CONTROLS ON MINERALISATION IN TUNSTEAD QUARRY, NEAR BUXTON, DERBYSHIRE

by

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Summary

Imperial Chemical Industries plc (I.C.I) Mond Division's Tunstead Quarry is one of the largest limestone quarries in Europe. It covers an area of 2 km^2 and produces some 4 m tonnes of lime products a year from the Bee Low Limestone (Chee Tor Rock) and the Woo Dale Limestones of Asbian and Holkerian age respectively. A number of east-west trending normal faults cut the quarry and in places contain galena, barite and calcite, however, the end product is extremely low in trace impurities due to quarrying techniques and subsequent treatment in the crushing, screening and washing plants. Raw materials and the finished products are checked by chemical analyses. This procedure indicated that the most heavily mineralised faults, occurring at the southern end of the quarry, are not uniformally mineralised for as the content of one fault decreases so that of a sub-parallel fault increases. It is proposed that the mineral fluids not only migrated along and up the fault planes, but also transgressed between the faults probably along the horizon that is between the underlying dolomitised Woo Dale Limestones and the overlying Bee Low Limestones.

Introduction

Tunstead Quarry (SK 093693) is located 4 km east of Buxton in north-west Derbyshire. Operated by I.C.I. for nearly fifty years, it has at the present day an area of 2 km^2 and produces over 4 million tonnes of high quality limestone products a year. The object of the quarry was primarily to meet the increasing demand for chemically pure limestone used in the production of sodium carbonate at the Cheshire works of I.C.I.. The main face, some 2.5 km long and with an average height of about 30 m has worked the Chee Tor rock of the Bee Low Limestone (Aitkenhead & Chisholm, 1982). In order to make the best possible use of the total reserves on the Tunstead site the underlying Woo Dale Limestones have been worked in the southern half of the quarry, south of Fault V (text-fig. 1). This is being done in two lifts each 18 m high. In that these underlying limestones are dolomitised to varying degrees, the Company, in order to maintain a consistent product, applied for and have been granted, permission to quarry the Carboniferous Limestone on Old Moor to the east of Great Rocks Dale (see text-fig. 1). Reserves are such that a life of over 50 years is anticipated for this operation.

The Chee Tor Rock is intrinsically extremely pure and uniform in its physical and chemical properties. It averages 98% $CaCO_3$ and certain beds exceed 99% purity (Harrison, 1981). The main sources of impurity in the formation are therefore extraneous and consist of three different types of material:

1. Clay wayboards in bedding planes, believed to have been formed from volcanic ash falls which preceded the eruption of the Lower Miller's Dale Lava.
2. Clays in vertical joints, representing residual deposits from the solution of the limestone *in situ* and also small quantitites of material from the weathering of superficial deposits.
3. Clays and other minerals in fault planes including galena, barite and calcite. The clays are mixtures of the bedding plane and residual clays dragged into the fracture by the fault displacement. As quarried the minerals are dispersed within the clay filling and fault breccia.

The separation of the extraneous material from the end products is achieved mainly by the washing plant where it is removed in the form of sludge and slurry which ultimately forms part of the feed material for the cement plant. Nevertheless the high toxicity of lead in even trace amounts has necessitated the most rigorous process control for the end products, backed by borehole analyses, face and fault sampling and in some cases by discarding of material from faulted areas. The overburden is removed as a completely separate operation.

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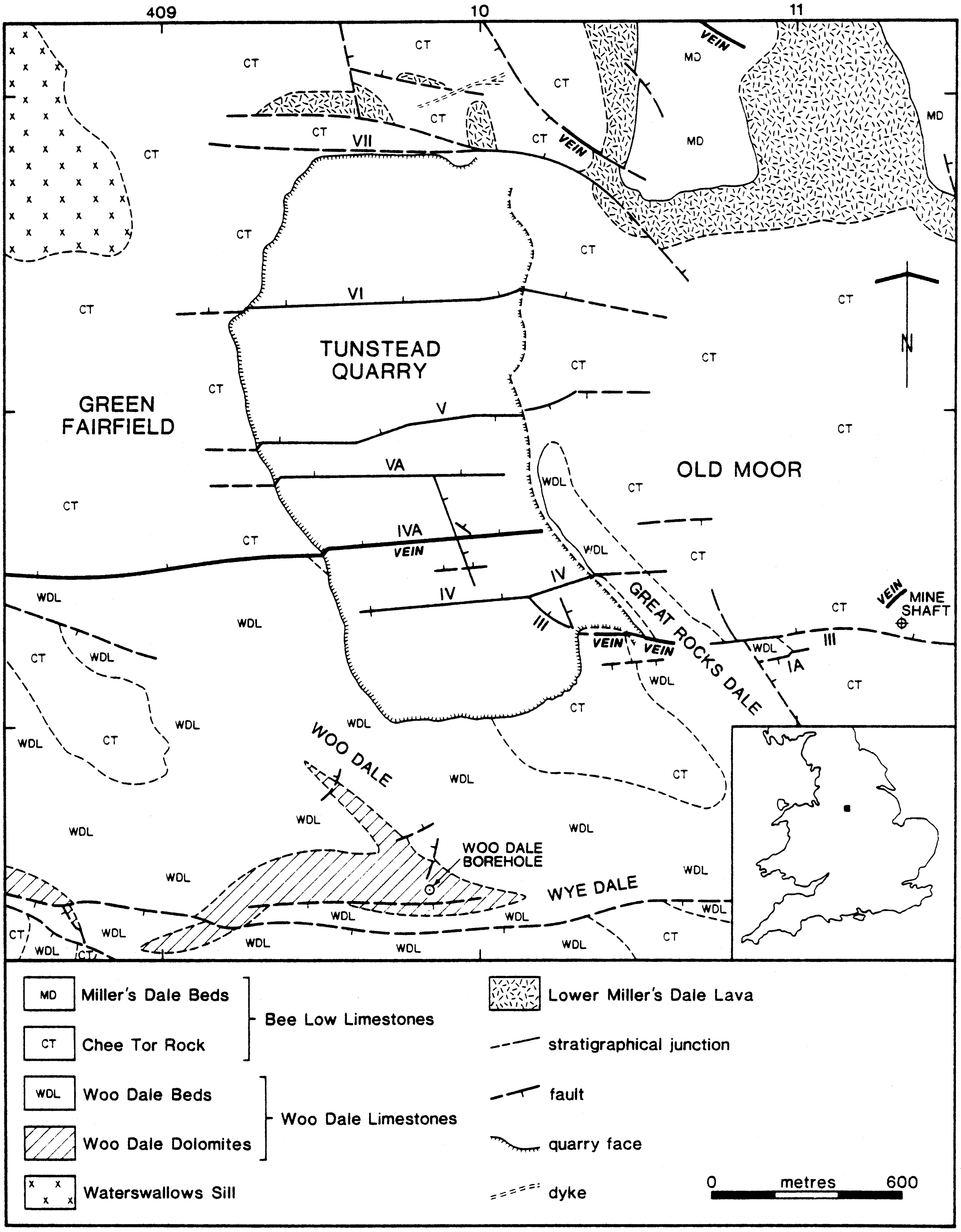


Text-fig.1 Sketch map of Tunstead Quarry and the surrounding area. Compiled from published maps of the Institute of Geological Sciences and published with the permission of the Director: Crown Copyright Reserved.

Geology

The geology of the area has been described by Stevenson and Gaunt (1971) and indicated in general on the 1:25,000 sheets of the Institute of Geological Sciences (1975 & 1976) and in detail on the 1:10,560 sheets SK 17NW, 07NE, 07SE and 17SW (I.G.S., 1971; 1973a; 1973b & 1974). Details of the succession have been published by Cope (1933 & 1939) who also described the Woo Dale Borehole at SK 09877247 (see text-fig. 1) located to the south of Tunstead Quarry (Cope, 1949 & 1973). Stevenson and Gaunt (1971, pp.52 and 366) also noted the Great Rocks Dale Borehole at SK 10347547 located to the north-east of the quarry, which penetrated the Lower Miller's Dale Lava and terminated in the Chee Tor Rock. The limestone and dolomite resources have been described by Harrison (1981).

Until recently Tunstead Quarry was located wholly within the Chee Tor Rock of the Bee Low Limestone, a biosparite and biopelsparite calcarenite, with 36 individual beds being recorded in the quarry. Pedogenic crusts and palaeokarstic features, as noted by Walkden (1974) are associated with a number of the major bedding planes, as are volcanic clay 'wayboards' (Walkden, 1972). Macrofossils, mostly corals and brachiopods, are confined to discrete beds. Notably the presence of *Davidsonina septosa* (Cope, 1934) in two horizons at the north end of the quarry, marks the uppermost beds of the Chee Tor Rock.

On account of the reducing quantity of the Chee Tor Rock and in order to make the best possible use of the reserves in the Tunstead Quarry area, extraction of the underlying Woo Dale Limestones is now taking place, from two 18 m lifts in the southern half of the quarry. At the same time further development is being concentrated on the Old Moor property to the east of Great Rocks Dale. The Woo Dale Limestones are biomicrites, biopelsparites and porcellaneous micrites with calcispheres which pass down into irregularly dolomitised limestones known as the Woo Dale Dolomites. The Woo Dale Borehole (Cope, 1973) proved 402.26 m of these beds resting on volcanics.

The general dip of the strata in the quarry is between 2° and 7° to the north-east, although this is interrupted by a series of east-west trending normal and scissor strike slip faults, all downthrowing to the north (see text-fig. 2) between 0 and 30 m. The only fault capable of being traced any distance is that labelled Fault IVA. It has a northerly displacement of some 10 m and extends 4 km into Buxton. The 'scissors' Fault V downthrows to the south towards the eastern boundary of Tunstead Quarry, some 8.5 m.

Mineralisation

General aspects

Descriptions of the lead-zinc-fluorite-barite-calcite mineralisation of the South Pennine Orefield have been given by Wedd and Drabble (1908), Schnellmann and Willson (1947) and Dunham (1952). They proposed that the orefield displayed a mineral zonation with the economic resources of fluorspar and galena, in fault controlled veins, located principally in the eastern part. Ford and Ineson (1971) described the varied mineral occurrences, noting that the main deposits are confined to veins (rakes) many of which are wrench faults which have been repeatedly reactivated. A survey of the distribution of the gangue minerals by Firman and Bagshaw (1974) indicated that, whilst stratigraphical, lithological and structural controls on the deposition of the minerals was important, the mineral fluids mainly migrated up the crests of plunging folds and along faults. They suggested that, locally, the fluids migrated down-dip through more porous and cavernous strata, and particularly if faults threw impervious strata against pervious, so creating hydrological barriers.

Ineson and Ford's (1982) compilation of the genetic theories of the South Pennine Orefield concluded that the majority of the fluids migrated from the east, nevertheless some of the minerals may have originated from fluids migrating from west to east. Mueller (1954), Schnellmann (1955) and Firman and Bagshaw (1974) had previously suggested this possibility and Robinson and Ineson (1979) provided isotopic evidence that a proportion of the mineralisation could only have been derived from the west.

No detailed descriptions are available of mineralisation in the Buxton area, indeed the comment by Harrison (1981, p.3) that 'lead-zinc mineralisation, which is extensively developed in these rocks elsewhere in Derbyshire, is of only minor importance in this district' summarises the situation. In Buxton there are traces of fluorite in veins exposed in Holker Road (SK 062735) and galena and calcite occur in Deep Dale (SK 098712 and SK 099715). Traces of mineralisation are therefore noted to the west of Tunstead Quarry but nothing to suggest the existence of a major deposit. Likewise to the east of Great Rocks Dale, the Institute of Geological Sciences Map SK 17SW (1974) recorded mineral veins cutting the Flag Dale boundary of Old Moor. A calcite vein 4.88 m wide was exposed in the Miller's Dale Lower Lava at SK 104748 during the construction of an access road by

I.C.I. on the east side of Great Rocks Dale, north of Tunstead Quarry. Also during the construction of an access road, at the south end of Tunstead Quarry, traces of blue fluorite were encountered in the Woo Dale Limestone.

In August 1960, occasional 3 mm crystals of sphalerite were recorded in a calcite-limestone contact adjacent to Fault VI. Although trace zinc values were occasionally reported in laboratory analyses this is the only record of zinc minerals being found in the quarry.

In the Woo Dale Borehole (SK 09877247) speckles of malachite were seen in a spot sample at 187 m O.D. in cavitous ground. Analysis proved 0.21% $CuCO_3$. Otherwise, apart from calcite and dolomite no mineralisation was recorded in the borehole.

Tunstead Quarry

Apart from a general lithological section reported by Stevenson and Gaunt (1971, p.43) the only details of the stratigraphy and geochemistry have been given by Harrison (1981). There have been no publications on the mineralisation, although the Company has been watchful of the situation for more than thirty years and in fact, initially when two of the lead veins seemed to be increasing westward in galena content, they were registered at the Great Barmote Court. Fortunately as the quarry advanced further west the mineralisation decreased. Borehole cores as well as quarry face, pit, trench and hand samples have been systematically analysed during the progressive extraction in a southerly and westerly direction. The whole of the south-west and westerly boundary was, in addition to boreholes, examined by closely spaced surface pits. In the northern and central part of the quarry the strata are cut by three east-west trending scissor faults (see text-fig. 2, Faults VI, V and VA; Plates 20 and 21). The most northerly, Fault VI, had traces of galena, barite and calcite in the fractured fault zone, with analytical results indicating a maximum content of 216 ppm Pb and 0.28% $BaSO_4$, and an average content of 6 ppm Pb and 0.19% $BaSO_4$ along its strike length. In Fault V only the occasional presence of barite and ubiquitous coarse grained calcite (sparry calcite) was noted. The plane of Fault VA is unmineralised.

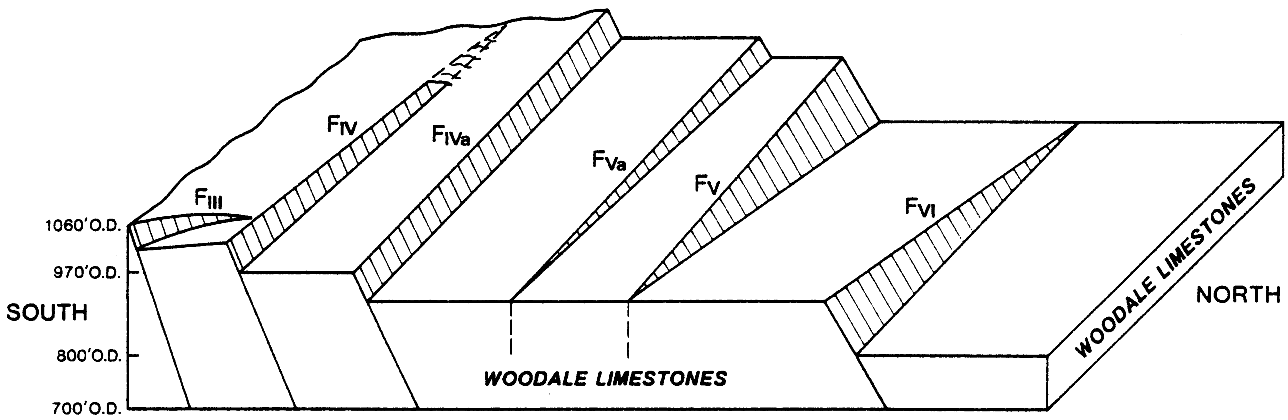
The southern part of the quarry has Faults IVA, IV and III displacing the strata (see text-fig. 1; Plate 22). In detail these three major faults are capable of subdivision with Faults IV and III having minor and localised sub-parallel faults labelled IVB and IIIA (see text-figs. 3 and 4). During quarrying these minor faults were recorded mainly for their effect on face stability and in this connection were considered as accommodation offshoots of the major dislocations. Nevertheless being mineralised they contributed problems in this respect as well. Mineralisation itself can often be a cause of instability in quarrying operations.

Without doubt the most heavily mineralised fault is Fault IV and its localised offshoot (Fault IVB), indeed on old O.S. maps of the area, and as shown in text-fig. 3, it was marked by a line of old mineral spoil heaps and abandoned infilled workings on Merehead Lane which delineated the line of the vein. Although no records of these operations have been located, it is assumed that they were extracting lead ore. The Institute of Geological Sciences (1974) show the fault continuing westwards into Buxton and eastwards across Great Rocks Dale and onto Old Moor. Neither to the east nor west do the Institute of Geological Sciences indicate that it was mineralised and indeed, from records of the quarrying activity, it was not mineralised in the eastern part of Tunstead Quarry, although Fault III was mineralised.

Fault IVB extended for a distance of some 200 m before its downthrow was totally accommodated into Fault IVA. When observed, it was infilled with clay and calcite, although galena and calcite were intermittently observed. A typical relationship between Faults IVA and IVB is shown in text-figs. 3 and 4 (section 5). A near N-S strike fault not numbered but shown in text-fig. 1, with a downthrow of only about 1 m east, caused quarrying difficulties and may also have served in the transfer of mineralising fluids from Fault IV northwards to Fault IVA.

A plan of part of Fault IV is shown in text-fig. 3. Of all the faults intersecting Tunstead Quarry it is unusual in having a wide (5 m) zone of broken and sheared ground either side of the actual fault plane, likewise it is the only fault which has been proved to terminate in a monoclinal flexture towards the west (see text-fig. 2). The wide brecciated zone is no doubt due to the close juxtaposition of crossfault IIIA and the interrelationships with Fault III. The fault carried concretionary barite, crystalline galena and calcite in a 1 cm wide vein, while in adjacent strata, vertical mineralised joints were infilled with traces of galena, barite and calcite. Westwards in the Woo Dale Limestone, fluorite, calcite and barite veinlets were noted in a crystalline dolomitic matrix. The almost complete absence of fluorite in the Chee Tor Rock at Tunstead with only occasional traces in the Woo Dale Limestone was extremely fortunate as it is harmful in cement manufacture. At the furthest point west, the fault was barren of mineralisation. Details of this fault are shown in two sections (3 and 4) in text-fig. 4, the location of which is shown in text-fig. 3.

The complexities of Fault III and its localised off-shoot (Fault IIIA) are shown on a plan (text-fig. 3) and in three sections (1, 2 and 3) on text-fig. 4. The fault contained galena, barite and calcite along its length from the west flank of Great Rocks Dale, however, as it coalesced with Fault IV, no clearly definable fault plane



Text-fig. 2. Block diagram of the major faults cutting Tunstead Quarry. See Text-fig. 1 for their location in the quarry.

was discernable, the line of the fault giving way to an area of broken ground (text-fig. 4, section 3) which contained more than 5% barite in total. Fault IIIA is a short cross-fault between Fault III and IV. It is considered to represent an accommodation fault and allowed for the movement resulting from the junction of Faults III and IV. It was mineralised with galena and barite along the whole of its exposed length.

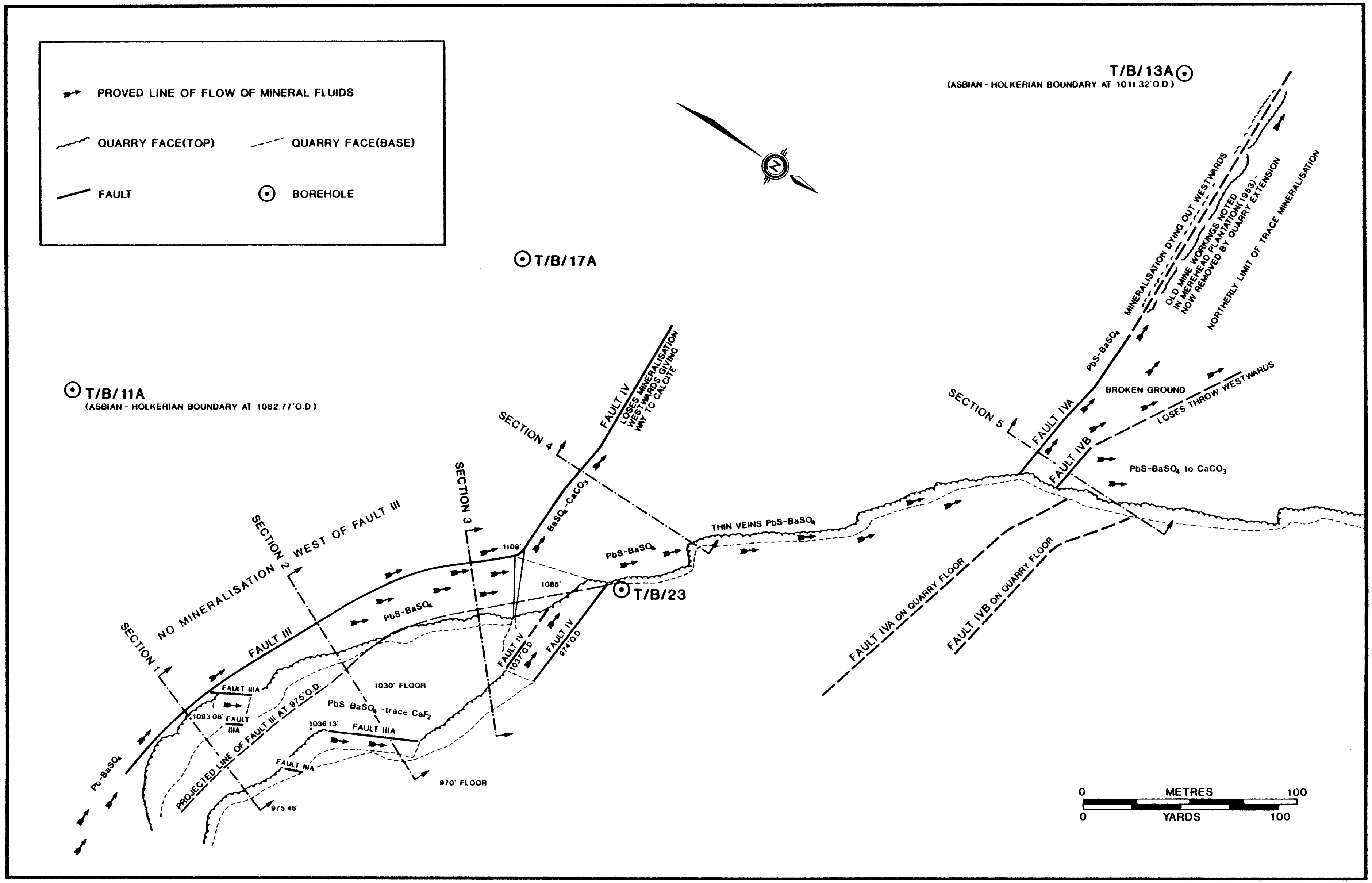
Conclusions

As the quarrying operations progressed in a southerly and westerly direction, a three-dimensional geological sequence and analytical sampling programme was capable of providing daily information with respect to the faults and their attendant mineralisation in the Chee Tor Rock (Bee Low Limestone) and the underlying Woo Dale Limestones, the results of which are diagrammatically summarised in text-figs. 3 and 4.

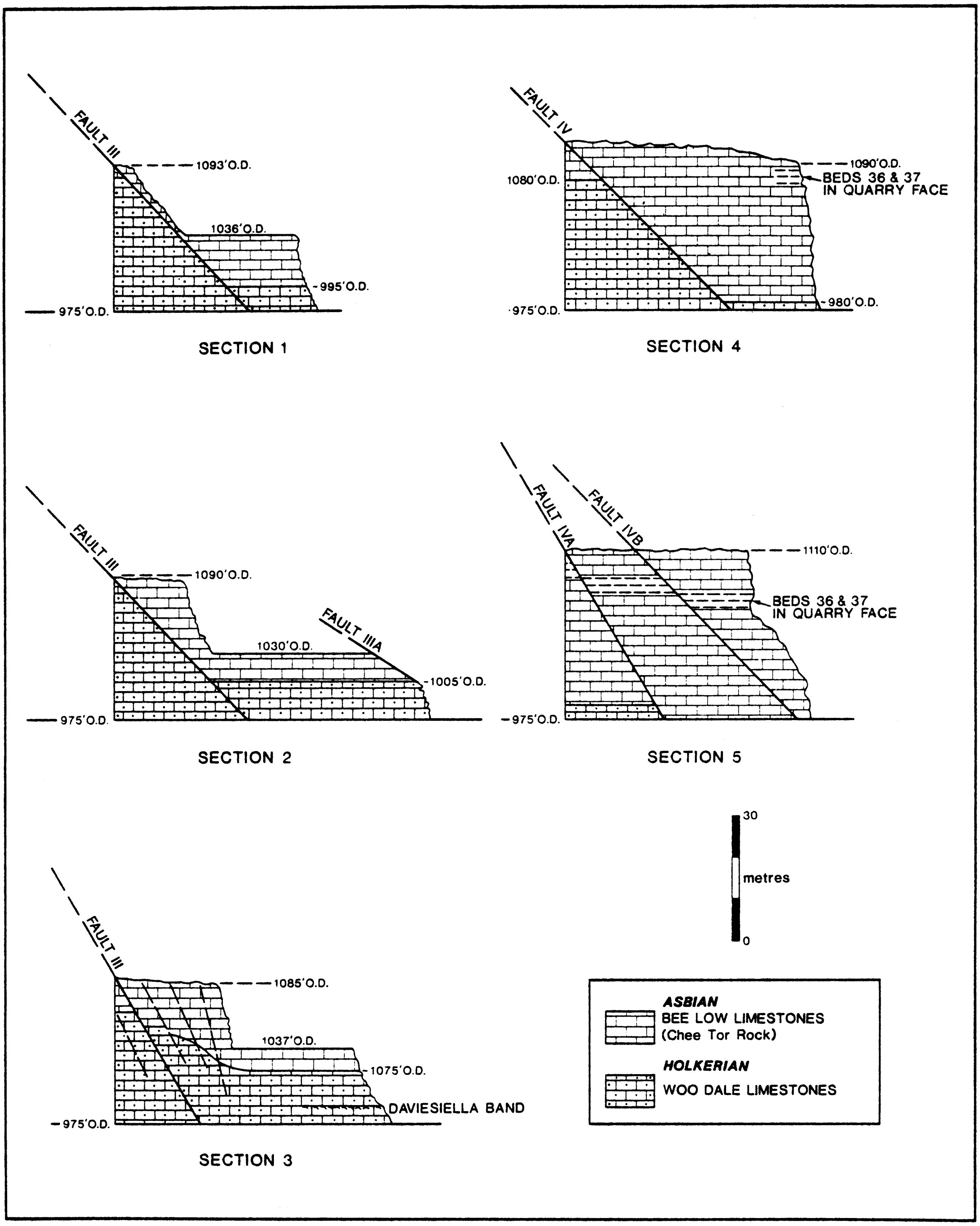
Access road operations, overburden removal and boreholes have shown that mineralisation, apart from very occasional traces of barites and blue fluorite, does not extend in a south-westerly direction beyond Fault III, and that likewise neither does it extend along Fault IV for any great distance, but occurred in numerous thin veinlets in the quarry face between Faults IV and IVA/IVB. It is concluded that the main mineral pathway was as indicated in text-fig. 3, i.e. from transgressing along/through Fault III, a minor component 'escaped' along Fault IV, while the majority of the mineral fluids were taken up in Faults IVA/IVB. Nor did any appreciable mineralisation extend northwards from Fault IVA; in recent quarrying operations none has been recorded and trace lead values in boreholes north of Fault IVA have also been consistently low. It is possible that the massive beds of the Chee Tor Rock resisted the passage of mineralisating fluids. There is also less shattering in fault-planes when limestones of similar lithology are in juxtaposition. The major amount of transference was along the junction separating the underlying Woo Dale Limestones from the overlying Chee Tor Rock (Bee Low Limestone). In that the underlying Woo Dale Limestones have an increased $MgCO_3$ content, i.e. up to, and sometimes exceeding, 10% $MgCO_3$, although not in any way being able to be considered as dolomitic limestones, it may be the interrelated porosities of these two horizons channelled the mineral fluids along this boundary. Lithologically the top of the Woo Dale Limestone is extremely fine grained and is characterised by the 'Calcite Mudstone Horizon' which although of variable thickness is present throughout the Tunstead area being proved in all boreholes reaching that depth.

The projected path of the mineralising fluids across the property, proved by intensive sampling and analyses has been completely substantiated by observations and tests made during the advance of the quarry faces in the succeeding years.

This area of Tunstead Quarry has now been almost totally extracted and until the subsequent workings contemplated to the east of Great Rocks Dale (Old Moor) have advanced to their projected southerly limit, no further information will be forthcoming from this, the largest limestone quarry in Europe.



Text-fig.3 Plan of the southern part of the Tunstead Quarry showing the line of faults III, IIIA, IV, IVA & IVB and the probable pathways of the mineral fluids.



Text-fig.4 Sections of the faults. The location of each section is shown on text-fig. 3.

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References

Aitkenhead, N. & Chisholm, J. I. 1982. A standard nomenclature for the Dinantian formations of the Peak District of Derbyshire and Staffordshire. *Rep. Inst. Geol. Sic.*, No. 82/8, 17 pp.

Cope, F. W. 1933. The Lower Carboniferous succession in the Wye Valley region of North Derbyshire. *J. Manchr. geol. Assoc.*, 1 (3), 125-145.

Cope, F. W. 1934. The *Cyrtina septosa* band in the Lower Carboniferous succession of North Derbyshire. *Summ. Prog. Geol. Surv. G.B.*, 1934, pt. 2, 48-51.

Cope, F. W. 1939. The mid-Viséan (S_2-D_1) succession in North Derbyshire and North-West England. *Proc. Yorks. geol. Soc.,* 24, 60-66.

Cope, F. W. 1949. Woo Dale borehole near Buxton, Derbyshire. *Abstr. Proc. geol. Soc. Lond.,* 1446, p.24

Cope, F. W. 1973. Woo Dale borehole near Buxton, Derbyshire. *Nature, (Phys. Sci.)*, 243, 29-30.

Dunham, K. C. 1952. Fluorspar. Spec. Rep. Mineral Resour. G.B., vol. iv (4th Ed.). *Mem. Geol. Surv. G.B.*, H.M.S.O., London, 143 pp.

Firman, R. J. & Bagshaw, C. 1974. A re-appraisal of the controls of non-metallic gangue mineral distribution in Derbyshire. *Mercian Geol.*, 5, 145-161.

Ford, T. D. & Ineson, P. R. 1971. The fluorspar mining potential of the Derbyshire orefield. *Trans. Instn. Min. Metall. (Sect. B: Appl. Earth Sci.)*, 80, 186-210.

Harrison, D. J. 1981. The limestone and dolomite resources of the county around Buxton, Derbyshire. Description of 1:25,000 sheet SK 07 and parts of SK 06 and 08. *Mineral. Assess. Rep. Inst. Geol. Sci.*, No. 77, 108 pp.

Ineson, P. R. & Ford, T. D. 1982. The South Pennine Orefield: Its genetic theories and eastward extension. *Mercian Geol.*, 8, 285-303.

Institute of Geological Sciences, 1971. Geological Survey Map, Sheet SK 17 NW (Solid & Drift), 1:10, 560, Inst. Geol. Sci., Col.

Institute of Geological Sciences, 1973a. Geological Survey Map, Sheet SK 07 NE (Solid & Drift), 1:10, 560, Inst. Geol. Sci., Col.

Institute of Geological Sciences, 1973b. Geological Survey Map, Sheet SK 07 SE (Solid & Drift), 1:10, 560, Inst. Geol. Sci., Col.

Institute of Geological Sciences, 1974. Geological Survey Map, Sheet SK 17 SW (Solid & Drift), 1:10, 560, Inst. Geol. Sci., Col.

Institute of Geological Sciences, 1975. Classical areas of British Geology. Sheet SK 07 (Solid & Drift)—Buxton, 1:25,000, Inst. Geol. Sci., Col.

Institute of Geological Sciences, 1976. Classical areas of British Geology. Sheet SK 17 (Solid & Drift)—Miller's Dale, 1:25,000. Inst. Geol. Sci., Col.

Mueller, G. 1954. The distribution of coloured varieties of fluorites within the thermal zones of Derbyshire mineral deposits. In:- *19th Int. geol. Congr. Algiers 1952*, 15, 523-539.

Robinson, B. W. & Ineson, P. R. 1979. Sulphur, oxygen and carbon isotope investigations of lead-zinc-barite-fluorite, calcite mineralisation, Derbyshire, England. *Trans. Inst. Min. Metall., (Sect. B: Appl. Earth Sci.,)* 88, 107-117.

Schnellmann, G. A. 1955. Concealed lead-zinc fields in England. *Trans. Inst. Min. Metall.*, 64, 477-485 & discussion, pp. 617-636.

Schnellmann, G. A. & Willson, J. D/ 1947. Lead-zinc mineralisation in North Derbyshire. *Bull. Inst. Min. Metall.*, No. 485, Apr., pp. 1-14; Aug., pp. 19-34; & Oct. pp. 17-18: & *Trans. Inst. Min. Metall.*, 56, 549-585.

Stevenson, I. P. & Guant, G. C. 1971. Geology of the country around Chapel-en-le-Frith. *Mem. Geol. Surv. G.B.*, 443 pp.

Walkden, G. M. 1972. The mineralogy and origin of interbedded clay wayboards in the Lower Carboniferous of the Derbyshire Dome. *Geol. J.,* 8, 143-160.

Walkden, G. M. 1974. Palaeokarstic surfaces in Upper Viséan (Carboniferous) Limestones of the Derbyshire Block, England. *J. sedim. Petrol.,* 44, 1232-1247.

Wedd, C. B. & Drabble, G. C. 1908. The fluorspar deposits of Derbyshire. *Trans. Inst. Min. Metal.,* 35, 501-535.

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Explanation of Plates 20–22

Plate 20

View of Faults VI and VIA. The fault planes and displacement of the clay wayboards can be seen.
Left of centre— Fault VI (displacement of 19 m to the north).
Right of centre—Fault VIA (displacement of 9 m to the north).
Height of face—40 m.
August, 1964.

Plate 21

View of Fault V looking to the west.
Bed 43—central left and Bed 37—upper right.
Beds 29 and 30—upper right.
Height of face—40 m.
February, 1981.

Plate 22

View of Fault IVA (centre of the photograph).
A northerly displacement (to the right) of 7 m was recorded.
Height of face—40m.
August, 1960.