) near Whirlpool Rising (see Fig. 10 and Table 12). Mineral identity was confirmed by XRD analysis. Similar crystals have been recorded by King (1980) from Tickow Lane Mine, near Shepshed.

Ford and Sarjeant discussed wulfenite in the Peak District Mineral Index (1964):

"Wulfenite ...... was recorded by Mawe (1802) at Odin Mine, Castleton, but has not yet been confirmed. Molybdenum was found in the Buxton spa waters (Stephens, 1929). Wulfenite is definitely known in the Magnesian Limestone of Bulwell, Notts., in association with galena and hydrocarbons (Deans, 1961), and has been found in the dolomitised Carboniferous Limestone of Breedon, Leics., by R. J. King".

Nichol et al (1970) record high molybdenum concentrations from the Namurian shales near Castleton. It is suggested that the wulfenite was formed from downward percolating meteoric water while overlying shale still covered the area above Winnats Pass and Longcliffe (probably pre-glaciation). Wulfenite is not an uncommon minor mineral in oxidized lead ore deposits but it would seem that this is the first definite confirmation of wulfenite in the South Pennine Orefield.

Paragenesis

In the fracture veins and mineralised pipe deposits of Speedwell Cavern wallrock alteration outside the limestone/mineral boundary is not common. The primary gangue minerals are calcite, chalky barite, and fluorite, in order of importance. Galena is common, but does not occur in great quantities; pyrite is generally microscopic. Smithsonite after sphalerite is only seen in the stopes of the Near Bung Hole Passage (Table 3). No evidence is seen for "thermal zonation" in this part of the Derbyshire orefield: the quantity of fluorite, barite and calcite, and ore minerals bear no relation to longitude in Speedwell Cavern.

(a) *The Main Stream Passage*

Two general parageneses can be constructed for Speedwell Cavern primarily on the order of fluorite/barite alone (Tables 22 and 23). The whole of the Main Stream Passage, from Cliff Cavern and Main Rising to the Bung Hole Near Series, shows a mineral sequence: calcite (the oldest) → barite → fluorite → columnar calcite → blocky calcite (the youngest). Galena is mainly associated with fluorite or also appears slightly before or after the fluorite episode.

Cliff Passage does not show development of early calcite. Here the mineralisation is mainly in calcite pipes, usually with an early cavity coating of barite, then fluorite. Late fluorite and galena is also seen in spaces between some large blocky calcite crystals. A final (purple) fluorite layer is also seen in a vein at the south-east end of the Whirlpool Passage.

Little fluorite is observed in the rest of the stream passage until the Bung Hole Stopes are reached downstream. Here, early calcite is partially corroded by dissolution and an overgrowth of iron-rich barite. A middle calcite layer is followed by purple fluorite and a second generation of barite. Galena and pyrite grew intermittently throughout.the formation of these gangue minerals but sphalerite only occurs once, beneath the purple fluorite. The columnar, then blocky, overgrowths of two calcite generations fill the remaining cavities in the pipes. Some speleothem deposits occur on the mineral veins in the Main Stream Passage. Early quartz, calcite, and goethite concentrated along stylolitic boundaries are emphasized by botryoidal muddy iron-rich concretions on the walls of the upper parts of the Main Stream Passage.

(b) *The Main Stream Passage/Whirlpool Passage Transition*

A pebble found at the Boulder Piles shows the order fluorite replacement + pyrite → fluorite + galena → and, finally, barite. This is characteristic of the fluorite/barite paragenesis in the Whirlpool Passage and Faucet Rake (see Table 22). Conversely a loose pebble found at location 5 (Fig. 17) at the Whirlpool Stopes shows a sequence of minerals barite → calcite → included fluorite. This sort of paragenetic order is only seen at the Near Bung Hole Stopes and suggests that the gravel at location 5 has its origin in unexplored mine workings (near the Whirlpool Stopes) with a paragenesis similar to the lower regions of the Main Stream Passage. The stopes above the Boulder Piles probably worked mineralization similar to that found in The Whirlpool Passage.

(c) *The Whirlpool Passage and Faucet Rake*

The rest of the Whirlpool Passage consists of pipes, stratiform bodies, and veins. The first mineral deposited after cavity formation is pyrite, and it has an intermittent appearance throughout the mineralization history, mainly at the start of renewed episodes of mineral growth, and is particularly common at the base of the late columnar calcite. This suggests that pyrite supercedes and/or is contemporaneous with a phase of dissolution of the limestone—frequently the roof. Early calcite is sometimes present, and is followed by fluorite, which is often purple due probably to microscopic inclusions of hydrocarbon. The fluorite is followed by about three colloform layers of barite—an order in reverse of that seen in the Main Stream Passage. Galena often occurs with the fluorite (and there may be several generations of both) but its time of growth is not greatly constrained and it sometimes interlayers with early calcite and often with later barite. Three layers of galena are often present, with the latest stringer usually incompletely developed. The ubiquitous columnar calcite and blocky vug calcite form coarse overgrowths. Both Faucet Rake and the vein at the end of Whirlpool Passage (location 13) show the same general fluorite, then barite, then calcite relationship. There is a minor repeat of this sequence in Faucet Rake, and then the main vein fill is thick layers of comb-textured calcite. The vein at the end of Whirlpool Passage is filled more with the later phase of blocky calcite but both are crosscut by a small vuggy calcite veinlet. A thick galena layer occurs between early fluorite, and it is proposed that galena formed at the same stage in Faucet Rake. Neither vein possesses early calcite, presumably because fault dilation was later than the time of formation of this phase. Early calcite deposition is recorded in some of the pipes and veinlets deeper in the system.

Conclusion

The mineral veins and cavity-fill deposits in Speedwell Cavern consist primarily of several generations of white calcite, chalky barite, and fluorite. Galena is a widespread early mineral but following mining activity is no longer visible in any quantity. The distribution of minor iron minerals throughout the paragenesis has been recognized, and frequently these microscopic inclusions correspond to periods of dissolution or cessation of gangue mineral growth. The blue coloration in some fluorite seems to be due to the inclusion of bitumen.

The system can be divided into two areas with a characteristic paragenesis and a general order of events: early calcite → fluorite/barite/galena → columnar calcite → blocky calcite (Tables 22 and 23). Later cave development has led to the development of speleothem deposits and the growth of secondary minerals; of particular interest is the first scientific confirmation of wulfenite from the South Pennine Orefield.

Acknowledgments

Heartfelt thanks to Mr P.E. Laffar for the use of his computer and word-processor and to Mr John Harrison for access to the mine. This study is part of a 3 year research project on the mineral paragenesis of the South Pennine Orefield, and I am grateful to the Isle of Man Board of Education for the encouragement and sponsorship. Thanks.also to Dr T.D. Ford for all his help and supervision.

References

Berry, L.G. (ed). 1974. *Selected powder diffraction data for minerals Data Book*. Joint C'ttee on Powder Diffraction Standards, Philadelphia, 833 pp.

Braithwaite, R.S.W., Flowers, W.T., Haszeldine, R.N. & Russell, M. 1973. The cause of colour of Blue John and other purple fluorites. *Mineralog. Mag.* 39, 401-411.

Carruthers, R.G. & Strahan, A. 1923. Lead and zinc ores of Durham, Yorkshire, Derbyshire and the Isle of Man. *Geol. Surv. Spec. Report Min. Res.* 36, 114 pp.

Ford, T.D. 1956. The Speedwell Cavern Castleton, Derbyshire. *Trans. Cave Res. Grp. G.B.* 4, no. 2, 97-124.

Ford, T.D. 1982. Old Derbyshire Lead Mine Plans and some Problems in their interpretation. *Chartered Land Surveyor/Chartered Mineral Surveyor.* 4, no. 2, 30-46.

Ford, T.D. & Sarjeant, W.A.S. 1964. The Peak District Mineral Index. *Bull. Peak Dist. Mines Hist. Soc.* 2, 122-150.

King, R.J. 1980. Wulfenite in Leicestershire. *Trans. Leic. Lit. & Phil. Soc.* Vol. 72, pp 51-58.

Nichol, L., Thornton, I., Webb, J.S., Fletcher, W.K., Horsnail, R.F., Khaleelee, J., & Taylor, D. 1970. Regional Geochemical Reconnaissance of the Derbyshire area. *Inst. Geol. Sci. Rep.* 70/2, 37 pp.

Stevenson, I.P. & Gaunt, G.D. 1971. The Geology of the Country around Chapel-en-le Frith. *Mem. Geol. Surv. G.B.*

Webb, J.S., Thornton, I. & Fletcher, W.K. 1968. Geochemical Reconnaissance and Hypocuprosis. *Nature.* 217, 1010-1012.

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Key to paragenetic tables

c	–	corrosion	colm.	–	columnar
p	–	purple	blky	–	blocky
( )	–	not always present	r	–	replacement
?	–	probable phase			prolonged mineralisation

LOCATION 1

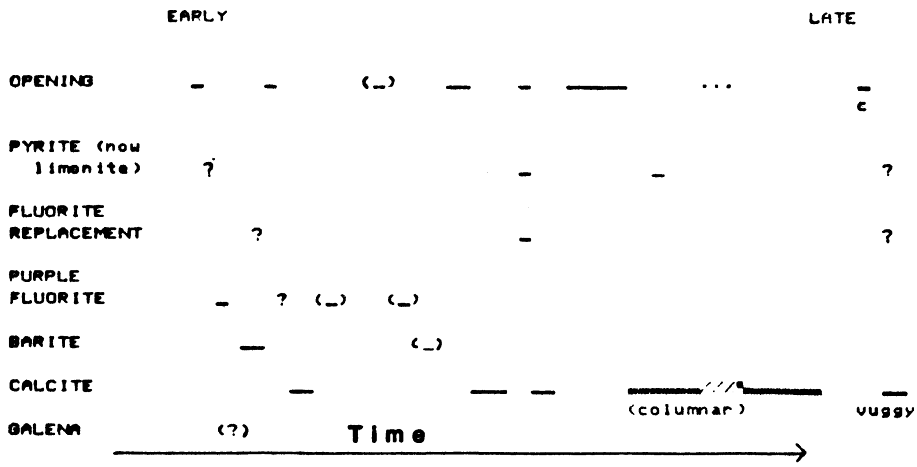

Table 1. Location 1, Faucet Rake, in Bottomless Pit Cavern.

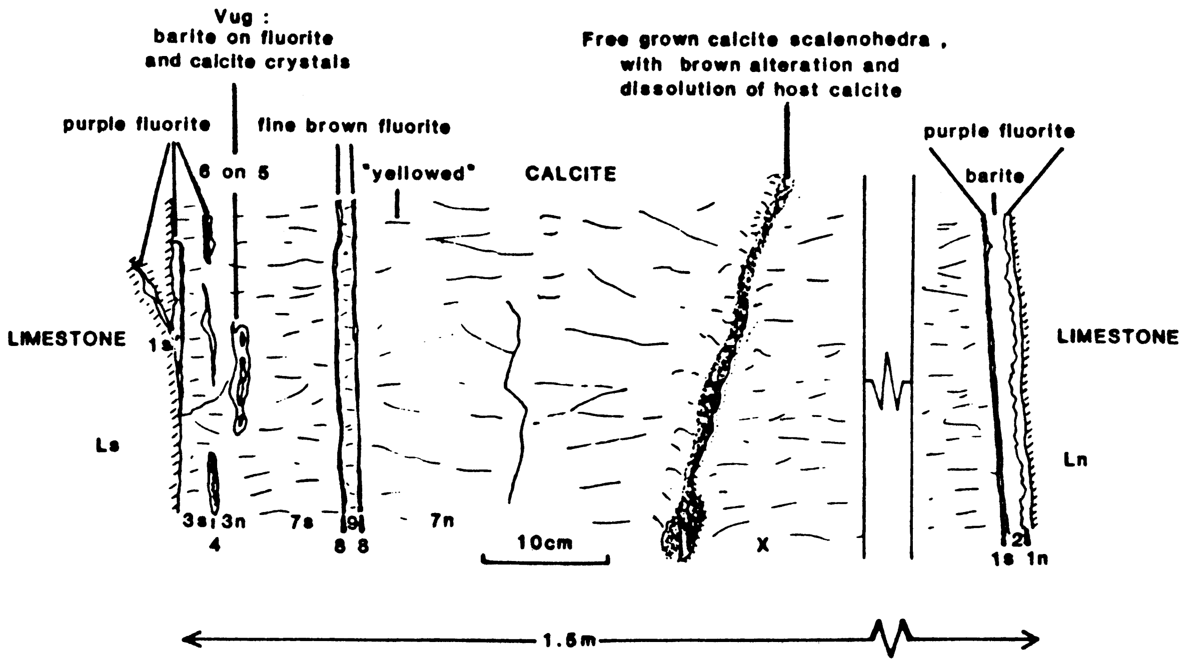

Fig.1. Faucet Rake, Location 1, Speedwell Cavern. Section through vein, looking west.

LOCATION 2

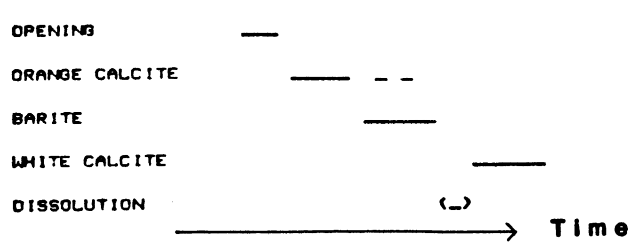

Table 2. Location 2, Block Hall.

LOCATION 3

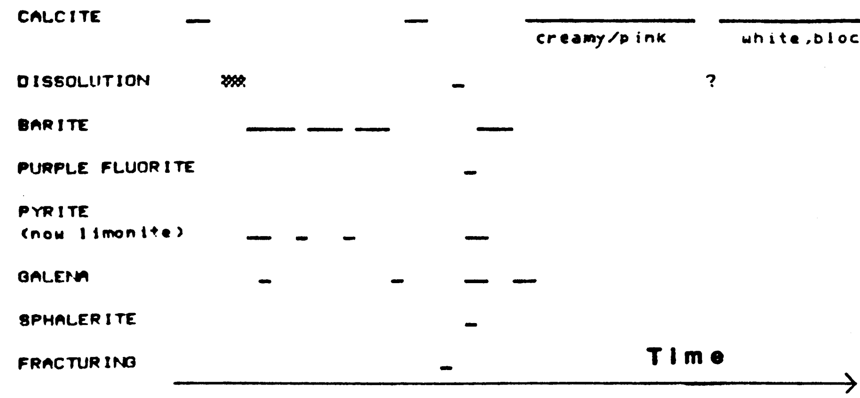

Table 3. Location 3, near Bung Hole Passage.

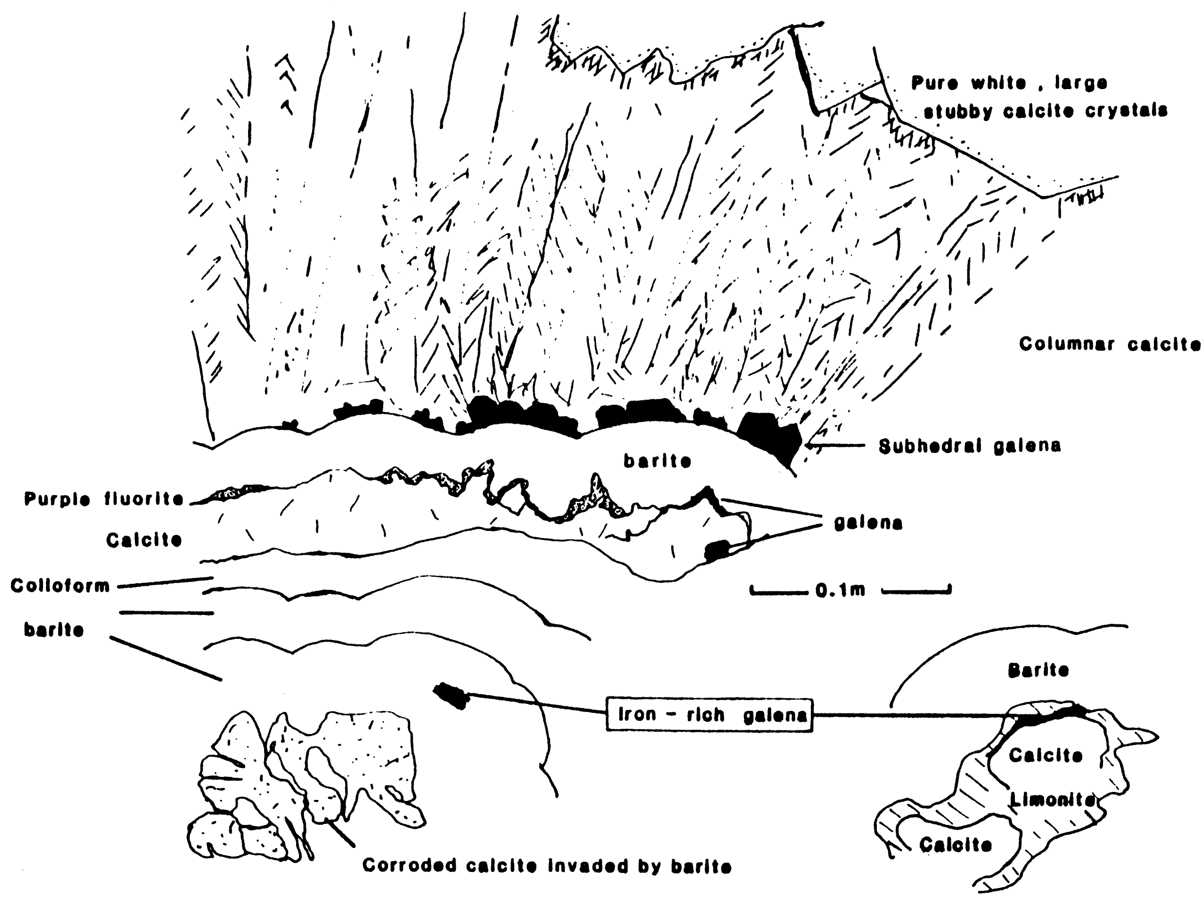

Fig.2. Mineralised area near Bung Hole Stopes, Location 3.

LOCATION 4

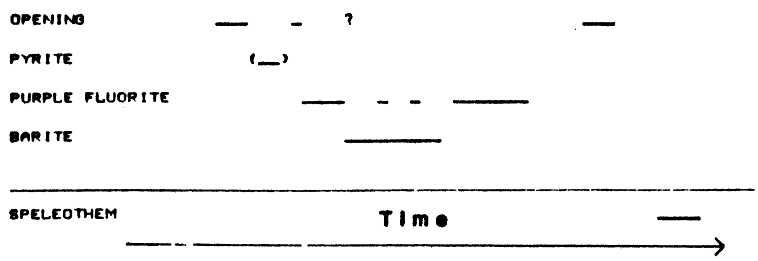

Table 4. Location 4, N.E. of Whirlpool Stopes.

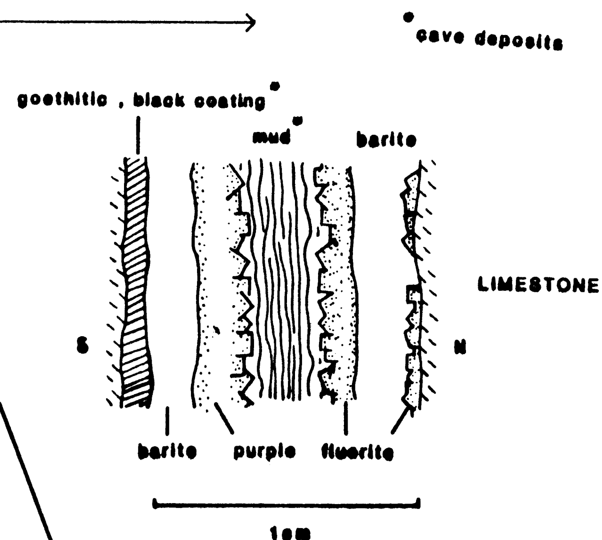

Fig.3. Location 4. Vein crossing passage northeast of Whirlpool Stopes.

LOCATION 5

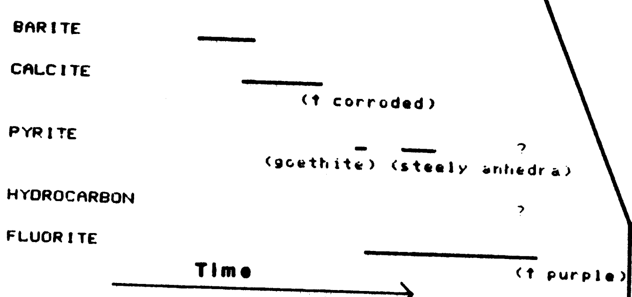

Table 5. Location 5, Exotic Pebble at Whirlpool Stopes.

LOCATION 6

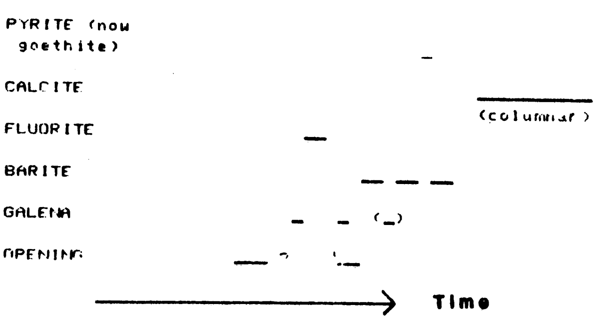

Table 6. Location 6, Whirlpool Passage.

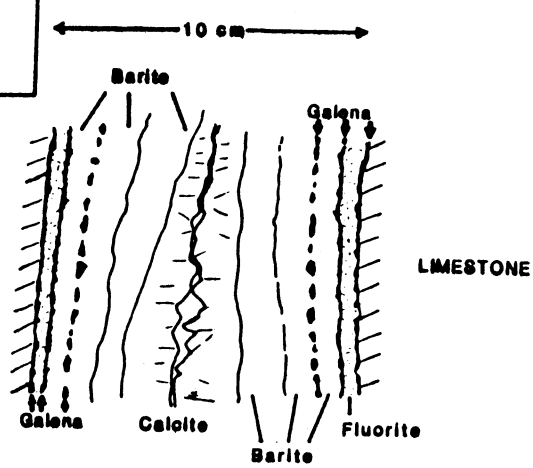

Fig.4. Vein, Location 6, Whirlpool Passage.

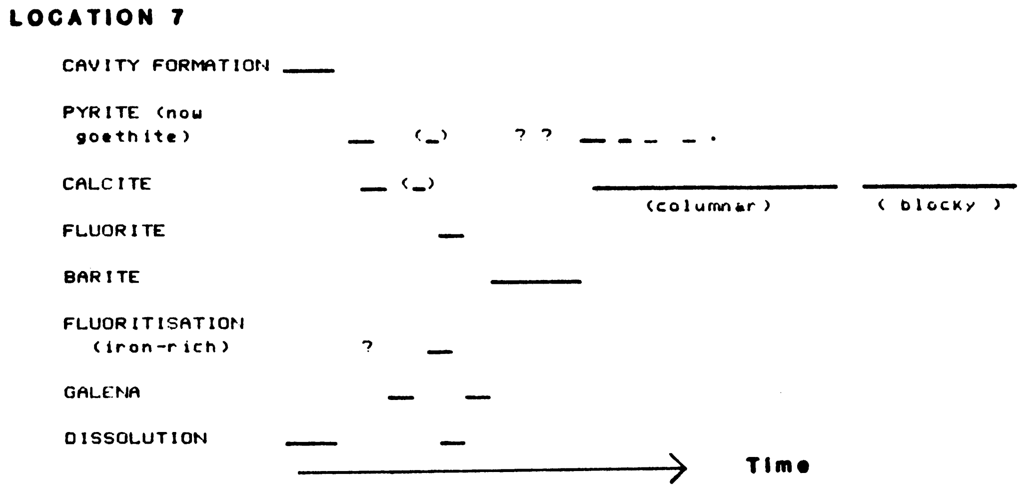

Table 7. Location 7, Whirlpool Passage.

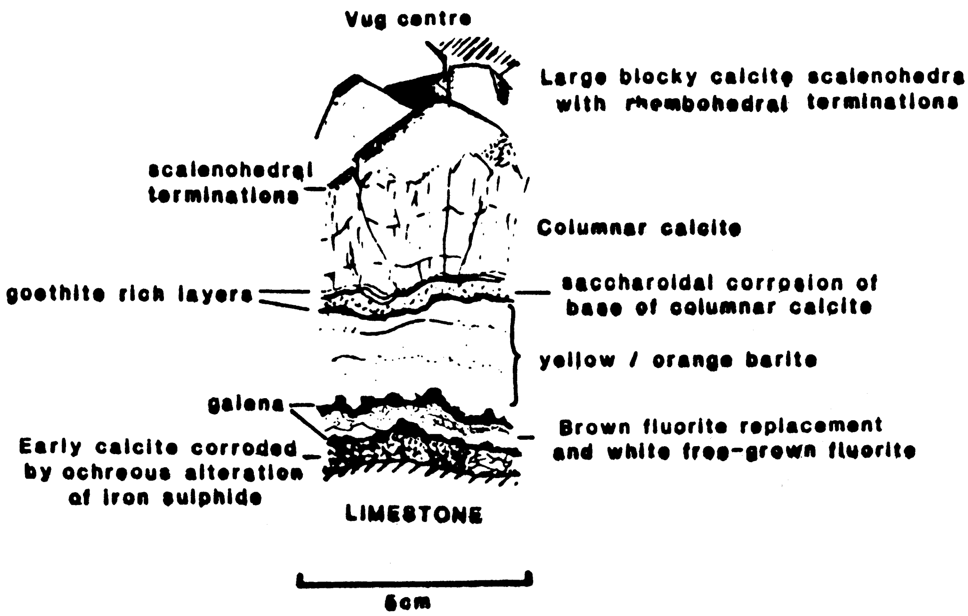

Fig.5. Lower segment of concentric, circular pipe near Location 7, Whirlpool Passage.

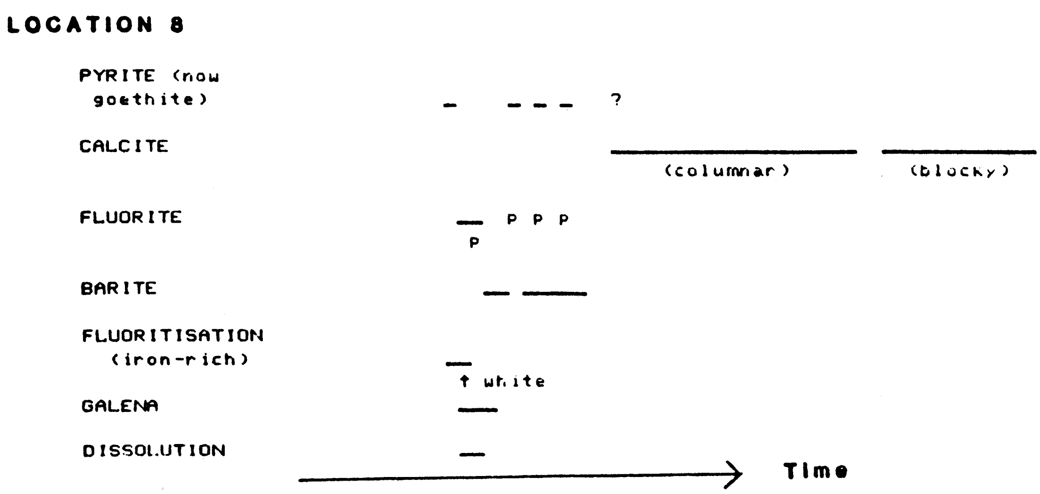

Table 8. Location 8, Whirlpool Passage.

LOCATION 9

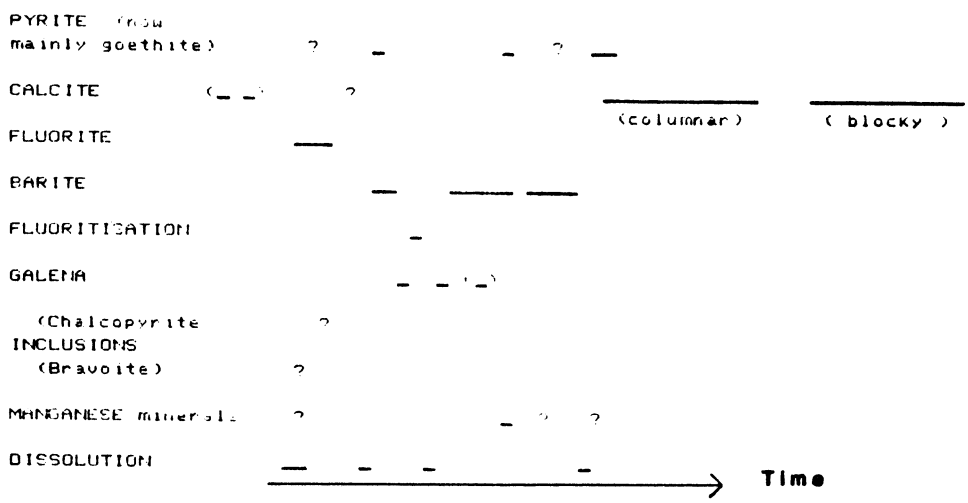

Table 9. Location 9, Whirlpool Passage.

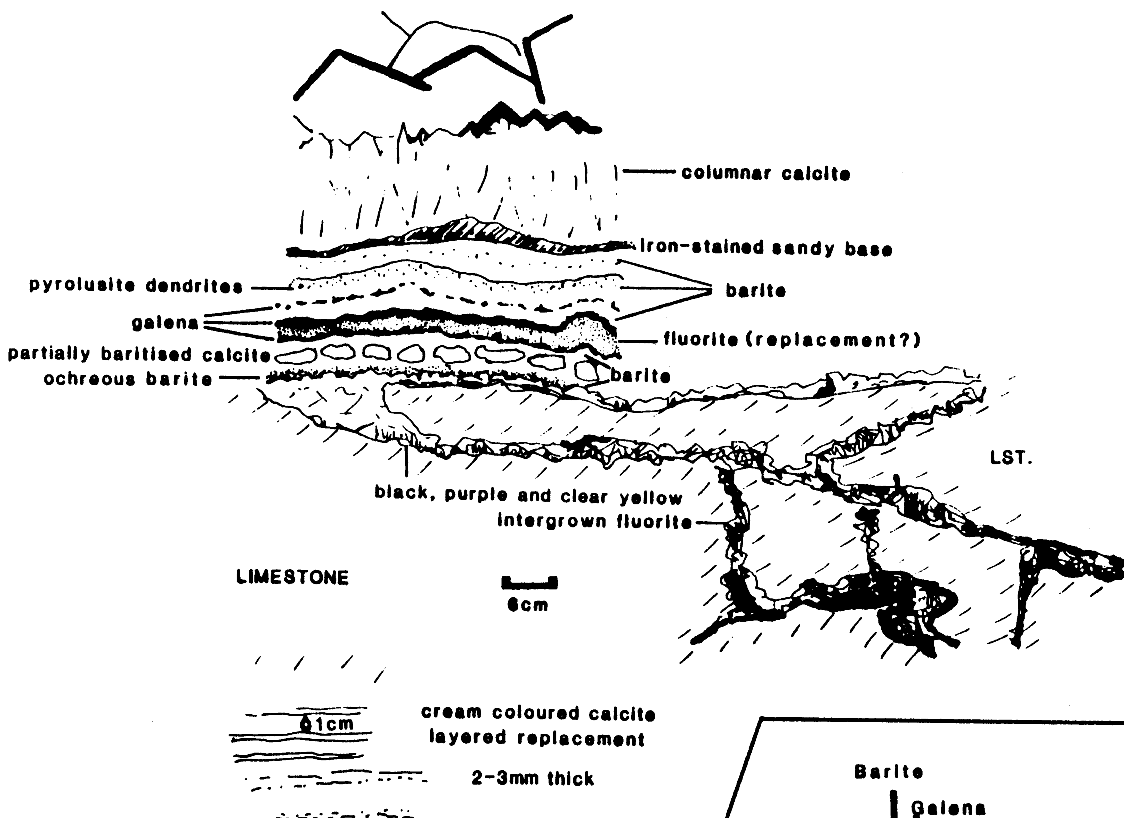

Fig.6. Stratiform body, about 1.5 m thick.

LOCATION 10

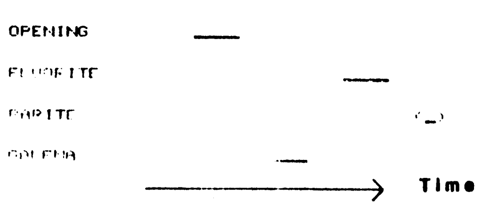

Table 10. Location 10, Whirlpool Passage.

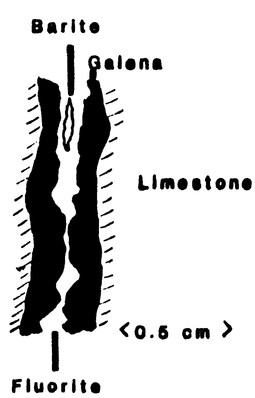

Fig.7. Location 10.
Veinlet crossing Whirlpool Passage.

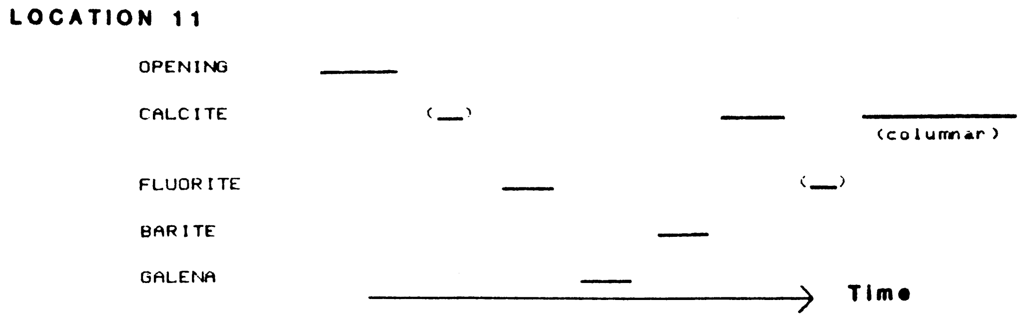

Table 11. Location 12, Whirlpool Passage.

Fig.8.Iron minerals in specimen from Location 11, Whirlpool Passage.

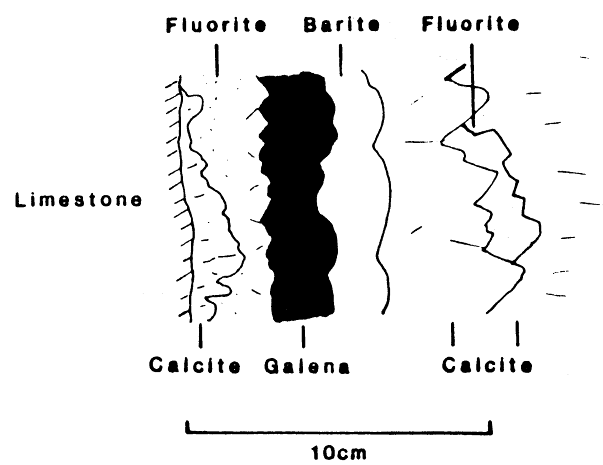

Fig.9.Location 11. Southeast side of vein at Whirlpool Rising.

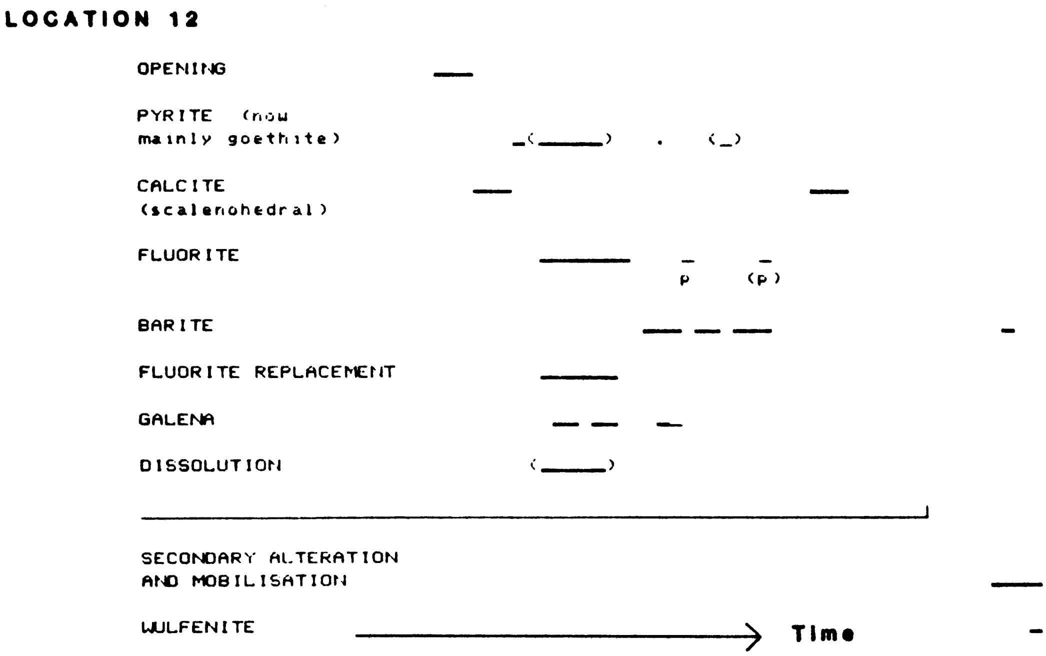

Table 12. Location 12, Loose Boulder, Whirlpool Rising.

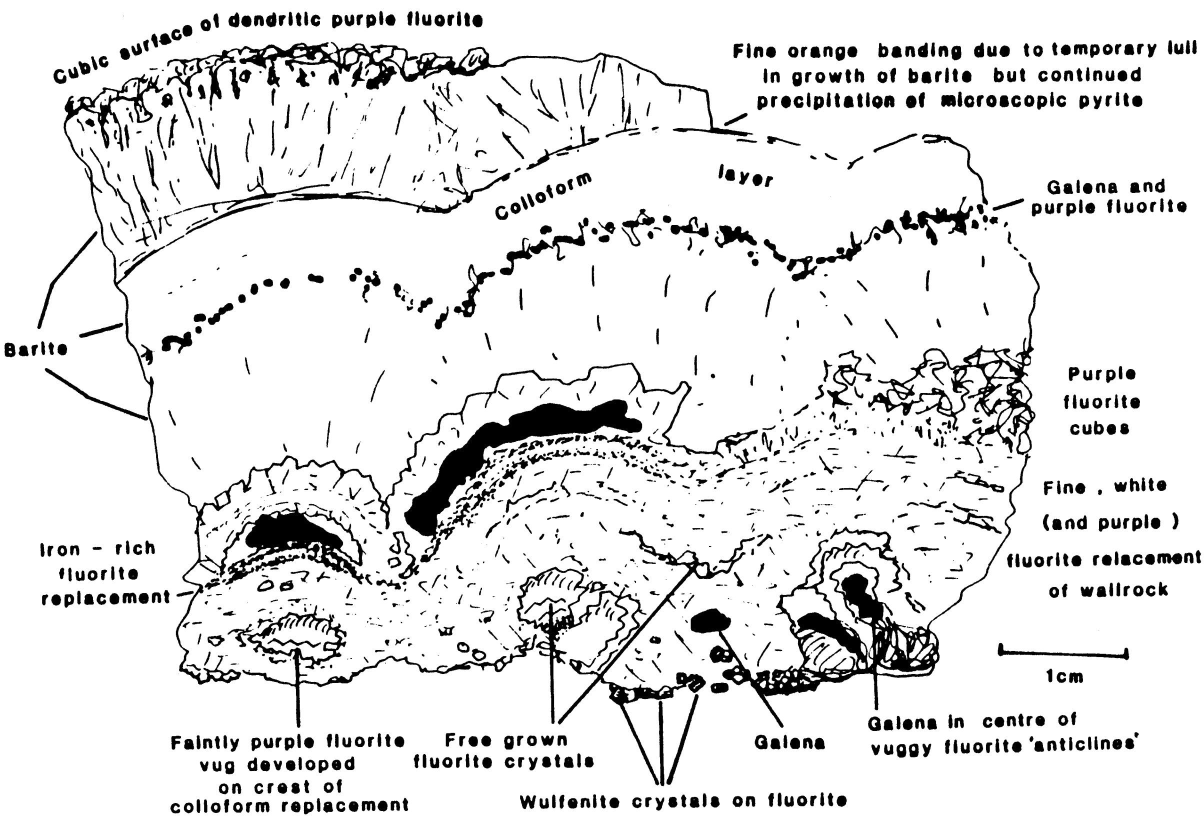

Fig.10. Location 12. Specimen from Whirlpool Rising showing reniform banding, replacement, contemporaneous dissolution and vug development. Note secondary wulfenite coating the fluorite/limonitic basal surface (see Fig. 16).

LOCATION 12 (continued)

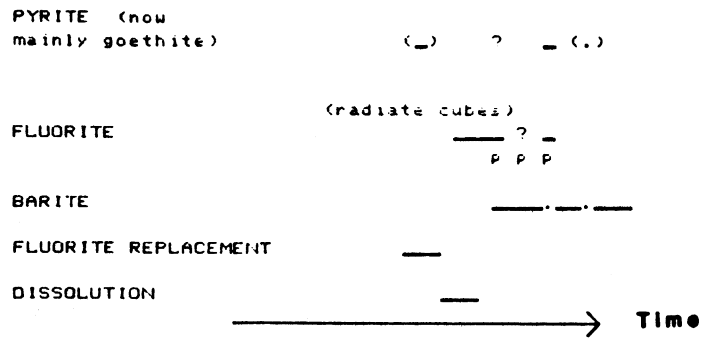

Table 13. Location 12, Loose Boulder, Whirlpool Rising.

LOCATION 13

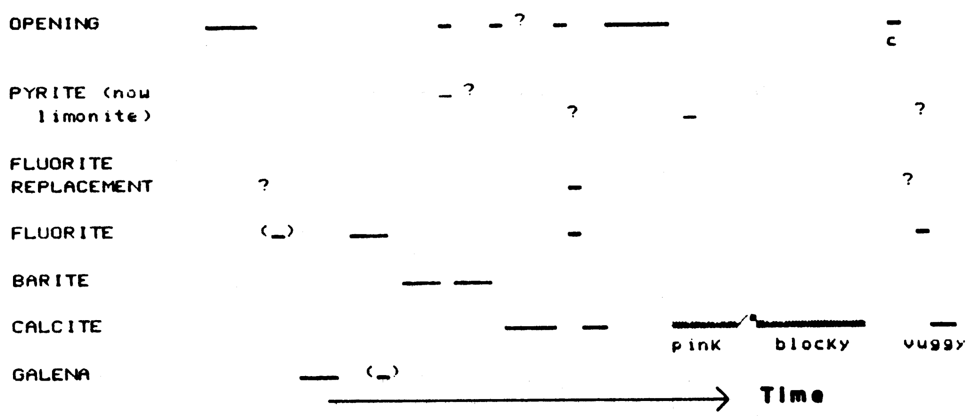

Table 14. Location 13, Branch off Faucet Rake (?) end of Whirlpool Passage.

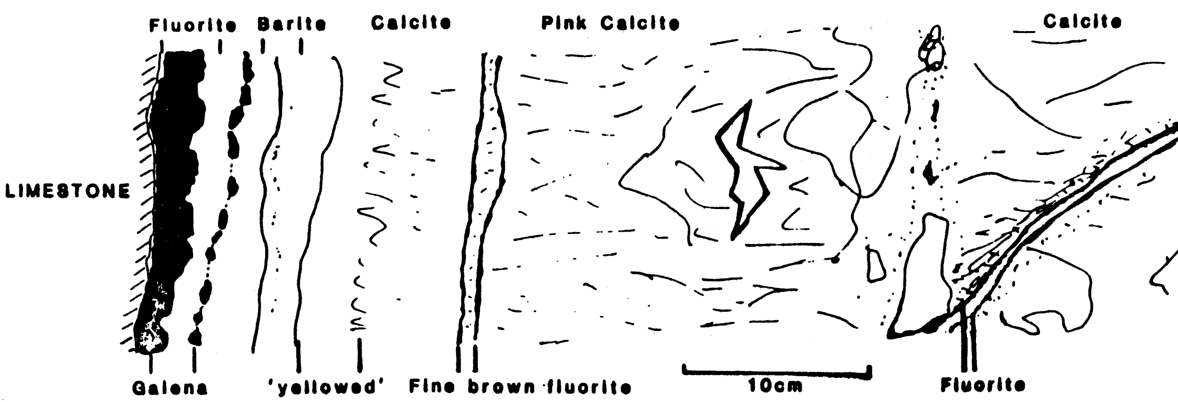

Fig.11. Location 13. Southeast side of vein at end of Whirlpool Passage, approximately 60 cm wide.

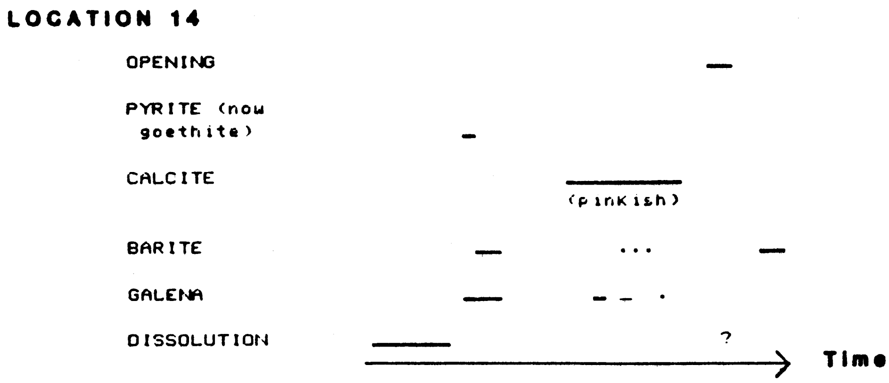

Table 15. Location 14, Main Stream Passage, Boulder Piles.

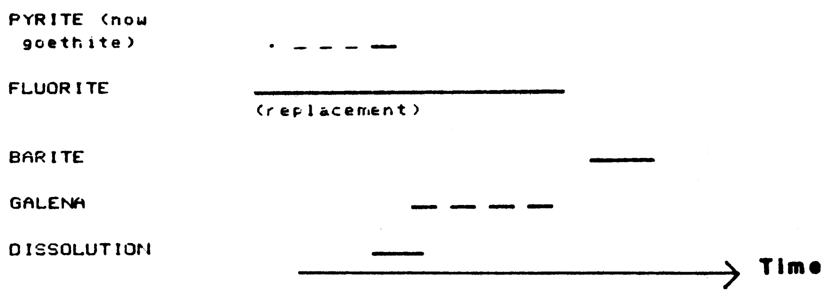

Table 16. Location 14, Pebble from Main Stream Passage, Boulder Piles.

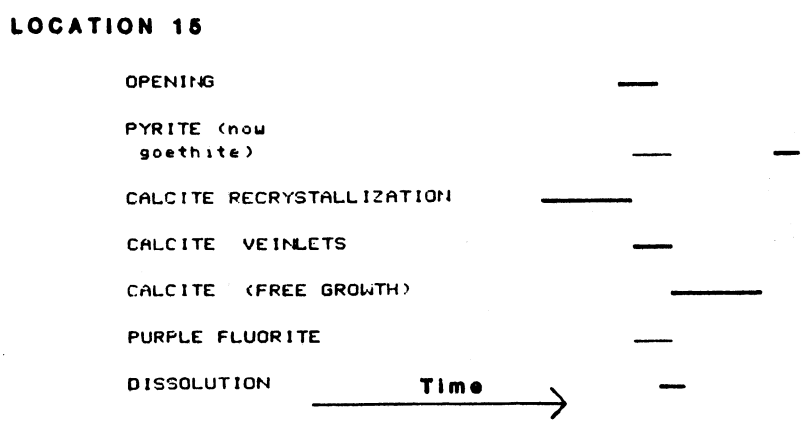

Table 17. Location 15, Main Stream Passage.

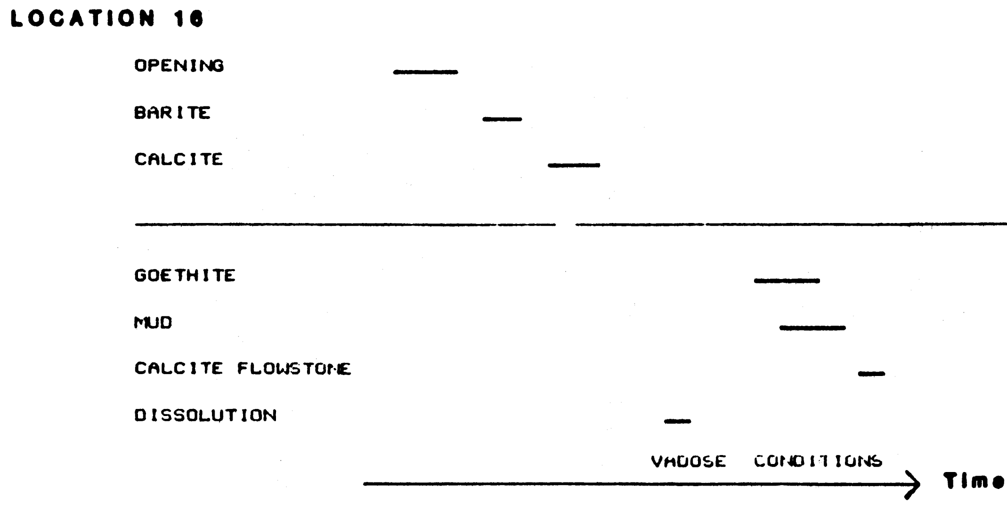

Table 18. Location 16, Main Stream Passage.

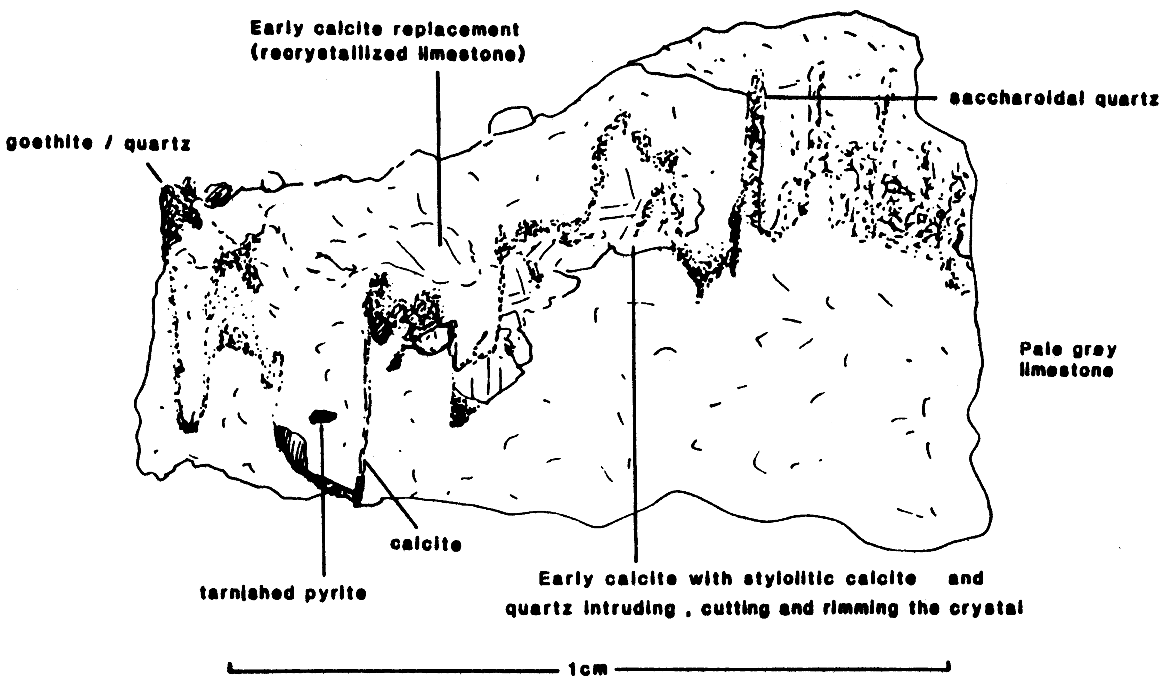

Fig.12. Location 16, Main Stream Passage. Section through wallrock beneath goethite/mud concretions. Quartz, pyrite, calcite stylolite crosscutting early calcite in recrystallized limestone.

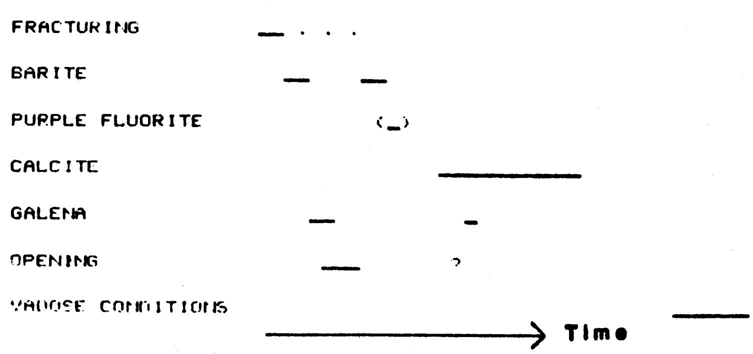

Table 19. Location 16, Vein at entrance to Cliff Passage.

LOCATION 16 (continued)

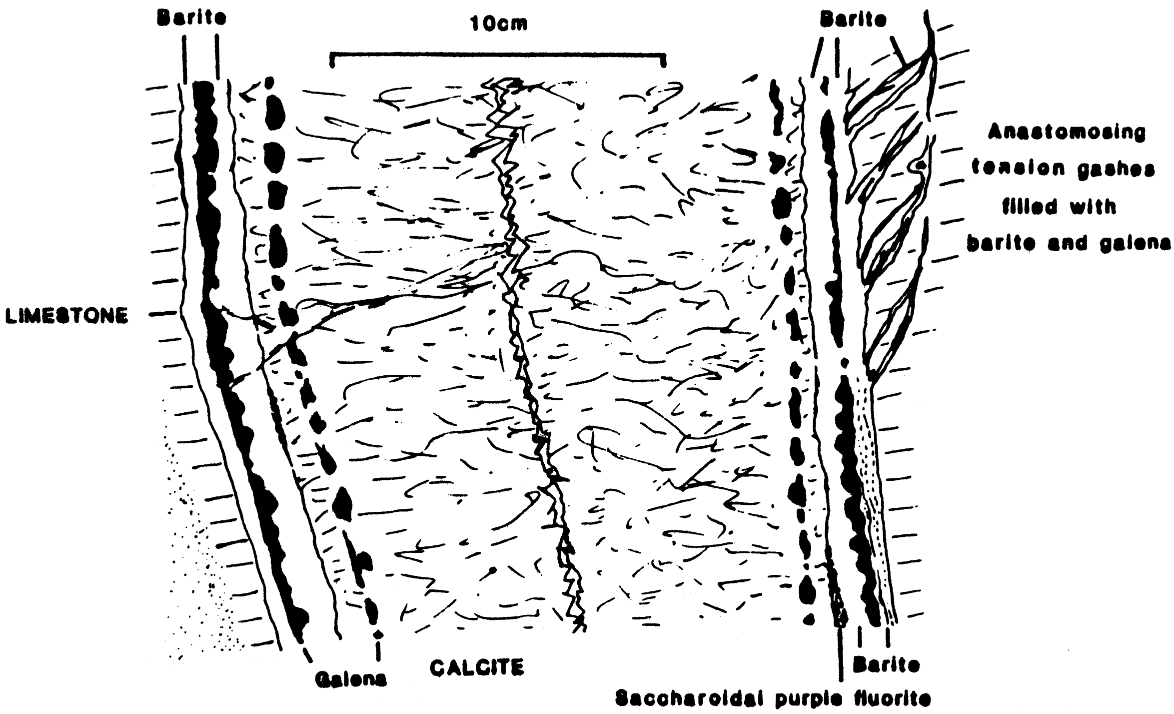

Fig.13. Location 16. Symmetric vein crossing entrance to Cliff Passage.

LOCATION 17

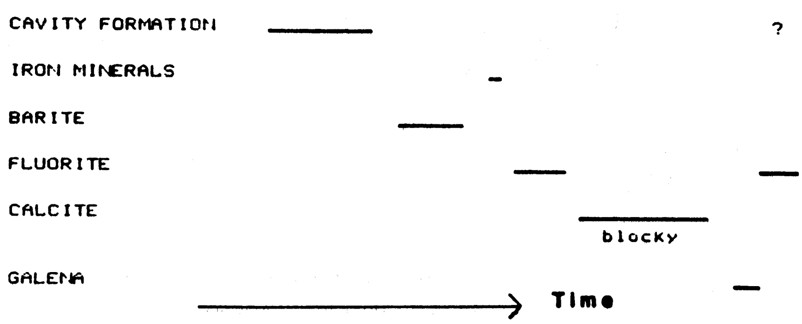

Table 20. Location 17, Calcite pipe in Cliff Passage.

LOCATION 19

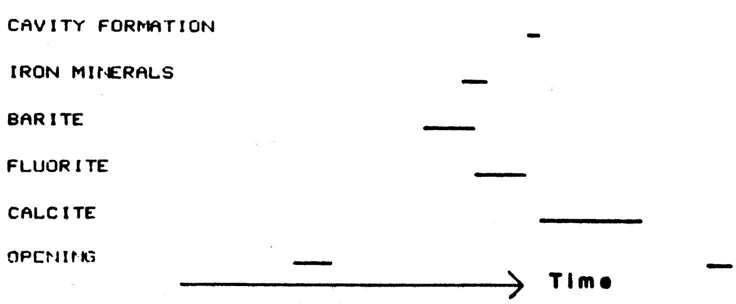

Table 21. Location 19, Cliff Cavern.

LOCATION 17 (continued)

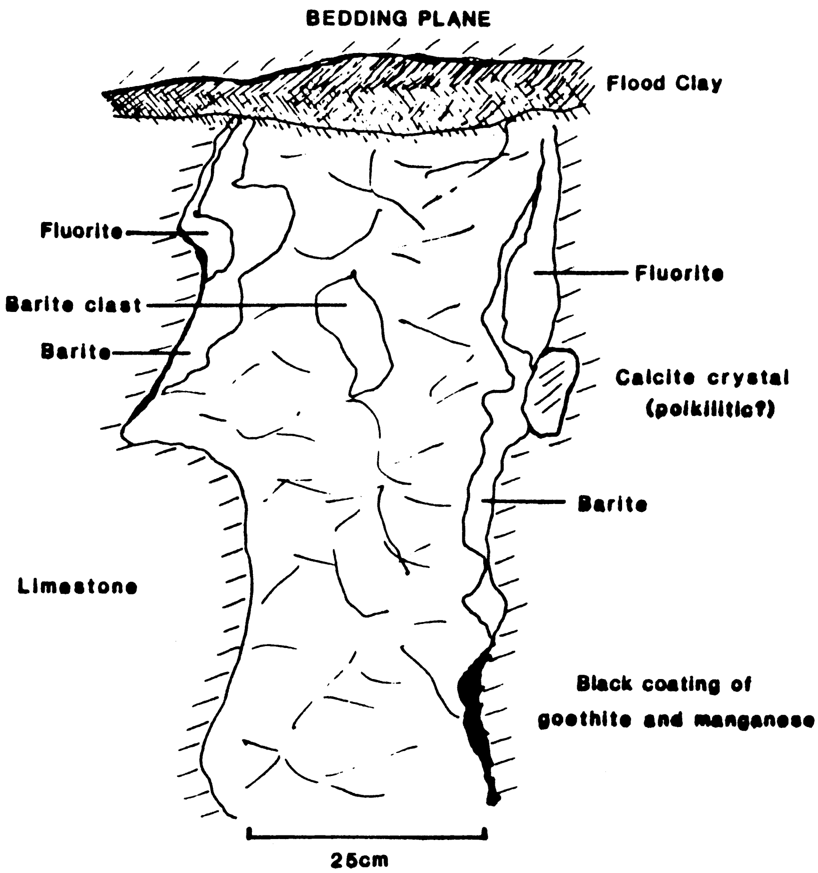

Fig.14. First calcite pipe, trending northwest. Location 17, Cliff Passage.

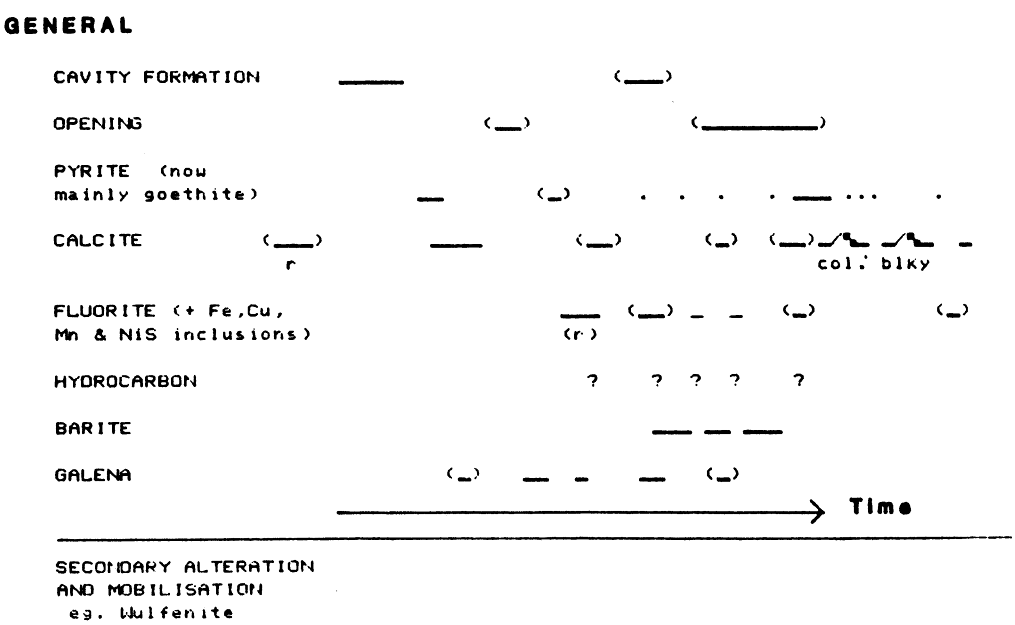

Table 22. General paragenesis for the Whirlpool Passage and Faucet Rake.

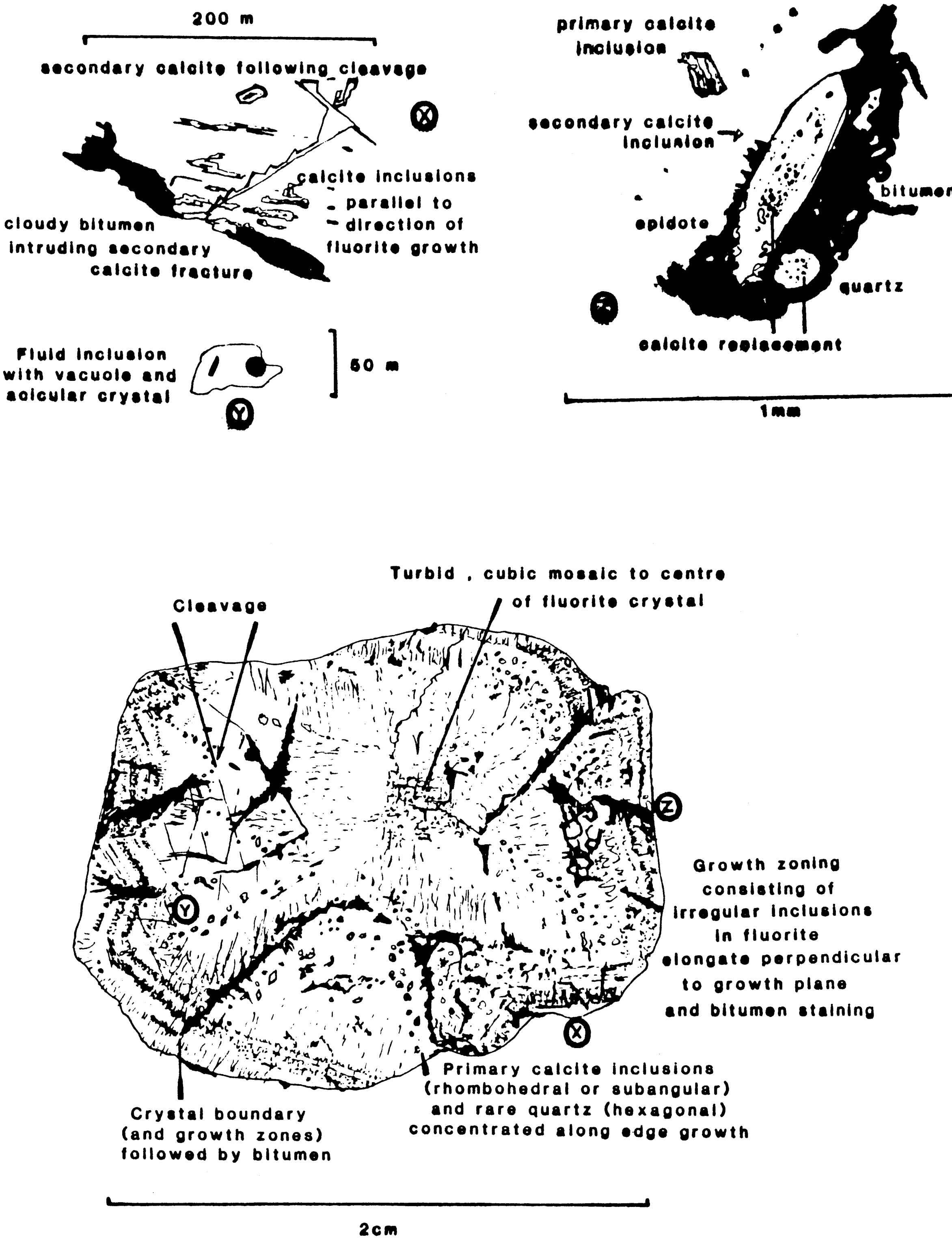

Fig.15. Polished thin section of cubes of dark blue fluorite, from mineral gravel found at Location 5, Whirlpool Passage. Note growth zoning depicted by elongate calcite inclusions and emphasized by hydrocarbon staining at edge of crystal faces. Bitumen is concentrated principally along crystal boundaries and minor fractures that displace the growth zones. Triangular secondary calcite inclusions are constrained by fluorite cleavage. Rare fluid inclusions are present. Details shown on the top, are all in a fluorite matrix.

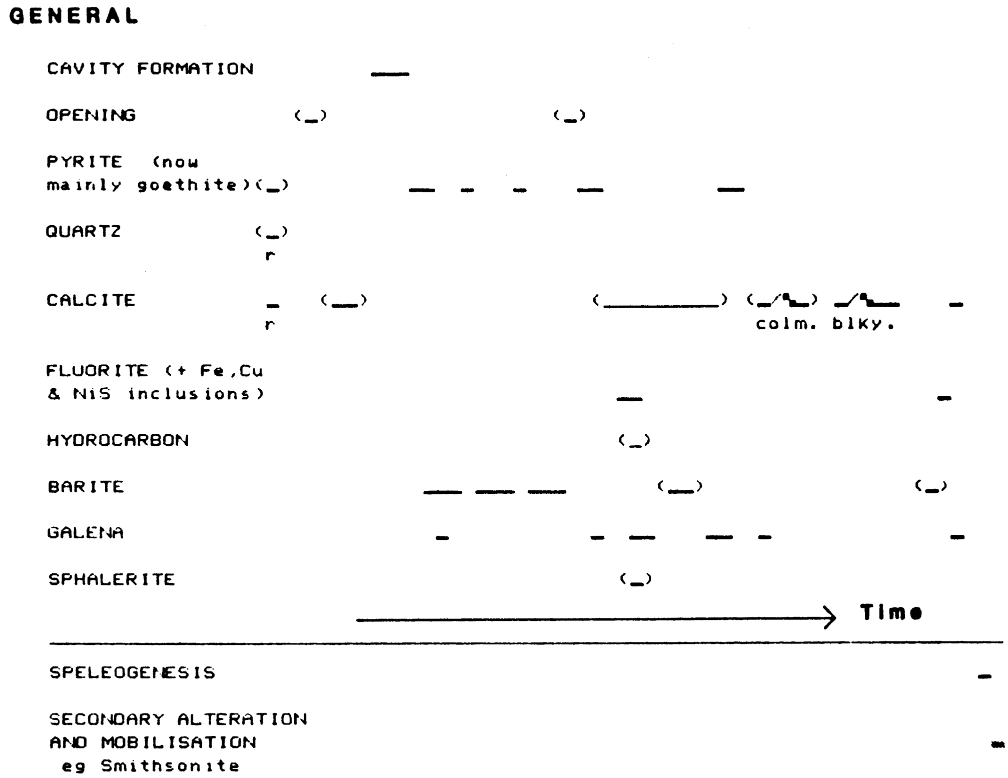

Table 23. General paragenesis for the Main Stream Passage, near Bung Hole Passage and Cliff Passage.

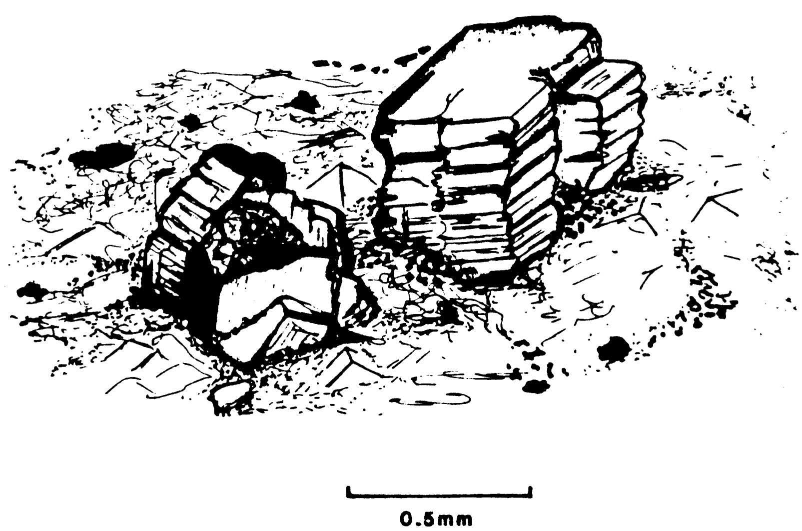

Fig.16. Multifaceted, tetragonal crystals of wulfenite, beeswax yellow in colour, on a limonitic fluorite surface (see Fig. 10). The prisms are horizontally striated at right angles to their length (C axis) due to bevelled (011) modification and development of (021) faces.

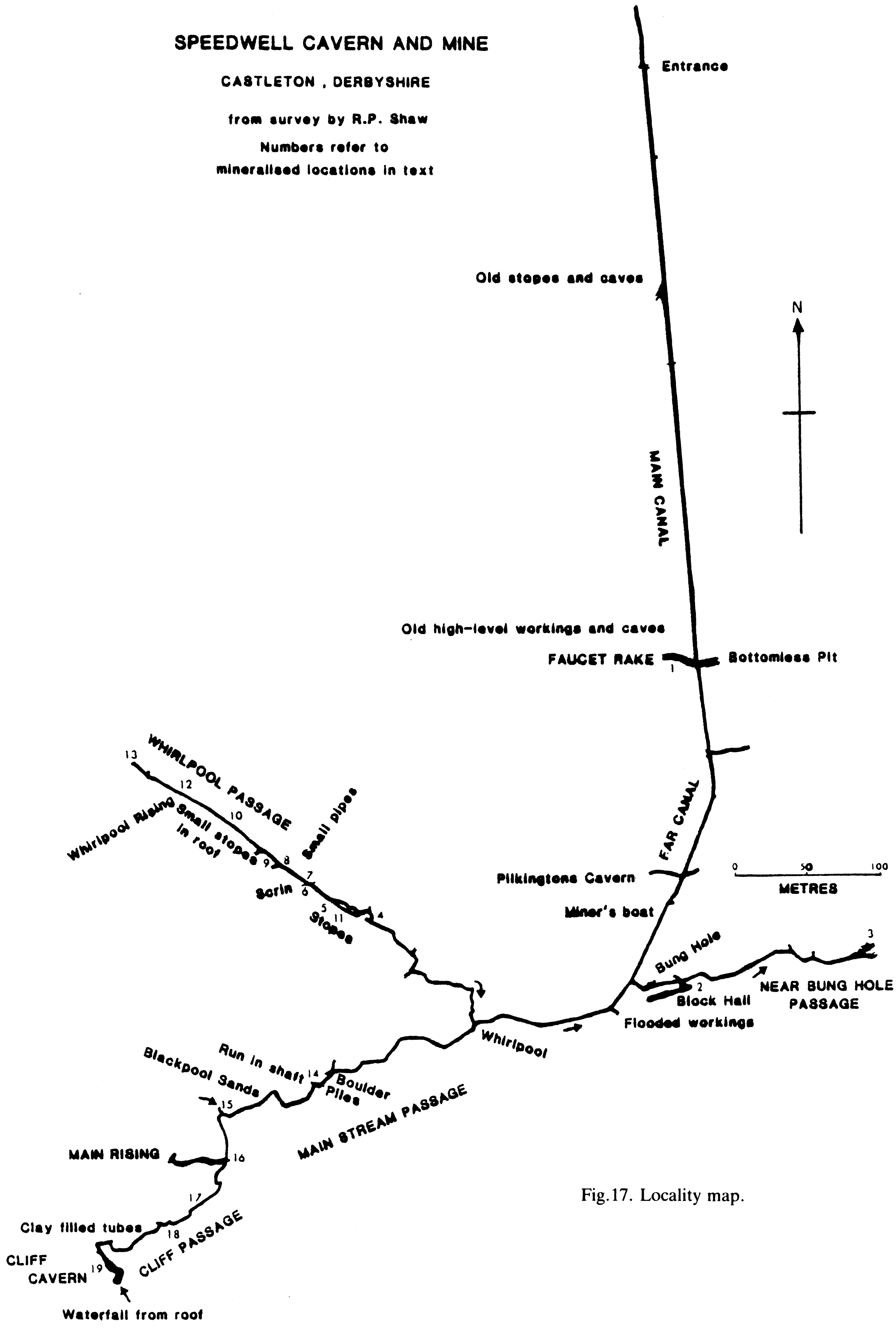

Fig.17. Locality map.