THE EMPLACEMENT OF A FLUORSPAR FLAT AT MASSON HILL, MATLOCK, DERBYSHIRE

by

R. A. Ixer

Summary

The fluorspar mineralization at Masson Hill is a discontinuous flat deposit with rich ore next to barren carbonates. The fluorite, quartz, barite, sulphide and calcite mineralization is a combination of metasomatic replacement of limestones and infilling of available open spaces.

Detailed mapping, structural and chemical analyses of the south-eastern half of the Masson Hill flat show that the mineralizing fluids encountered a complex sequence of rock-types, which were themselves the result of the interaction of a number of diagenetic and structural processes, the most important being dolomitization and silicification, faulting and jointing. The major controls on the emplacement of the ore included the distribution of replaceable limestones, together with the associated dolomites, basaltic lavas and ash bands. The juxtaposition of the various rocks produced porosity and permeability interfaces, often parallel to the original bedding and these controlled the horizontal movement of the ore fluids, whilst the faulting and jointing channelled vertical migrations. Locally, emplacement was influenced by the presence of premineralization solution cavities within both the limestones and dolomites.

The economically significant ore, found mainly within coarse-grained limestones at the base of the Matlock Lower Limestone Formation, was the result of the entrapment of mineralizing fluids above the thick Matlock Lower Lava, below a 0.60 m volcanic clay horizon and down-dip of a clay filled fault.

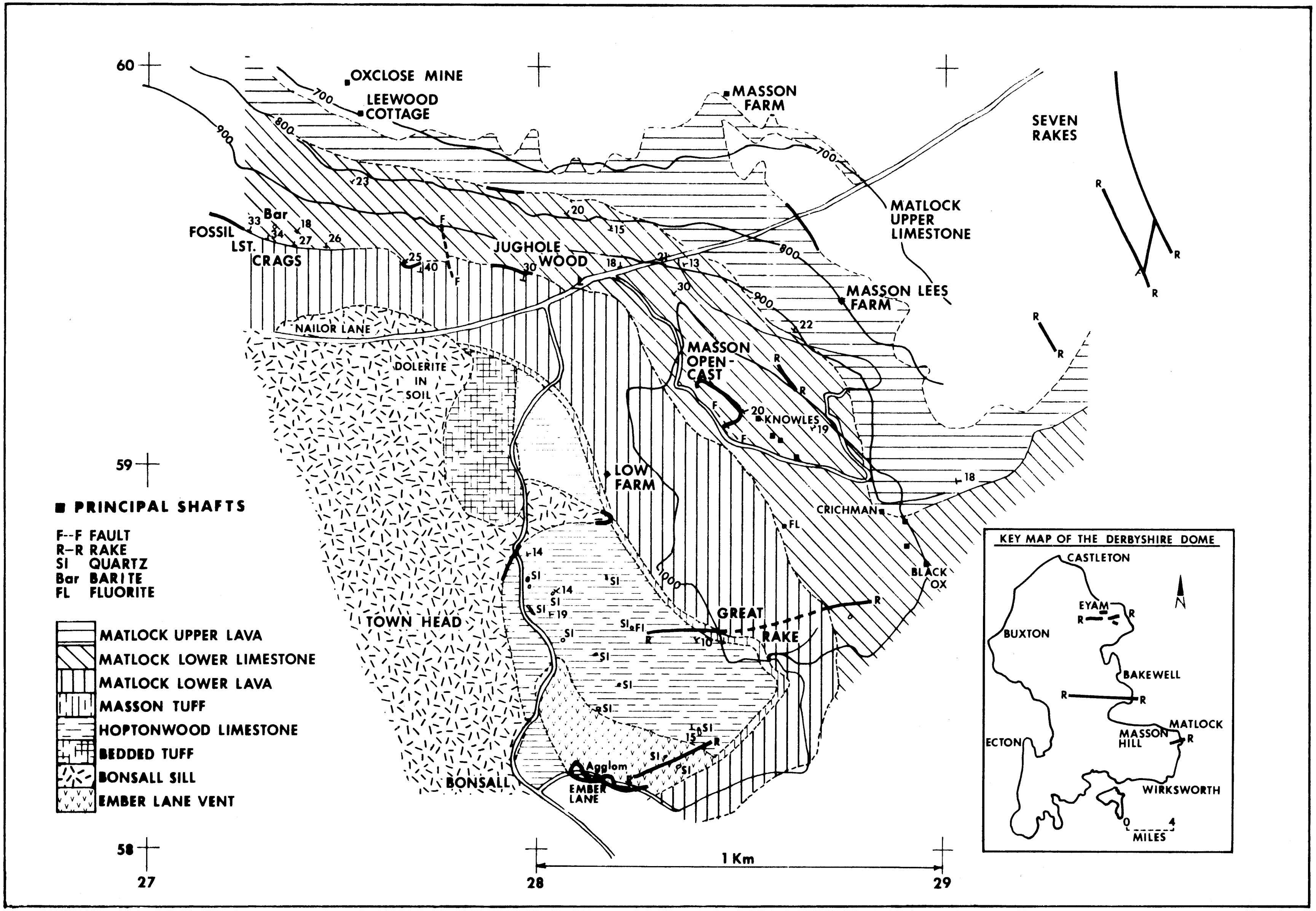
Introduction

Mining has been active around Matlock, Derbyshire, from medieval times to the present, firstly for lead and more recently for fluorspar. Amongst the more important areas has been the summit of Masson Hill (SK 28505920) which has been intensely mined for fluorspar throughout this century, most recently (1973) by La Porte Chemicals Ltd. Although there is no extensive mining at present, future exploitation is intended. More detailed discussions of the workings have been given by Dunham (1952) and Ford and Ineson (1971).

The mineralization consists of a series of intermittent smaller flats and/or pipes over a distance of 1.5 km. The largest single flat (or more strictly a pipe since the strike length is greater than its width along the dip) is that at the site of Masson Opencast Quarry and has a strike length of greater than 500 m and width of 240 m, (Dunham, 1952). The main ore horizon is restricted to the basal 6 m of the Matlock Lower Limestone (Lower Carboniferous, Brigantian age) although mineralization is found to occur above this within the overlying dolomites of the same formation.

Mineralogically the ore consists of approximately 60% fluorite, 20% quartz, 15% calcite and less than 5% barite, and traces of galena, sphalerite and other sulphides. It occurs as replacements of the limestone and as open space infilling, and is the direct result of the interaction of a number of geological processes. These influenced the availability of a suitable host rock or open void space; or controlled the direction and rate of flow of the mineralizing

Mercian Geol. Vol. 6, No. 4. 1978.
pp. 245-255, 4 text-figs. Plate 17.



Text-fig. 1. Geology of Masson Hill, Derbyshire.

fluids. Amongst the more important, and the ones to be considered here were:-

(a) The regional and local structures - these effected the vertical pathways of the ore solutions and produced open spaces.

(b) The varying lithologies - these provided suitable or unsuitable host rocks and permeability/porosity interfaces that controlled horizontal fluid movements.

Detailed mapping and sampling along the Matlock Lower Limestone outcrop from (SK 27005970) to Matlock Bath (SK 29005800), and especially within Masson Opencast Quarry, supplemented by underground mapping at Jughole Mine (SK 27935971) and Knowles Mine (SK 28705918) allows a semiquantitative analysis of the importance of the two controls upon the emplacement of the ore bodies.

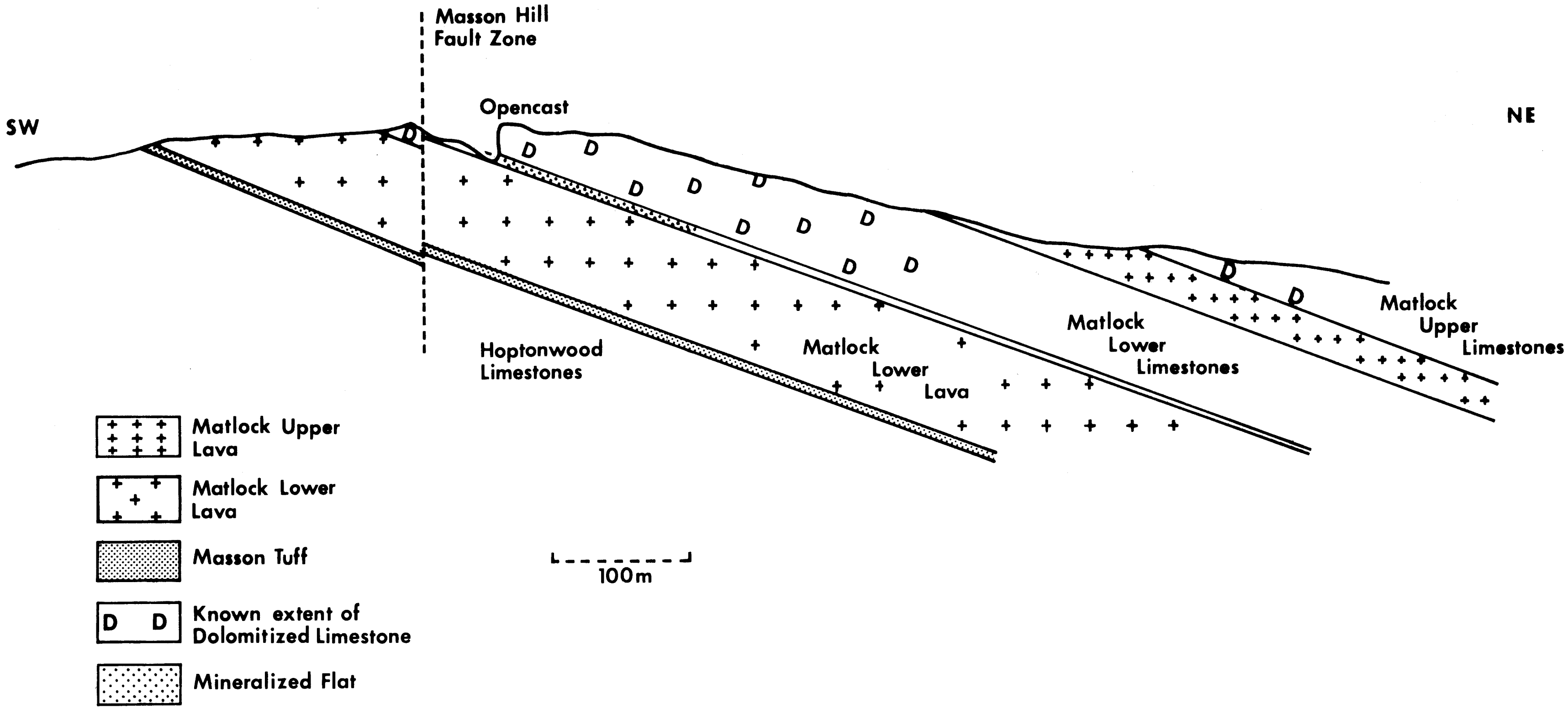
The first detailed description of the fluorspar deposits of the Masson Hill flat was given by Dunham (1952, pp. 97 - 100); more recent descriptions have been given by Smith *et al.*, (1967, pp. 43 - 44), Ford (1967, pp. 64 - 68; 1969, pp. 83 - 84), and Ixer (1972). Only Dunham was able to study the main economic ore-body at Masson Mine (the site of the present-day Masson Opencast Quarry) prior to its removal during the Second World War. The local structure has been discussed by Dunham (1952), Weaver (1974) and Firman and Bagshaw (1974) and the stratigraphy by Dunham (1952) and Ixer (1975). The mineralogy and paragenesis of the ore has been discussed by Dunham (1952) and Ixer (1974).

Structural Controls

Text-fig. 1 illustrates the geology of Masson Hill and shows the main areas of mining, which correspond to the more extensively mineralized portions of the Masson Hill flat. These are at Jughole Wood, Masson Opencast Site and a zone running south-eastwards from Knowles Mine to Black Ox Shaft. The mineralization occurs within the gently dipping (20 - 30°) Matlock Lower Limestone and this, together with the enclosing Matlock Upper and Lower Lavas, occurs on the northern limb of the eastward plunging Matlock Anticline. The axis of the anticline lies to the north of Great Rake and is subparallel to it. Superimposed upon the anticline are a series of approximately north-west trending faults, exemplified by Seven Rakes and by the fault zone along the topographic crest of Masson Hill. Within this zone faults occur at Jughole Mine (SK 27935971), west of Jughole Wood (SK 28795946) and within the Masson Opencast Mine (SK 2848591), the last is shown in plate 17, fig. 1). They all have small downthrows to the south-west of 10 m. or less and are filled with clay-gouge and hence unmineralized. None of them can be traced far but all are up-dip of the main mineralization. An extension of the fault found within the opencast excavation projected south-eastwards to some faulting, seen to be cut by Great Rake at (SK 28725865), would continue to be up-dip, parallel and close to the zone of greatest mineral workings. Although the evidence for this continuation is slight, such a fault would explain the distribution of mineralization in this part of the flat.

Text-fig. 2 shows a schematic section through the Matlock Group at Masson Opencast Quarry, together with the Masson Hill Fault and its associated flat. It can be seen that any mineralizing fluids travelling from the north-east up-dip towards the crest of the anticline would be stopped by the impermeable barrier of the clay filled fault, so producing a concentration of fluids on the down-dip side of the fault. This situation of vertical ponding by infilled faults is fairly common in Derbyshire (Firman and Bagshaw 1974, p. 153).

In addition to the major structures, jointing is well developed, especially within the dolomites, although the limestones beneath them are only poorly jointed. Structural measurements were taken from the Matlock Lower Limestone Group within the Masson Opencast Quarry. Both the mineralized and barren joints occur as a conjugate set, trending northwest-southeast and northeast-southwest. The master set has a mean orientation of 314° (317 readings) which is parallel to the Masson Hill fault zone, whilst the subordinate set has a mean orientation of 049° (233 readings). This compares with Dunham's (1952) suggestion for the mineralized master set having an orientation of 300°, with a conjugate pair at approximately 030°. The apparent difference may be due to



Text-fig. 2. A section through the fluorspar flat at Masson Opencast Quarry showing the proximity of the mineralisation to the Masson Hill Fault.

Dunham having taken his structural measurements within the main economic ore-body which has since been mined out to give the Masson Opencast Quarry. For the Matlock areas as a whole, north of the Bonsall Fault, the main mineralized joint set has an orientation of 305° and the minor set 045° (Weaver, 1974).

Weaver (1974) has suggested that this jointing is Variscan (Upper Carboniferous-Permian) in age, but if this is so, the difference in joint density between the limestones and dolomites must indicate that both lithologies were present prior to the imposition of the jointing. Thus the dolomitization could not be related to the overlying Zechstein Sea as suggested by Ford (1969) and must be of Carboniferous age. This is consistent with studies of the dolomitization of the Carboniferous Limestone in other areas, notably in South Wales (Bhatt, 1976).

Text-fig. 3 shows the distribution of poles to joints when plotted with regard to the dominant mineralization that they carry. No major differences for the distribution of minerals between the two sets is noticeable, although there is a slight tendency for the master set to carry the fluorite and fluorite-calcite mineralization and the minor set to carry the barite, gelena and calcite. From textural and paragenetic evidence it can be shown that the fluorite is early, whilst the barite, galena and calcite mineralization is later (Ixer, 1974).

The results suggest that both joint sets were open throughout the mineralization providing open spaces for deposition and allowing the fluids free access to the host rocks. The difference in mineralization between the joint sets may indicate some differential movement between them, or, if the mineralization is polyphase as suggested by Firman and Bagshaw (1974), that the later fluids did travel along slightly different pathways.

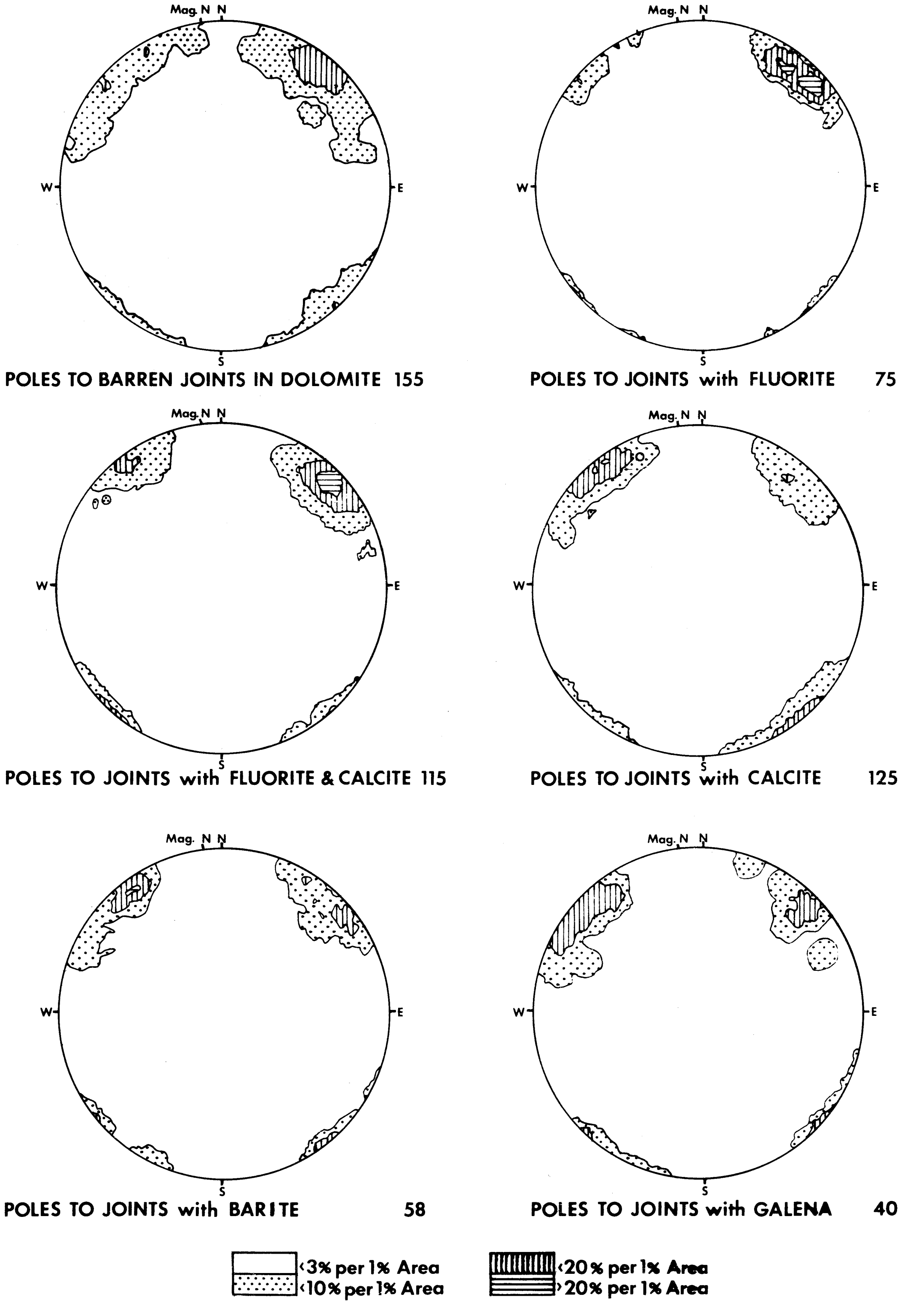
Litholgical Controls

A detailed stratigraphical and lithological description for much of the Matlock Group is given by Ixer (1975) based on measured sections within Masson Opencast Quarry and on borehole data. With the addition of the section given by Dunham (1952), a generalized stratigraphy for the southern half of the Masson Hill Flat can be derived (Table 1). Included within this stratigraphy is the important volcanic clay horizon known as the 'Little Toadstone'. This horizon is not seen in Masson Opencast Quarry although its stratigraphical position coincides with the main dolomite - limestone junction.

Table 1

	metres
Matlock Upper Lava	21.50
Dolomite and fine-grained limestone rafts	13.50
Clay bentonite (Wayboard 4)	0.30
Dolomite	2.65
Clay bentonite (Wayboard 3)	0.10
Dolomite	10.40
Clay bentonite (Wayboard 2)	0.02
Dolomite, silicified at the base	3.00
Clay bentonite (Little Toadstone)	0.80
Coarse crinoidal limestone	2.45
Clay bentonite (Wayboard 1)	0.05
Coarse crinoidal limestone	3.05
Matlock Lower Lava	78.00

The major lithologies found at Masson Hill are coarse and fine-grained limestones, dolomites and their silicified equivalents, together with altered volcanic rocks, namely olivine basalts and bentonite clays. It is generally accepted on textural evidence that all these rock types were present prior to the main mineralization (Ford 1969, Smith *et al.* 1967) and that it was upon these rocks that the ore fluids interacted. It should be remembered that this assumes that the carbonate diagenesis of the limestones and alteration of the volcanics was completed prior to mineralization. An examination of each of the lithologies and their associated styles of mineralization should, therefore, help explain the small scale distribution of the ore. Additionally, text-fig. 4 which shows the results of chemical analyses for lime (CaO), magnesia (MgO) and silica (SiO_2) for a measured section within Masson Opencast Quarry, semi-



Text-fig. 3. Equal area projections of poles to joint planes, plotted according to their dominant mineralisation.

quantitatively demonstrates the distribution of the various lithologies with respect to each other and illustrates some of the fluid pathways. The magnesia and its equivalent lime is assumed to be found as dolomite and any excess lime as calcite. Neither the Little Toadstone nor Wayboard 1 are shown in text-fig. 4 as neither occurred within the section sampled.

Lithologically the limestones vary from fine-grained and porcellanous to coarse-grained and bioclastic, comprising crinoidal and shell debris. Text-fig. 4 shows that the unaltered limestones (containing less than one per cent by weight magnesia) are at the base of the sequence, whilst incompletely dolomitized limestones lie above and below clay wayboards 2, 3 and 4. The isolated porcellanous limestone rafts can be seen to lie above Wayboard 4 in plate fig. 2 but were not included in the sampled section and are, therefore, not represented in text-fig. 4.

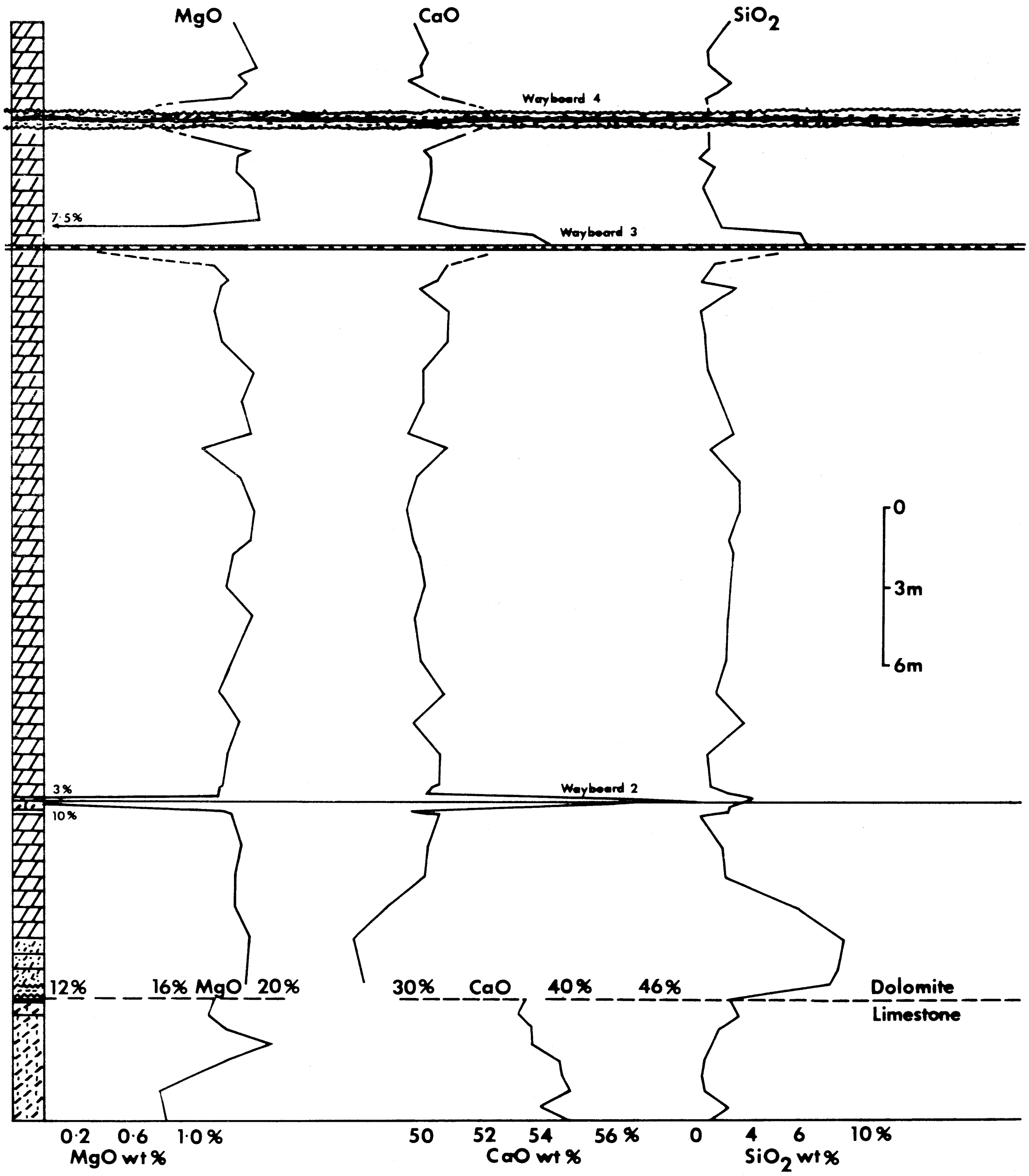
Open space infilling is associated with the poorly developed jointing and within the large (up to several metres across) solution cavities; in both cases as 5 - 10 mm thick skins of mineralization. Replacement occurs wherever the ore solutions contacted the limestones and hence is found at all the limestone-dolomite junctions, usually penetrating up to 0.20 m into the limestone. Complete metasomatic replacement is limited to the limestones beneath the Little Toadstone and above the Lower Lava. Macroscopically and microscopically the replacement can be seen to have been initiated within the coarsely-grained recrystallized fossil fragments (particularly corals and brachiopods) and then to have continued into the fine-grained matrix.

Dolomitization is sporadic throughout the Matlock Lower Limestones, decreasing in importance towards the north-west of Masson Hill until it becomes absent. Within Masson Opencast Quarry the dolomitization is extensive, and text-fig. 4 shows its remarkable compositional uniformity away from the clay horizons and also the very sharp junction with the basal limestone; the change from pure limestone to pure dolomite occurring within 15 mm. This abruptness is also characteristic of the porcellanous limestone-dolomite boundaries. As most of these junctions are parallel to subparallel to the bedding, the intensity of dolomitization would appear to reflect a primary lithological (grain size variation or porosity difference) or chemical variance between differing limestone posts.

Visible mineralization shows on joints, some open bedding planes, and in solution cavities which are normally rimmed by 0.01 - 0.05 m. of fluorite and completely filled with calcite scalenohedra. Microscopically, mineralization is restricted to small veinlets or within coarse calcite spar representing undolomitized fossil fragments.

The average silica content of the limestones and dolomites is less than 2% by weight and is found as small (2 - 10 mm) nodules. Greater silicification shows as 5 mm thick skins of intensely silicified dolomite/limestone along joint planes. Extensive development of this has produced 3 - 4 m high vertical pipes, an example of which is shown in plate 17, fig. 2. Equally important is the silicification that followed the previously established permeability interfaces. Text-fig. 4 shows that the major silification (up to 10% by weight) lies directly above the main dolomite-limestone junction, whilst slightly enhanced silicification occurs within the dolomitized limestones above and below wayboards 2 and 3. If within the dolomites the silica and lime contents are compared, a strongly antipathetic relationship is found confirming the petrographic evidence that only calcite is replaced by the quartz and that dolomite is unaffected. Hence the slight increase in silicification next to the wayboards may be related more to the increase in calcite content of the adjacent carbonates than to the thickness and ponding ability of the clay horizons themselves.

Total silicification is rare and associated with the mineralization forming two rock-types, cherts and 'silica-rock'. The cherts are found parallel to the bedding within the upper dolomites as discontinuous black bands. In thin section the rock comprises a quartz mosaic with embayed and isolated fluorite, barite and calcite, suggesting that the main silicification is later than some of the mineralization. By contrast the silica-rock, which is randomly distributed in the limestones, but more extensively developed away from the flat, towards Bonsall Village



Text-fig. 4. Stratigraphical variations of magnesia, lime, and silica within the Matlock Lower Limestone at Masson Opencast Quarry.

(Bemrose 1898, Smith *et al.*, 1967, pp.39 and 265), is light coloured and has an open-box structure of quartz stringers upon which euhedral fluorite and quartz have grown. The rock appears to be the result of the complete dissolution of the calcite from a fractured and partially silicified limestone, followed by open space mineralization.

The thickness of the Matlock Upper Lava (21 m) and Lower Lava (78 m), together with their poorly developed jointing and high clay content, has made the basalts highly impermeable. Therefore they have exerted a constant control upon any fluids passing through the sequence. The presence of large solution cavities and extensive mineralization found in the basal Lower Limestone shows that early groundwaters and subsequently the mineralizing fluids were floored by the underlying basalt. A small pond within the base of the open pit (which is excavated down to the Lower Lava) suggests that the basalt is still an effective impermeable horizon. The basalts are themselves largely unmineralized.

The wayboards vary in thickness from 0.80 m to less than 0.05 m and are composed of clays. The presence of premineralization solution cavities above and below the wayboards (examples are shown in plate 17, fig. 2) and the inhibition of the dolomitization indicate that the clay horizons influenced the movement of the fluids within the limestones. However, within the dolomites the degree of silicification and of later mineralization within the carbonates adjacent to the wayboards is only slightly greater than the average for the rock. This suggests that the wayboards were insufficiently thick (all are less than 0.30 m) to form an effective barrier to the vertical movements of the later fluids through the now established jointing. Only within the basal, undolomitized and hence poorly jointed limestones, did the wayboards influence the movement of the mineralizing fluids producing the 6 m thick metasomatic replacement flat beneath the 0.80 m thick Little Toadstone.

Sequence of Events

The following were probably the major events leading to the production of the Masson Hill flat:

1. The deposition within shallow waters of mainly coarse-grained limestones and intermittent volcanic ash bands, between the extrusion of two basaltic lava flows. A variety of early diagenetic changes within the limestones (namely the aragonite to calcite transition, pressure solution and compaction) would result in volume changes. The establishment of the limestone-lava and limestone-ash band horizons is important in controlling horizontal fluid movement.

2. Groundwaters produced solution cavities by dissolution of adjacent limestones above and below the limestone-volcanic junctions.

3. Dolomitization of the coarse-grained limestones by magnesian fluids again following the established bedding and lithological horizons. The intensity of dolomitization was controlled by grain size and chemistry of the limestones and inhibited by proximity to the volcanics. The volume change resulting from the dolomitization increased the permeability of the dolomites and led to the establishment of the major dolomite - coarse-grained limestone junction (at the same stratigraphic level as the Little Toadstone) plus many minor dolomite - fine-grained limestone horizons as important pathways.

4. The Matlock Anticline and Masson Hill Fault zone were formed by the Variscan earth-movements, establishing an approximately north-eastward dip on the limestone/lava sequence. The establishment of good vertical pathways within the well-jointed dolomites and the loss of the dolomite-clay wayboard junctions as effective horizontal pathways/ barriers.

5. Silica-rich fluids, following all the vertical and horizontal pathways, locally silicified limestones and dolomites.

6. Hot dense acidic mineralizing fluids moved up the Masson Anticline until they encountered the clay filled Masson Hill fault. The fluids followed the established pathways. Metasomatic mineralization occurred when calcite encountered large volumes of moving mineralizing fluids (i.e. at the limestone-dolomite junctions) or where the fluids were physically ponded (as in the case of the basal limestones beneath the Little Toadstone). Void emplacement also took place and was related to the volume of fluids passing through, as witnessed by the completely filled solution cavities in the dolomites but their only partially filled equivalents in the limestones.

Acknowledgements

This paper is based on the major part of a Ph.D. thesis submitted to the University of Manchester. Thanks are due to Dr. A. C. Dunham who suggested the topic and supervised the work. Financial assistance and help were obtained from La Porte Chemicals Ltd. and are gratefully acknowledged, as is help from their Divisional Geologist, Dr. J.E. Mason. Dr. P. Turner too is thanked for critically reading the manuscript.

References

ARNOLD-BEMROSE, H.H. 1898. On a quartz-rock in the Carboniferous Limestone of Derbyshire. *Q. Jl. geol. Soc. Lond.*, vol. 54, pp. 169-183.

BHATT, J.J. 1976. Geochemistry and petrology of the Main Limestone Series (Lower Carboniferous), South Wales, U.K. *Sed. Geol.*, vol. 15, pp. 55-86.

DUNHAM, K.C. 1952. Fluorspar 4th Edit. *Mem. Geol. Surv., Min. Resources*, 4.

FIRMAN, R.J. and BAGSHAW, C. 1974. A re-appraisal of the controls on non-metallic gangue mineral distribution in Derbyshire. *Mercian Geol.*, vol. 5, pp. 145-161.

FORD, T.D. 1967. *Some mineral deposits in the Carboniferous Limestone of Derbyshire.* pp. 53-75 (in Neves and Downie, 1967, see below).

FORD, T.D. 1969. The stratiform ore-deposits of Derbyshire. In "Sedimentary ores: Ancient and Modern" (Revised). *Proc. 15th Inter-University Geological Congress.* Leicester, 1967.

FORD, T.D. and INESON, P.R. 1971. The fluorspar mining potential of the Derbyshire oilfield. *Trans. Inst. Mining. Metall.*, vol. B80, pp. 186-210.

IXER, R.A. 1972. *Controls of Mineralization in Derbyshire.* Ph.D. thesis, University of Manchester.

IXER, R.A. 1974. The mineralogy and paragenesis of a fluorspar flat at Masson Hill, Matlock, Derbyshire. *Miner. Mag.*, vol. 39, pp. 811-815.

IXER, R.A. 1975. A revision of part of the Matlock Group at Masson Hill, Matlock, Derbyshire. *Mercian Geol.*, vol. 5, pp. 181-188.

NEVES, R, and DOWNIE, C. 1967. *Geological Excursions in the Sheffield Region and Peak District National Park.* 163 pp. Sheffield.

SMITH, E. G., RHYS, G. H., and EDEN, R. A. 1967. Geology of the country around Chesterfield, Matlock and Mansfield. *Mem. Geol. Surv. G. B.*, 430 pp.

WEAVER, D. J. 1974. Systematic jointing in South Derbyshire. *Mercian Geol.*, vol. 5, pp. 115-132.

R. A. Ixer, B. Sc., Ph. D.,
Department of Geological Sciences,
The University of Aston in Birmingham,
Gosta Green,
Birmingham B4 7ET.

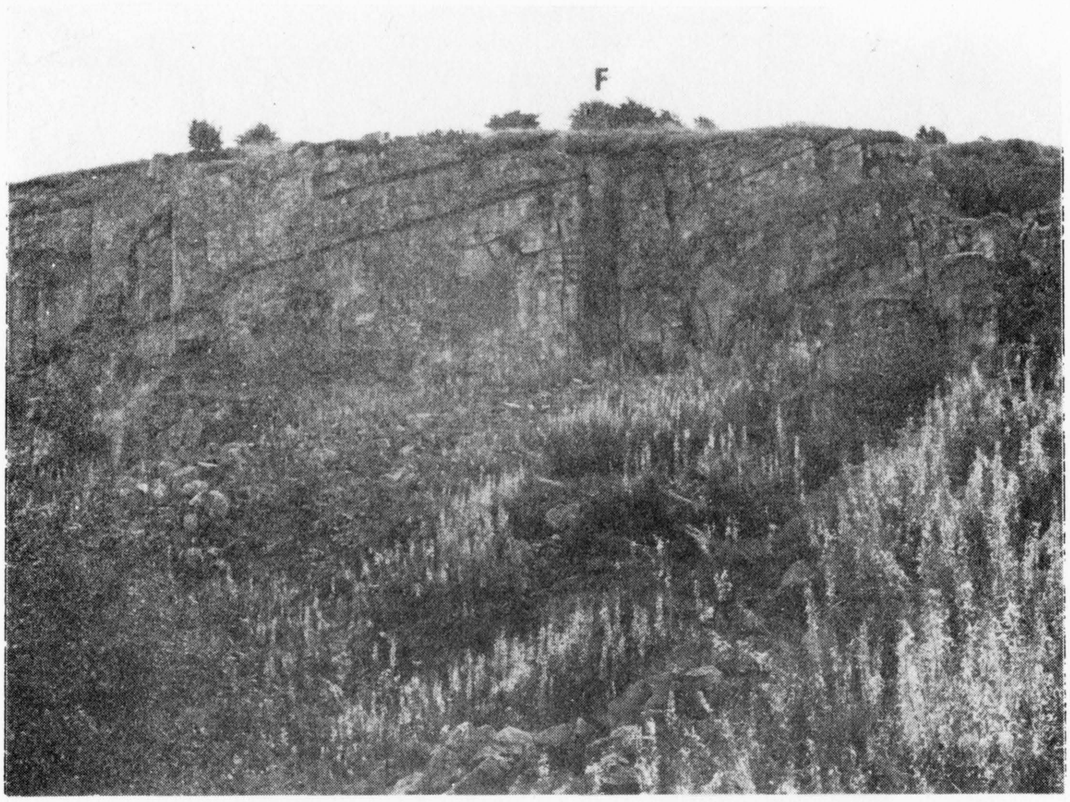


Fig. 1. View of Masson Opencast Quarry looking south-eastwards. The clay filled Masson Hill fault (F) can be seen cutting the Matlock Lower Limestones, with the dolomites on either side having slightly different dips.

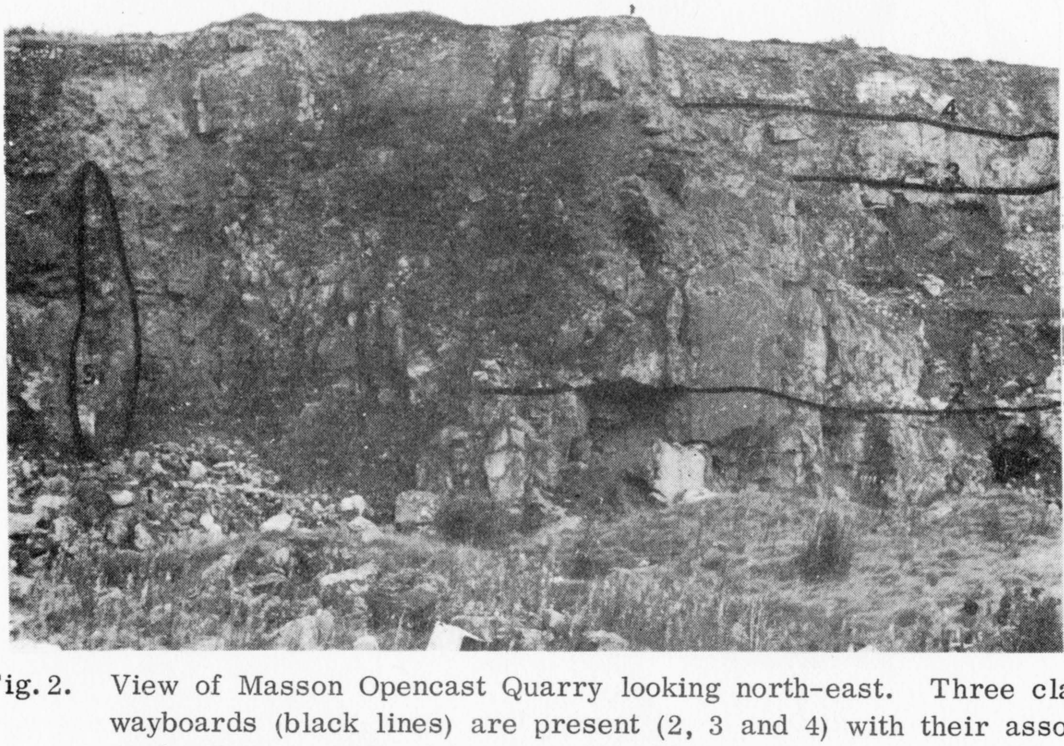


Fig. 2. View of Masson Opencast Quarry looking north-east. Three clay wayboards (black lines) are present (2, 3 and 4) with their associated solution cavities (below wayboards 2 and 3). An isolated porcellenous limestone raft can be seen (just above wayboard 4). A prominent silicified limestone-dolomite rib can be seen on the left of the photograph (labelled Si).