THE MINERALOGY AND PARAGENETIC SEQUENCE OF LONG RAKE VEIN AT RAPER MINE, DERBYSHIRE

by

P.R. Ineson and F.A.M. Al-Kufaishi

Summary

Long Rake is the longest of a group of approximately east to west trending mineral veins in the Carboniferous Limestone of the Derbyshire orefield. Raper Mine, located on Long Rake, is situated where the vein intersects the fluorite zone of the regional mineral zonation on the eastern margin of the orefield.

Opencast and old mine workings have enabled a paragenetic sequence of mineralisation to be established. Both fissure-filling and replacement types of mineralisation are recognised. Paragenetically, three generations of barite and five generations of fluorite are discernible. Minor amounts of galena and pyrite are present, together with their secondary oxidation minerals.

Introduction

The Derbyshire orefield, which is broadly delimited by the boundaries of the Carboniferous Limestone massif is crossed by hundreds of mineral veins. Figure 1 illustrates the major veins as well as indicating the outline of the limestone area. The mineralisation is predominantly fluorite, barite and calcite, although the area has, until recently, been mainly a lead mining field. Sporadic occurrences of sphalerite have been economically exploited, *e.g.* at Millclose Mine, while limited amounts of iron and manganese ore have also been extracted.

The veins are known under terms which were coined by the old Derbyshire miners, and are classified as rakes, scrins, flats and pipes (Kirkham, 1949).

Long Rake vein, the location of which is shown in Figure 2, is, as the term implies, one of the rake veins. These are of considerable lateral extent across the orefield and are commonly many feet in width, even up to and exceeding 150 feet where dilation of the lode and wall replacement have occurred. The walls are horizontally slickensided, implying transcurrent faulting.

The thermal zonation of the gangue minerals (minerals other than the metal ores) has been known for some time. The orefield does not display a zonal closure, as shown by the Northern Pennine orefield, but a north-south trending zonation. Fluorspar is predominant along the eastern margin of the limestone, followed westwards by barite and still farther west by calcite.

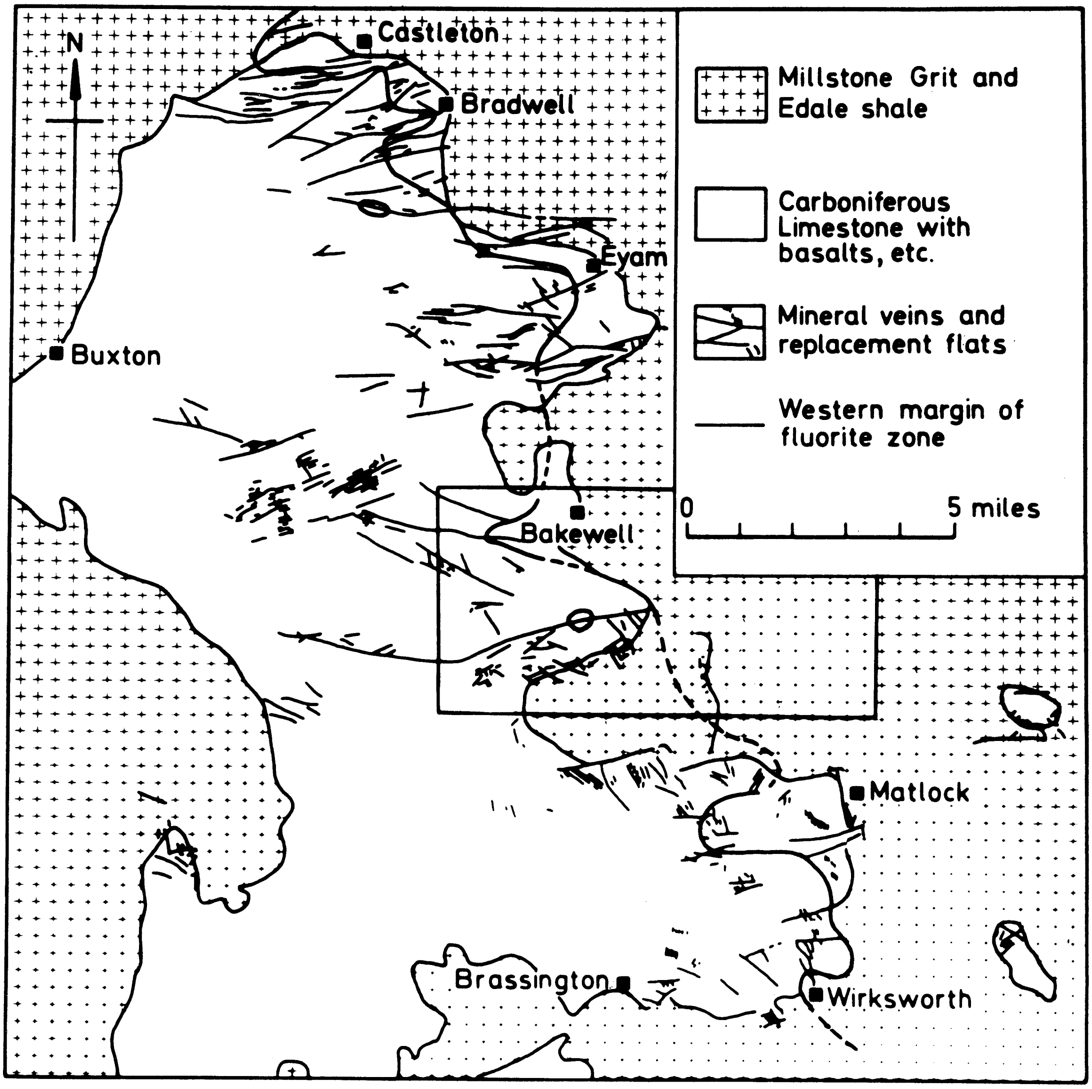


FIGURE 1 Geological sketch map of the Derbyshire Orefield, illustrating the outcrop of the Carboniferous Limestone and the position of the major veins. The area covered by Figure 2 is indicated (after Dunham - 1952).

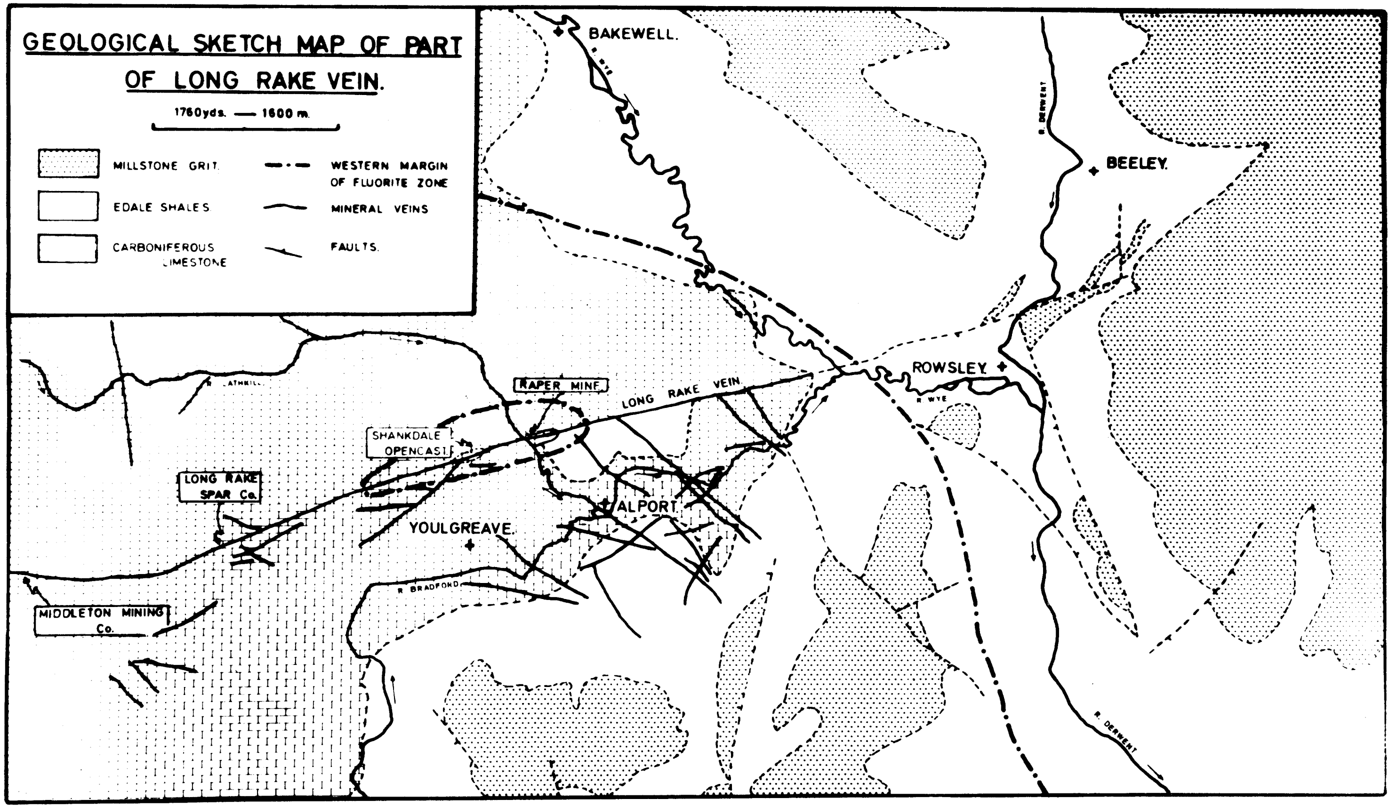


FIGURE 2 Geological sketch map of part of Long Rake vein.

Dunham and Dines (1945), Ford (1967), Varvill (1937) and Wedd and Drabble (1907) have all described many of the deposits, but no general account of the orefield has been forthcoming. There is also no detailed account of the geological history of any one vein and a structural analysis of the veins and their relationship to the stratigraphy has not encompassed the whole orefield. This paper, it is hoped, will initiate interest in the mineralogy and paragenesis of some of the mineral deposits, with a view to a better understanding of this complex and economically important region.

Geology of Long Rake Vein

Long (or Ladies) Rake is the longest single rake vein in the Derbyshire orefield. It extends for approximately five miles from the eastern boundary of the limestone massif in a general west to south-westerly direction before changing its course to a west to north-westerly direction, and splitting into a number of minor veins.

The rake, therefore, intersects the north-south thermal zones of the orefield. The western part of the rake is predominantly calcitic and is being actively exploited by the Middleton Mining Company and the Long Rake Spar Company (Fig. 2). Both mines are now more than 400 feet deep and are extracting calcite for terra cotta, pebble-dash and other ornamental purposes. Along this length of its strike the rake is approximately 15 feet wide, with horizontally slickensided walls, often lined with strings of galena. The vein has a curved vertical profile, as seen in the shaft at Long Rake Spar Mine. Intersecting the shaft in a west south west - east north east direction, the vein dips southwards to a depth of 250 feet and northwards between 250 feet and 340 feet. Owing to this reversal of dip, the shaft commences in the vein at the surface, passes through it into limestone and enters the vein again near the bottom.

Eastwards, the calcite gives way to barite and fluorite, and still farther eastwards to predominant fluorite with occasional barite stringers. The fluorite section of the vein is being exploited by opencast workings, on either side of the River Lathkill; Shankdale Opencast to the west and Raper Mine and Opencast to the east. (Fig. 2).

Green (1887) was the first to describe Long Rake and the subsidiary veins. He also indicated that the section of the rake east of the River Lathkill has been known as Black Sough. This term may have originated due to the presence of a shale outlier on the southern side of the vein (Fig.2). This shale outlier has enabled the throw of the fault to be calculated as approximately 80 feet down to the south. Green did not give a detailed account of the mineralogy of the vein, while Wilson et al (1922), in their special report on Barite and Witherite, briefly referred to Long Rake as "the master vein in this locality, contains lead and fluorspar, but no barites."

Varvill (1959), describing Long Rake, stated that "of the content of the Long Rake itself, nothing is known, except near its western end where it is being worked at shallow depths for calcite". He considered the eastern section of the vein to be a fluorite 'hot spot', as it intersected his hypothetical lead belt axis.

Dunham (1952) described the deposit at Raper Mine as "a replacement of the limestone for unreplaced nodules of chert are to be seen in the upper part of it" (*i.e.* the opencast).

Ford (1967) suggests that the Rake, as exposed at Raper, showed "unconformable shale cover downthrown some 80 feet on the south side (so that the base of the shale is about 40 feet below the surface on the south wall). Both sides have also a cover of boulder clay with scattered Lake District erratics. The walls are not clearly visible, but patches may be seen to be unaltered dolomitised or silicified limestone. The Rake is a plexus of veins alternating with horses of limestone, sometimes dolomitised, or of shale. The plexus is up to 80 feet wide''. He also states that earth movements at Raper Mine were of a repeated 'shuffling' to and fro rather than a single major movement causing the faulting. Ford also recognises the complexity of the mineralisation in stating that ''barite is cemented by fluorite and vice versa, chert is cemented by fluorite, fluorite is cemented by chert. Composite blocks may be cemented by fluorite chert or calcite''. Ford (1969) briefly notes that sedimentary structures form part of the matrix of the brecciated vein. He coins the term ''sand'' for the stratified galena, barite and fine-grained quartz material which cements the normal crystal growth textures.

Ineson (1969) shows that the trace element aureole next to the vein at Raper Mine has abnormal features, compared with other localities in the orefield, and states that ''the deposit of fluorite with barite and traces of galena is believed to be partly a replacement of the limestones in which numerous chert nodules have been left unreplaced''. Celenk (1970) also reports irregular dispersion patterns in the wall-rocks of Long Rake, and suggests that these indicate ''that the wall-rocks were fractured prior to mineralisation''.

Raper Mine

The old mine workings and opencast operations are owned by G.E. Bacon and Sons of Youlgreave. There are records (personal communication - Mr. R. Bacon) which indicate that the mine was owned and worked by the Bacon family in the 1770's. The present owners commenced underground mining in 1948. In 1955 the opencast operations were initiated. The ensuing years have seen the removal of over 100,000 tons of mineral, 20,000 tons of overburden (mainly boulder clay) and recently the extraction of 80,000 tons of shale, to facilitate the extraction of metasomatised limestone beneath the unconformable shale. Since 1948 the mine and opencast workings have produced an ore with an average composition of:

CaF_2 - 45-50%

PbS - 1-2 %

$BaSO_4$ - 3-4 %

Mineralisation

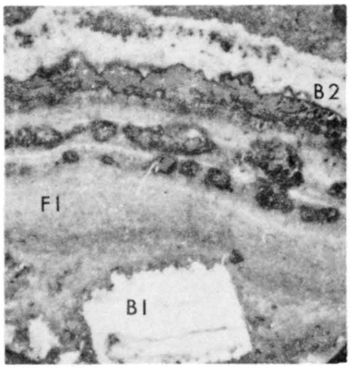
The Mineralisation of Long Rake is here postulated as being of two different types. The predominant ore is of a typical fissure filling variety, bounded and cut by frequent intersecting oblique, post-mineralisation, slickensided fault surfaces which are sub-vertical in attitude. The mineral fill between these blocks illustrates numerous phases of brecciation and recementation. Quasi-sedimentary banding is also displayed in these areas. The second type of orebody is characterised by material located beneath the shale, on the southern side of the opencast. Silicification, dolomitisation and fluoritisation as well as unaltered limestone blocks are characteristic of this part of the deposit. The width at present exposed in the opencast is approximately 140 feet, and the whole extent may not, as yet, have been exploited. Extensive replacement deposits are envisaged beneath the Edale Shales.

Polished slabs, 2 inches thick, were prepared, in order to study the large scale relationships between the mineral fragments of different generations. Polished sections were mainly used in working out the detailed mineralogical sequence.

EXPLANATION OF PLATE 25

A	A brecciated fragment of the first barite generation (B1) surrounded by fluorite of type 1 (F1). The second period of barite mineralisation is shown by the band (B2) in the polished specimen. Magnification x 3.
B	The third period of barite mineralisation is shown by small veinlets (B3) cutting massive fluorite. Natural Size.
C	A band of fluorite (F1) above a mass of light grey (F2) fluorite. Within the first fluorite generation is colloform-like barite (B2) and galena (G). The galena has been fragmented and enclosed by the barite and may therefore have acted as a 'fracture belt' for the injection of barite (B2). Polished specimen. Magnification x 3.
D	A complicated breccia of various mineral episodes. Barite (B1) forming large areas, while barite (B2) is banded with galena crystals (black dots) interspersed within the mineral. Three fluorite generations are present, predominant in this plate is F2, characterised by its dark colour and fractured outline. Polished block. Natural size.
E	Fluorite (varities 3 and 4) enclosing fractured chert (Ch). Veinlets of barite (B3) are also shown in the polished block. Natural Size.
F	Silicified limestone with numerous crinoid fragments. Magnification x 2.
G	Barite (B3) veinlets transgressing massive microcrystalline fluorite (F5). Post B3, pre F5 faults have displaced the barite veinlets. Polished slab. Natural Size.
H	Photomicrograph of subhedral pyrite (P) enclosed in fluorite (F). Cerussite (C) is well developed at the border of the fluorite and galena (G). Magnification x 120.
J	Photomicrograph illustrating 'granular texture' boundary relationship between galena (G) and fluorite (F). Along the boundary are islands of fluorite surrounded by cerussite (C). Magnification x 120.

Plate 25



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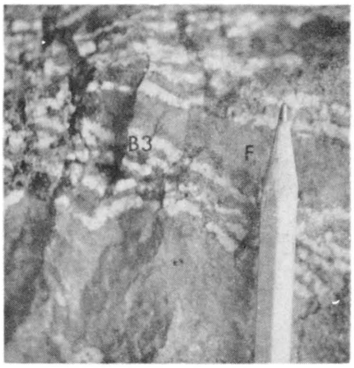

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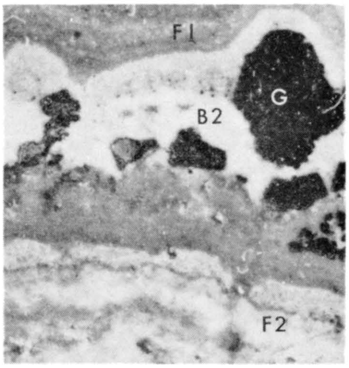

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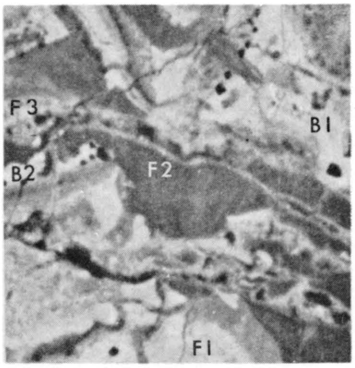

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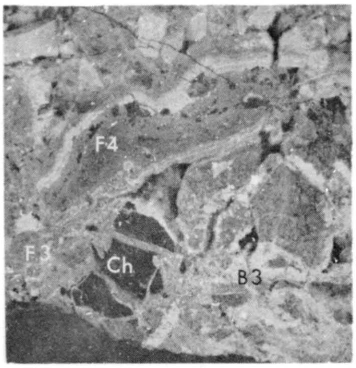

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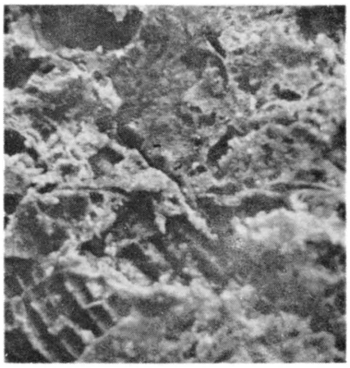

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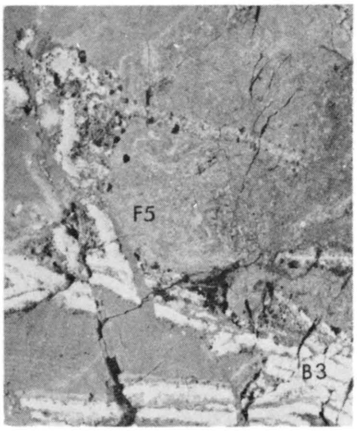

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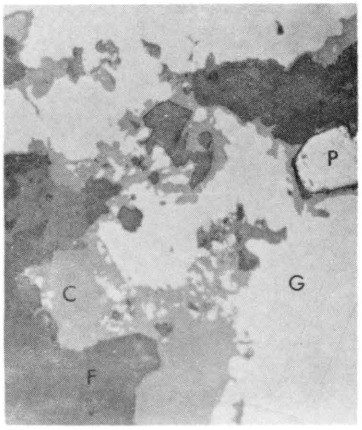

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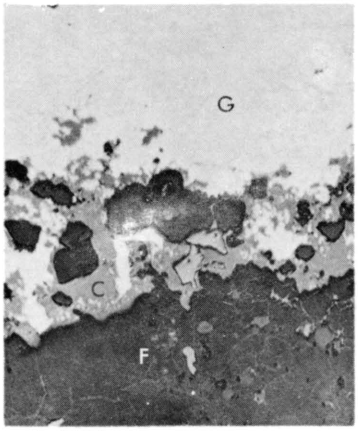


J

Barite

Three barite generations are discernible at Raper Mine. Types 1 and 2 are very early varieties while type 3 is very late, and may perhaps represent the final mineralising episode.

Type 1 barite occurs as colour-differentiated, encrusted and subsequently brecciated bands. It is distinguished from other varieties by the absence of associated galena fragments. It also occurs as lath-like fragments up to 6 mm. in length in subsequently deposited fluorite and barite. It is now only recognisable as brecciated fragments in a groundmass of subsequent mineral episodes.

Type 2 barite is found as encrusting layers with fluorite, galena and traces of pyrite. Brecciated fragments of type 1 are situated in a matrix of type 2, hence the differentiation. Plate 25A illustrates this generation as well as the previous type; as a brecciated mass of barite with fluorite, the whole being incorporated in a subsequent generation of fluorite. Both barite generations illustrate radiating, acicular or lath-like crystals within each lamina.

The third type of barite (see Plate 25B) is thought to be a very late stage injection product. It is sporadically distributed in small veinlets across the whole width of the veins, and associated principally with dark violet-coloured fluorite.

Fluorite

Five varieties of fluorite are discernible. Three generations are principally restricted to the fissure-filling part of the lode, while the fourth only occurs in the replacement zone. The fifth type intersects both parts, of the deposits.

Type 1 fluorite is massive, cryptocrystalline and pale brown in colour, although banding is indicated by slight colour variations in the encrusted masses. It is invariably associated with type 2 barite. Type 1 fluorite occurs as brecciated fragments enclosed in a subsequent fluorite generation (see Plate 25C).

The second stage of fluorite deposition is recognised by its invariably occuring as a cementing matrix to types 1 and 2 barite and type 1 fluorite. Fragmental galena is often included in the fluorite, presumably derived after the deposition of type 1 barite, but prior to the influx of the type 2 fluorite mineralisation.

Euhedral yellow fluorite occurring in veinlets up to several centimetres in width and transgressing the previously deposited and brecciated episodes, characterises the third stage of fluorite deposition (see Plate 25D). Plate 25E illustrates type 4 fluorite forming a groundmass for brecciated chert fragments. It is often coated with type 3 barite and thus predates the final barite episode.

The fluorite mineralisation occurring in the replacement flats beneath the shale is extremely friable, microcrystalline and amber in colour. Silicified crinoids and chert nodules are a common feature of this part of the lode (see plate 25F).

Distinctive violet coloured holocrystalline fluorite (type 5) is located on the northern wall of the vein. It is invariably associated with type 3 barite, which transgresses the massive fluorite. Plate 25G illustrates the barite stringers in the fluorite and very late stage micro-faults within the lode.

EXPLANATION OF PLATE 26

A Photomicrograph of subhedral fluorite (F) at the junction of galena (G) and cerussite (C). Massive fluorite also present. Magnification x 120.

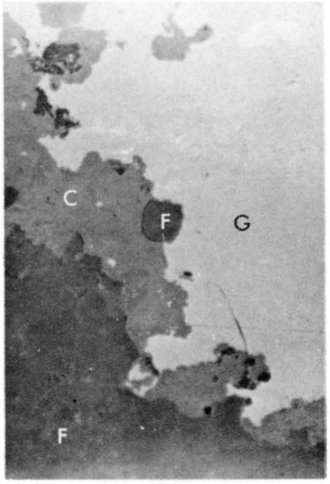
B Photomicrograph of euhedral quartz (Q) situated along the boundary of massive galena (G) and fluorite (F). Magnification x 120.

C Photomicrograph illustrating the progressive alteration of galena (G) to cerussite (C). The fragment of galena on the left has not been completely replaced by cerussite and shows replacement rim texture. The fragment on the right has been completely replaced by cerussite. The whole is enclosed in massive fluorite (F). Magnification x 120.

D Photomicrograph of cleavage replacement texture between galena (G) and cerussite (C). Magnification x 120.

E Photomicrograph showing 'caries texture' between galena (G) and cerussite (C). A small amount of fluorite (F) is also shown. Magnification x 120.

F Photomicrograph showing another type of boundary relationship between galena (G) and cerussite (C). This is classified as irregular replacement boundary texture. Fluorite (F) is also present. Magnification x 120.



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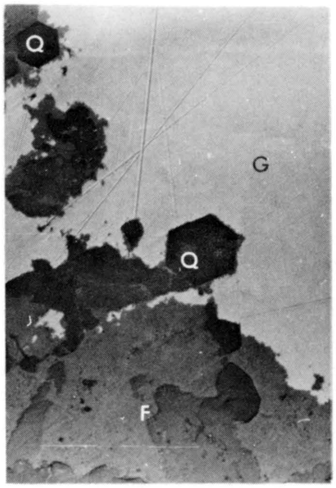

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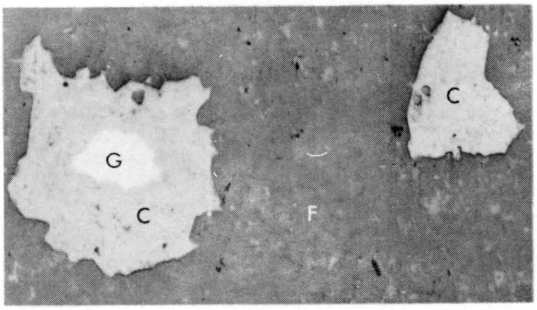

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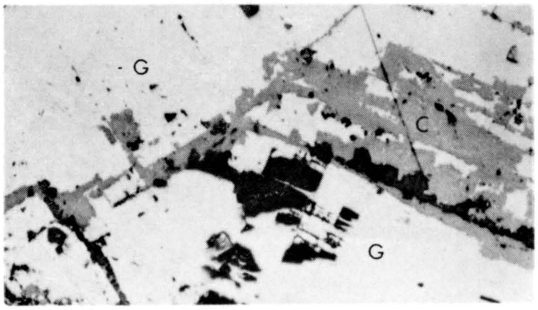

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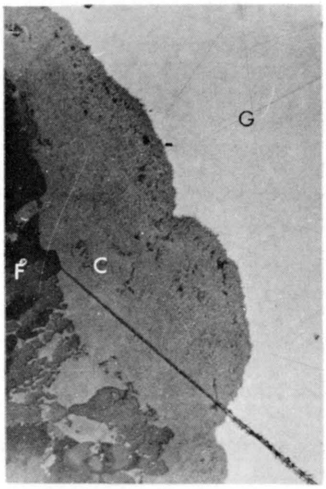

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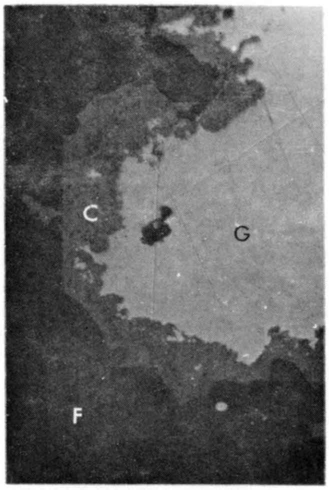


F

Galena

Galena occurs throughout the whole mineralised complex illustrating replacement textures and inclusion features.

Pyrite, fluorite and quartz are included in the galena. Plate 25H illustrates subhedral pyrite surrounded by haematite, enclosed in fluorite, the whole surrounded by galena which is converted to cerussite along the grain boundaries.

Edwards' (1954) "granulár texture" boundary relationship is shown in Plate 25J, where fluorite is distributed at the junction of galena and fluorite. Subhedral fluorite within galena is illustrated in Plate 26A, while euhedral quartz inclusions in galena are displayed in Plate 26B.

The secondary alteration of galena to cerussite is a common feature. The complete replacement of galena by cerussite has taken place as illustrated in Plate 26C, while other specimens show the selective cleavage replacement of the galena (see Plate 26D). Caries texture, (Lindgren in Bastin et al, 1931), between the galena and cerussite is displayed in Plate 26E, while Plate 26F illustrates the irregular boundary replacement of the galena by cerussite.

Specific generations of galena are not distinguishable as it occurs as rounded or brecciated fragments in all other mineral generations. It often forms cores for the colloform textures of subsequent minerals.

Pyrite

Euhedral, fractured pyrite is dispersed throughout the deposit. It is associated with all the other ores, and often displays secondary alteration to haematite. As with galena/cerussite, successive stages of replacement are recognised.

Replacement rim alteration occurs where the pyrite is not fractured (Plate 27A) while fracture line replacement is common, in previously fractured pyrite (Plate 27B). Core replacement, however, is shown in Plate 27C, and complete replacement with haematite pseudomorphs after pyrite is shown in Plate 27D.

Conclusions

Comparing the zonation of the Northern Pennine orefield with the Derbyshire orefield, Schnellman and Wilson (1947) suggested that, in view of the ill-defined zonation of the Southern Pennines, the mineralisation was not a single 'surge' but several separate pulsations. They further stated that "in any particular rake, there may have been more than one mineralising stream, each following an independent course."

Raper Mine, therefore, afforded an excellent locality where the sequence of events on Long Rake could be elucidated.

It is postulated that Long Rake was a fracture initiated late in the Hercynian orogenic episode and that further dilation and lateral movement took place during the post-Triassic movements which affected large areas to the east and west of the Pennines.

EXPLANATION OF PLATE 27

A Photomicrograph of replacement rim texture between pyrite (P) and haematite (H). The haematite having partially replaced the pyrite. Granular fluorite (F) forms the matrix. Magnification x 120.

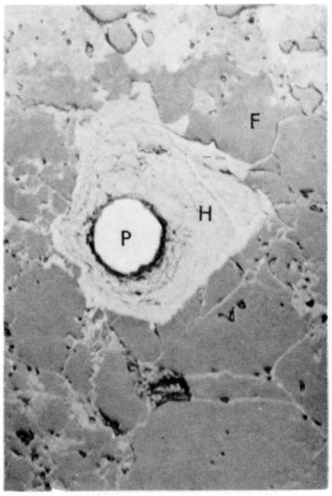
B Photomicrograph of fracture line and boundary replacement texture between pyrite (P) and haematite (H). The haematite has partially pseudomorphed the pyrite cube, as well as selectively replacing the pyrite along fracture lines. Fluorite (F), cerussite (C), and galena (G) are also present. Magnification x 120.

C Photomicrograph of core and replacement rim rexture between pyrite (P) and haematite (H). The haematite has selectively replaced the outer rim and the innermost areas of the pyrite cube. Fluorite (F), cerussite (C) and galena (G) are also present. Magnification x 120.

D Photomicrograph of pyrite cubes pseudomorphed by haematite (H). The original outline of the pyrite cube and the fractures are clearly visible. Granular fluorite (F) has a number of euhedral to subhedral quartz (Q) interspersed in the whole mass. Galena (G) and cerussite (C) are also present. Magnification x 120.

E Photomicrograph of euhedral to anhedral fluorite cubes in a matrix of microcrystalline fluorite. This may represent two mineral episodes, but more probably two crystallisation periods within one major fluorite influx. Magnification x 75.

Plate 27



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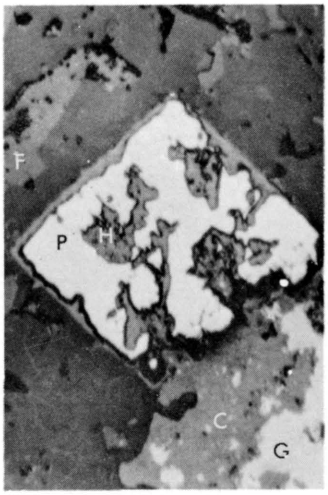

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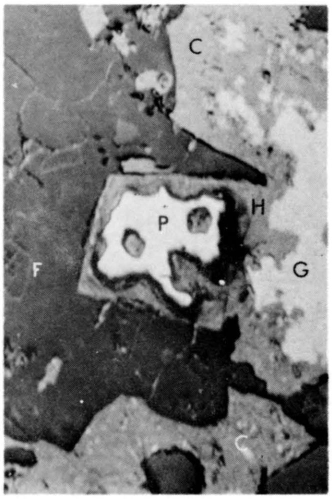

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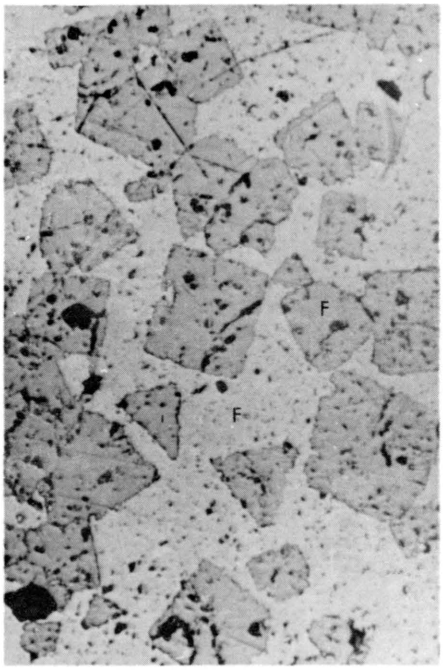


E

Dunham et al (1968) concluded, from age determinations in the Northern Pennines, that at least three episodes of hydrothermal activity had occurred. It is suggested that the textures seen at Raper Mine indicated a multi-phase mineralisation. Until detailed radiomatic dates are available, however, no more positive suggestions can be made with respect to the chronology of these phases in relation to other aspects of the geological history of the Southern Pennine orefield.

Stages of Mineralisation

An early type of barite represents the initial mineralising fluids. Brecciation of this together with the stoping of blocks of limestone into the vein (which have subsequently been metasomatised) may have resulted from minor earth movements, themselves sufficient to rejuvenate the inflow of fluids. The second stage of barite and first stage of fluorite mineralisation, with traces of galena, represent this influx of fluids. Encrustation of these minerals may indicate "rhythmic fractional crystallisation" of the assemblage as suggested by Edwards (1954).

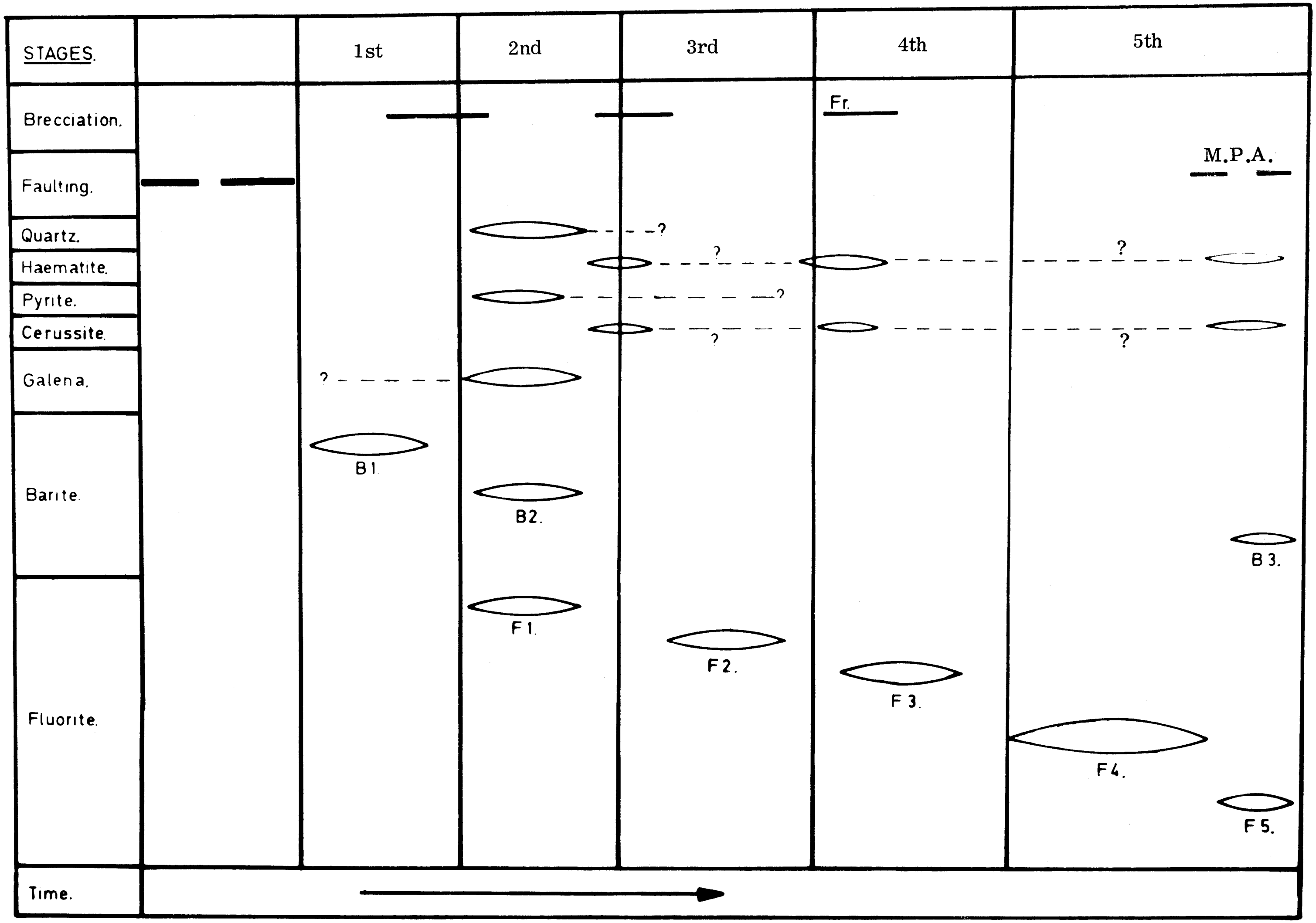
A second period of brecciation, in which all the pre-existing lode was involved, may have heralded the injection of the third stage of mineralisation. Type 2 fluorite was predominant during this episode. Plate 27E illustrates euhedral fluorite in a groundmass of microcrystalline fluorite, and as these two generations are both related to type 2 fluorite, it is possible that the stage is represented by a dual injection of fluorine rich solutions.

Fracturing of the lode, rather than brecciation, is next suggested and is shown by type 3 fluorite, which is restricted to veinlets transgressing the previously deposited mineral suites. Additional wallrock stoping is in evidence, as this type of fluorite often encases fractured chert nodules. This stage may represent a completely separate episode or may only have resulted from the rejuvenation of a previous stage. Fragmented galena is present in the fluorite matrix of this period.

The final stage of mineral deposition is the introduction of the late stage barite and fluorite. The relative period during which the dark purple fluorite was injected is uncertain although very late stage deposition is envisaged, due to micro-faults intersecting both the barite (type 3) and purple fluorite.

The stages when galena and pyrite were deposited cannot be ascertained with any accuracy. It is possible that both show various generations or the re-working of previously deposited material. The latter is strongly suggested by the fractured nature of the minerals. Likewise the secondary alteration products, resulting from the action of the near surface circulating solutions, may have been initiated at various periods, especially during brecciation, where a maximum percentage of voids would be present.

Prior to the final mineralising episode, extensive limestone replacement on the southern side of the vein occurred, forming a marked contrast with the northern side of the vein, where only a minimal alteration is evident. It is postulated that this alteration is directly related to the shale cap rock which is only present on the southern side. The shale would provide a trap to the uprising solutions, facilitating outward migration and subsequent metasomatism. The extensive silicification of the limestone wall rocks is also restricted to this area, and may have resulted from the same process. Pyrite may not be an original constituent of the vein; it is more likely the result of the leaching of the shale (often sulphurous) by downward and laterally migrating connate waters.



Fr. = Fracturing. M.P.A. = Minor pressure adjustments.

FIGURE 3 A possible paragenetic sequence of mineralisation at Raper Mine and related fracturing of the lode.

The presence of euhedral quartz inclusions in galena is evidence for the hypothesis of limestone stoping and subsequent incorporation in the vein. Throughout the D_1 and D_2 limestones of Derbyshire, occur bands of minute (< 1 mm) authigenic euhedral quartz crystals. Although these bands have not been recorded in the limestones near Long Rake, it is suggested that their presence in the mineral lode may have resulted from limestone stoping, subsequent alteration and the release of the resistant quartz crystals into the circulating mineral fluids.

The various periods of mineralisation and brecciation of the lode are summarised in Figure 3, which attempts to formulate a paragenetic sequence of mineralisation for this part of Long Rake Vein.

Acknowledgements

Without the permission and generous assistance of G.E. Bacon and Sons Limited of Youlgreave, this work could not have been undertaken. We are indebted to them for their encouragement and far-sighted interest. To Mr. R. Bacon goes our special thanks for his continual interest, many hours of fruitful discussion and his intimate knowledge of the Alport mining area.

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P.R. Ineson, B.Sc., Ph.D., A.M.I.M.M.
Department of Geology,
The University,
Mappin Street,
Sheffield, S1 3JD.

F.A.M. Al-Kufaishi, B.Sc.,
Department of Mineral Exploitation,
Newport Road,
Cardiff, CF2 1TA.

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