Bulletin of the Peak District Mines Historical Society, Vol. 7, No. 4 pp. 177-191 Oct. 1979

A GEOLOGICAL OUTLINE OF THE ECTON COPPER MINES, STAFFORDSHIRE

by Martin F. Critchley

ABSTRACT

Ecton Hill is composed mainly of muddy thin-bedded and shaly limestones of the Milldale and Ecton Limestone Formations of Lower Carboniferous Age. Deposited in the basin west of the migrating reef margin the thin-bedded and more massive reef limestone have responded differently to the stresses of east-west compression. In particular the thin-bedded limestones have crumpled into an anticlinorium, with a regional plunge of some 10° to the northwest. The mineral veins include fracture-fills along north-south minor faults, vertically oriented "pipes" with cavity-fill textures aligned along a north-south fracture zone in the area of most intense folding, and minor replacements along bedding in folds, which are broadly saddle-shaped.

A new survey of the accessible parts of Waterbank Mine is included.

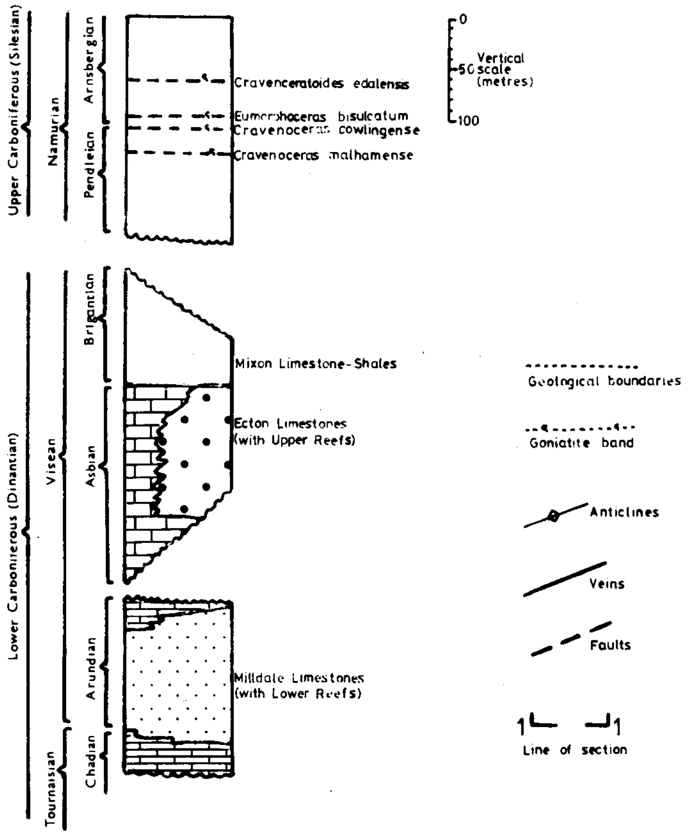
The Ecton Copper Mines are situated just within the Staffordshire border, about 10 km NW of Ashbourne, in the valley of the River Manifold; to the west of the Peak District lead mining field.

The history of these mines is long and complex, and has been summarised by Robey and Porter (1970, 1971 and 1972). The underground and surface features have been documented by Porter (1969 and 1970). However, the geology of this important mining area has never been fully studied.

Ecton lies within the 1 inch to 1 mile Geological Survey Old Series sheet 81SE, published in 1858. Prentice (1951) published a small-scale map of the region, but his correlation was subsequently modified by Parkinson and Ludford (1964). Recently, the Institute of Geological Sciences (1975) has published provisional 6 inches to 1 mile detailed maps but the author's B.Sc. mapping thesis mas suggested certain differences from the IGS maps (Critchley, 1977). As far as is known the I.G.S. surveyors did not do detailed work underground.

It is the purpose of this paper to present an outline of the stratigraphy and structure of the Ecton Copper Mines and the surrounding area, although the studies have not been exhaustive, and there still remains much work to be done, particularly regarding mineralogy and paragenesis.

Generalized Vertical Section



GEOLOGICAL HISTORY

The oldest rocks cropping out in the Ecton area belong to the Chadion and Arundian stages of the Lower Carboniferous when sedimentation was well-established on the south-west margin of the Derbyshire Carbonate Platform. In this region the Platform was bound by extensive apron reefs, which periodically shifted in their positions, from the line of the River Dove to that of the River Manifold. To the east of the reefs mainly pure limestones of the marginal and massif (shelf) facies were deposited, whilst to the west more muddy basinal facies limestones and mudstones were deposited. Contemporary volcanics produced abundant wayboards during the Arundian and Asbian, but no extrusive igneous rocks have been found in the Ecton area. (See geological map presented in Fig. 1 and sections in Fig. 2).

Beds of the Holkerian stage are not seen in this area. They were either not deposited, or were removed

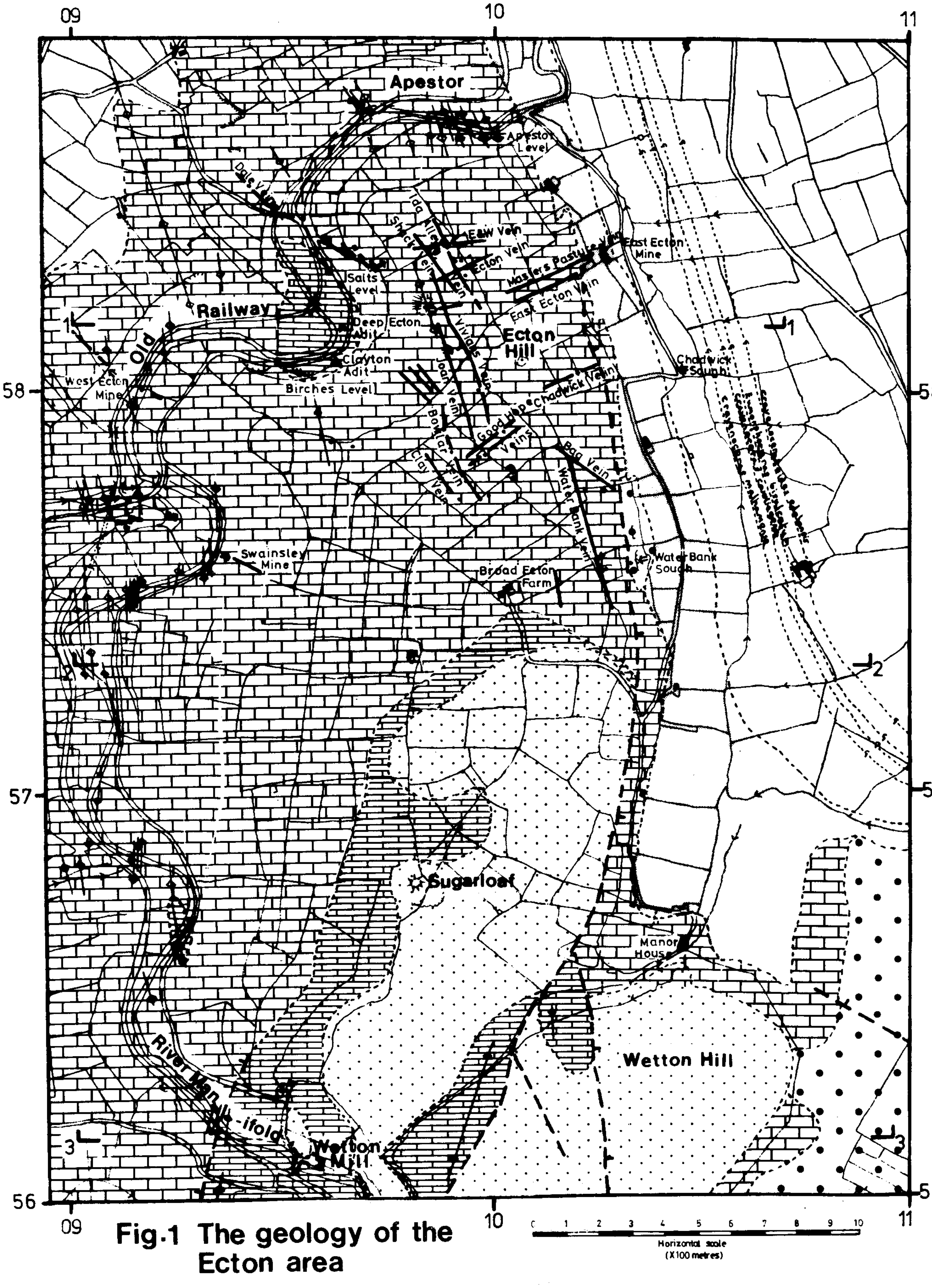


Fig.1 The geology of the Ecton area

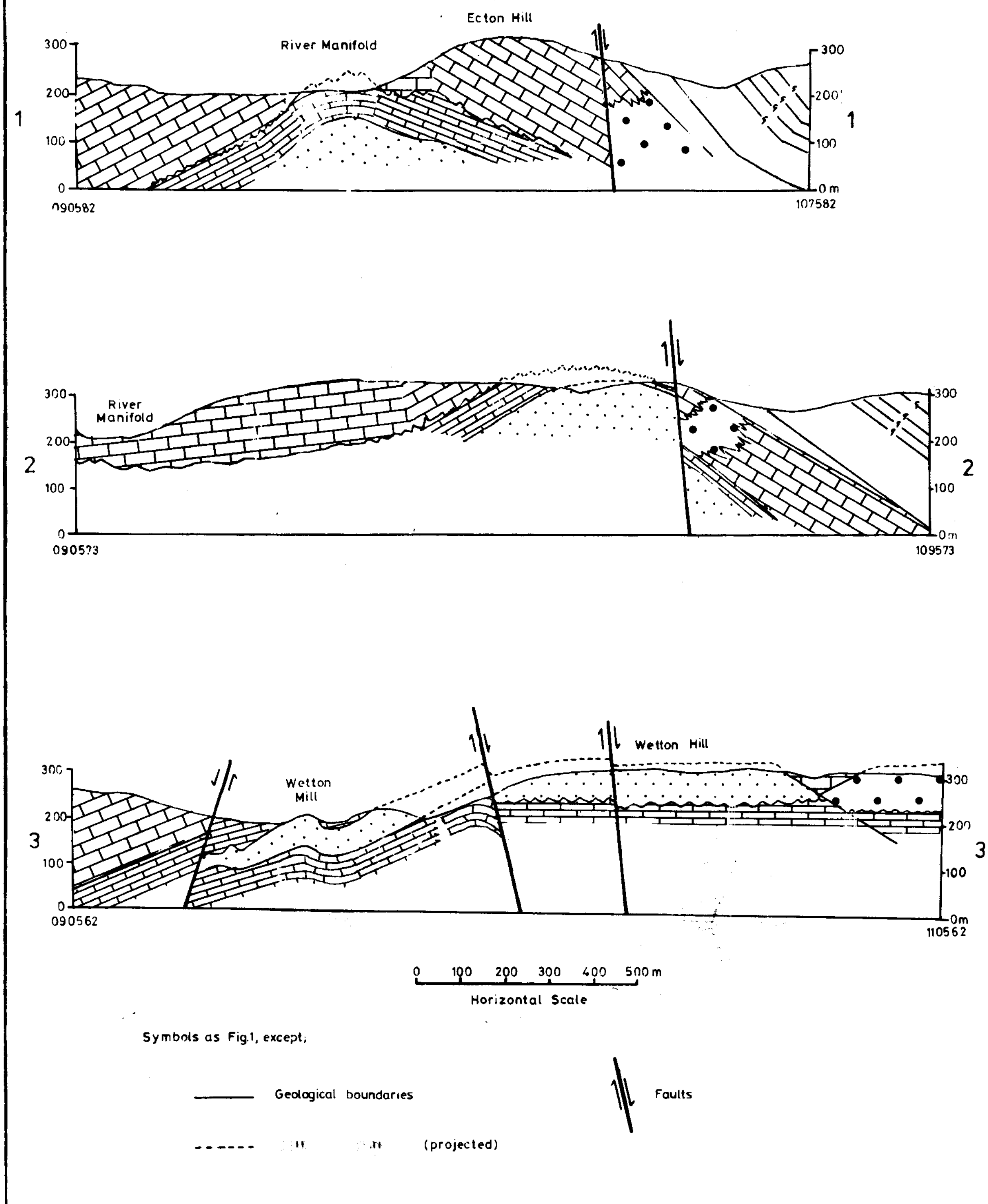


Fig. 2 West-east geological cross-sections M.F. Critchley, 1979

by pre-Asbian erosion. During the Asbian a sequence of sedimentation occurred which was similar to the Arundian, but with more muddy facies towards the top. There was a marked increase in argillaceous sedimentation during the Brigantian.

The Namurian transgressed unconformably across the region, depositing frothy thin-bedded black shales, and later arkosic sandstones. Post-Namurian earth movements, possibly associated with the Hercynian Orogeny, resulted in the high degree of folding seen over much of the area. Mineral deposition in the Peak District probably occurred episodically from late Carboniferous into Permian and Triassic times (Ineson & Mitchell, 1972).

During the Pleistocene this area must have been subjected to glaciation, but few traces remain. Meltwaters from the glaciers are thought to have carved out the deeply incises Manifold Valley (Ford, 1972). Cemented limestone screes are probably the result of solifluction during the late Pleistocene (Prentice and Morris, 1959; Burek, 1977).

LOWER CARBONIFEROUS (DINANTIAN) ROCKS

Although the Lower Carboniferous sequence is most complete in the basinal areas, such as at Ecton, zonation and correlation of the rocks is hindered by the paucity of fossils. Furthermore, the effects of transgressions and regressions, as recorded by Ramsbottom (1973) on the shelf areas, are less noticeable in the basinal areas.

Chadian (approx. = C_1)

Rocks of definite Chadian age have not been identified. The lower part of the Milldale Limestones has been assigned to the Chadian mainly on lithological grounds. The Lower Milldale Limestones crop out below the Lower Reefs in the floor of a tributary of the River Manifold, about 0.75 km SW of the Manor House (SK 100564).

The Milldale Limestones in this area are a dark facies equivalent to those seen in the Dovedale area (Parkinson, 1950). The succession consists predominantly of a fine-grained, black limestones (termed a 'cementstone' by Prentice, 1951), interbedded with thin calcareous shales.

The very top of the Chadian succession consists of sparry, light-coloured limestones with abundant crinoid fragments. This is interpreted as representing the regressive phase at the close of the Chadian.

Arundian (approx. = C_2S_1)

The base of the Arundian appears to be conformable on the Chadian. The Lower Reefs, initiated during the Chadian regression, continued during the Lower Arundian, forming a unit up to 120 m thick. These Lower Reefs crop out over a large area in the southern part of the region, forming a 'tongue' extending northwards as far as Broad Ecton Farm. Further north the reef Limestones dip beneath the Asbian rocks, appearing to form the core of Ecton Hill (see Fig. 2, section 2).

The Lower Reefs are composed of pale-grey micritic limestones, often with a mauve or pink tint. The reefs form upstanding masses which show poor bedding, and are often characterised by numerous minor shear planes up to a few metres in length.

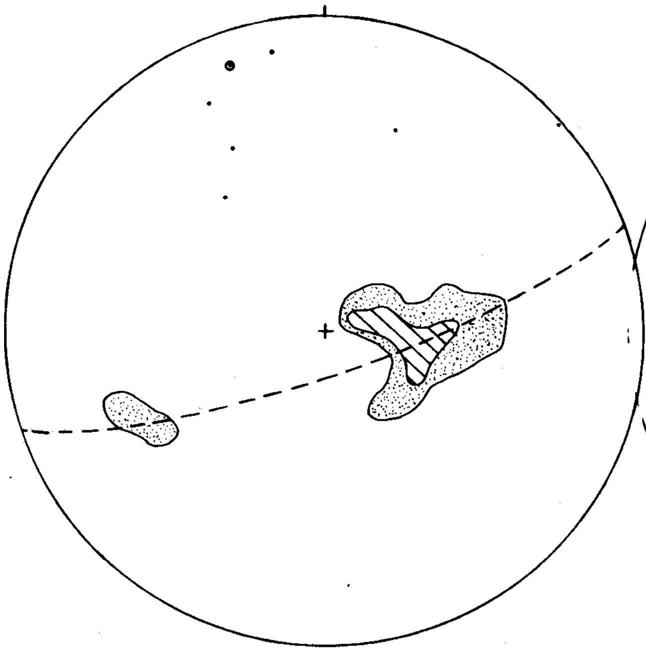
The north-south strip of Lower Reefs is interpreted as an apron reef system, fringing the western margin of the Derbyshire Massif. Reefs of similar age occur 5 km to the east along Dovedale. The Dovedale reefs possibly separated marginal facies (between the Dove and Manifold Valleys), from the lagoonal facies of the Massif. The reefs along the Manifold Valley in turn separated the marginal facies from the basinal facies to their west.

During upper Arundian times thin-bedded muddy limestones, shales and calcareous shales of the (Upper) Milldale Limestones were deposited to the west of the reefs.

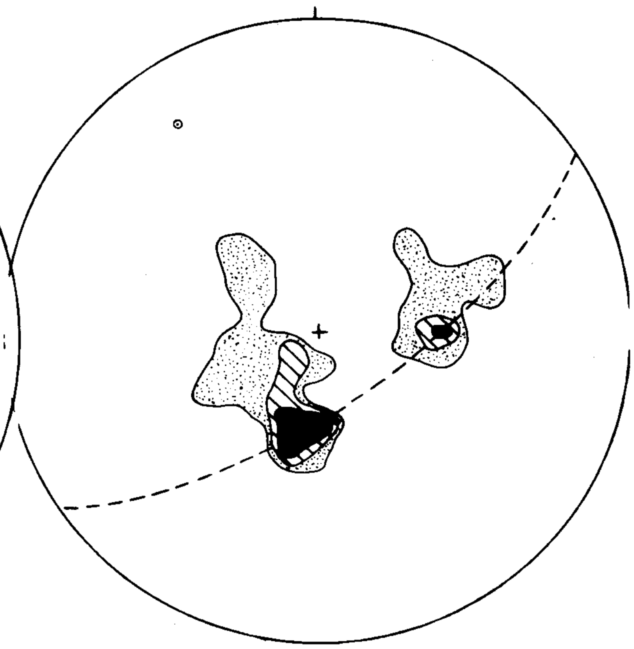
The main outcrop of the Upper Milldale Limestones is a north-south strip along the western margin of the reefs. These are also brought up in two small inliers to the north and west. The 1:10 000 IGS maps (1975) show a third inlier around the entrance to Dutchman's Mine (SK 098582). However, mapping in the mine levels has shown this to be very unlikely on a structural basis as the top of the Arundian lies at least 100 m below the surface at this point.

Asbian (approx. = D_1)

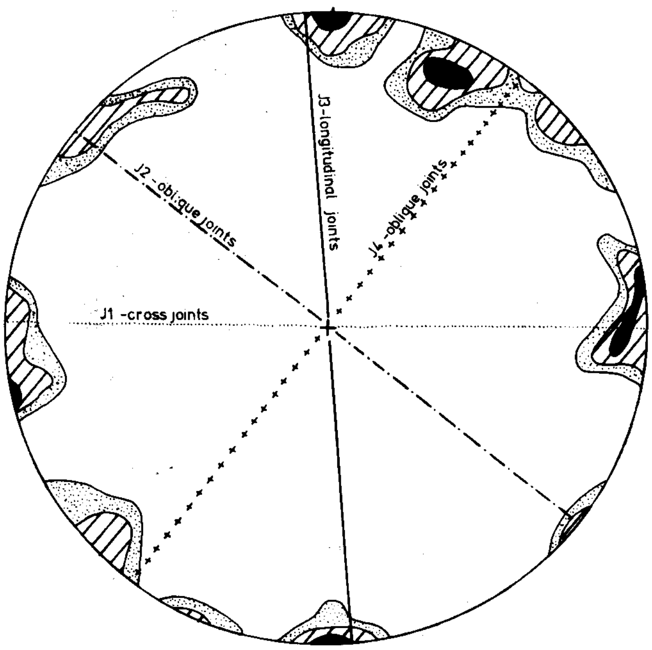
The Asbian unconformably overlies the Arundian in this region, although the contact between the two is not exposed. The bulk of the Asbian is composed of the basinal Ecton Limestones. (These were formerly divided



(a) Poles to bedding of non-reefal limestones (sub-area 1)
n=113



(b) Poles to bedding of reef limestones (sub-area 2)
n=42



(c) Poles to joints in reef and non-reefal limestones (sub-areas 1& 2)
n=64

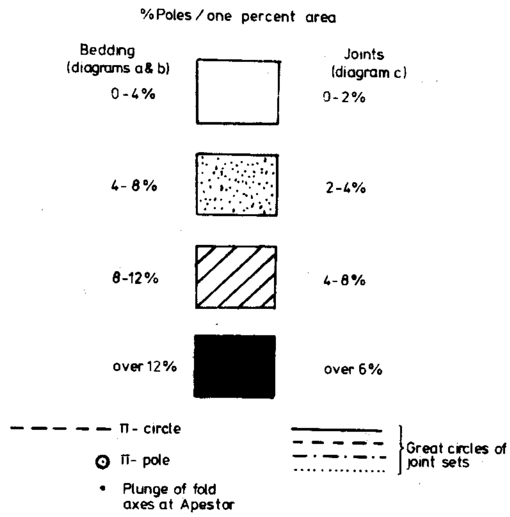


Fig.3 Stereographic plots

The diagrams show equal-area stereographic plots of poles to bedding and joints. They have been contoured on the percent--age density per a one percent area, using the Kalsbeck counting net method (For discussion see text) into the Apestor Limestones and Brownlow Mudstones Formations by Prentice, 1951.) Upper Reefs were deposited to the east.

Near the base of the Asbian, the Ecton Limestones consist of medium grey biosparite beds up to 0.5 m thick, separated by thin shale partings. The Limestone beds are often graded, with coarse biosparite at the base, and paler micrite at the top. Higher up the succession calcareous mudstones predominate.

To the east the Ecton Limestones become purer and lighter in colour, and appear to be transitional between the basinal facies to the west and the marginal facies further east.

The Upper Reefs were initiated during the Asbian regression in the east of the region. They are similar in aspect to Lower Reefs, but generally tend to be whiter in colour. In places stromatolites are present, indicating very shallow water deposition. Weathering of the Upper Reefs is irregular, probably due to partial dolomitisation.

A small area of massive light-grey micritic limestones near Water Bank Sough may represent a small biostrome near the top of the Ecton Limestones succession.

Brigantian (approx. = D_2)

The argillaceous sedimentation of the Upper Asbian continued into the Brigantian, with the deposition of the mixon Limestone-shales. The main outcrop of this formation at Ecton is a north-south strip along the Back of Ecton.

The sequence is a thinly-bedded succession of cyclic dark-grey, muddy limestones, calcareous shales and black shales. In a short trial at East Ecton Mine (SK 102583) the base of the Mixon Limestone-shales is marked by a 15 cm thick conglomerate of lime clasts and fossil fragments, set in a dark micritic matrix.

UPPER CARBONIFEROUS (NAMURIAN) ROCKS

The Namurian follows the Brigantian apparently disconformably, though poor exposure precludes elucidation. In the lower parts the sediments are predominantly argillaceous, but higher up thick sandstone units appear. Several goniatite marker bands are present. The cyclicity evident in the Dinantian appears to have continued during the Namurian (Ramsbottom *et al.*, 1978).

STRUCTURE

Folding

The majority of Carboniferous rocks in the Peak District are characterized by low dips and a low degree of folding (Butcher, 1977). The Ecton area, however, is noted for its high degree of folding, which is most evident in the Ecton Limestones. The folding can best be displayed by the use of stereographic plots (Fig. 3).

A stereographic plot is a diagram on which it is possible to plot both the dip and strike of a plane, be it a bedding plane or a joint plane. The planes are represented by their poles, a pole being a line at right-angles to a plane. If a plane is horizontal, then its pole is vertical, and this pole plots at the centre of the stereographic plot. If a plane strikes north-south and dips 45° E, then its pole plots on the stereographic plot as a point approximately mid-way between the centre of the diagram and the edge, and on the west (left) side of the centre.

In all the stereographic plots shown in Fig. 3, the plots of poles to the given planes have been contoured on their density per unit area.

Fig. 3a shows a stereographic plot of poles to bedding of the non-reefal limestones. This plot shows two maxima, representing the average dip of the bedding on each limb of the folds. A line (the π-circle) can be drawn through these maxima, the pole of which (the π-pole) represents the average plunge of the fold axes. This is about 10° to the NNW. Folding in the Ecton Limestones appear to have occurred with marked slippage along shale bedding planes.

The plunges of the fold axes as seen at Apestor are also shown on Fig. 3a, showing a broad agreement with the average plunge as represented by the π-pole.

Folding is also evident in the reef limestones (Fig. 3b), but in these the dips are rarely more than 15°. Again the average plunge of the fold axes is about 10° to the NW. However, the scatter of the ploes to bedding around the centre of the diagram suggests that the folding has been less intense than in the Ecton Limestones. Deformation probably occurred more by fracturing than by folding. The broader scatter of the poles to bedding in the reefal limestones may represent the original sedimentary dip of the beds away from the centres of the reefs.

Joints

Jointing is prominent throughout the region. The joints have been analysed using a stereographic plot of poles to joint planes (Fig. 3c).

The stereographic plot shows four main maxima representing the average joint directions. Planes at right-angles to these maxima (known as Great Circles) represent the average strike of each joint set. If the maximum compression in the area was east-west (as suggested by the north-south folding), then joint set 1 (J2) should represent cross joints parallel to the maximum compression. J2 would then represent longitudinal joints perpendicular to the maximum compression, but parallel to the fold axes. J3 and J4 in turn should represent conjugate sets of shear joints, oblique to maximum compression.

Faults

The major faults strike generally NE or NW, and typically downthrow to the east. A major north-south fault bounds the eastern side of Ecton Hill, and downthrows to the east by at least 70 m at Water Bank Mine (Green *et al.*, 1887).

Minor faults are present in most of the joint directions and some of the mineral veins appear to follow them.

The unusual north-south trend of structures in this area may be related to movement along the western margin of the Peak District Block.

MINERALIZATION

Mineralogy

The principal copper ores worked at Ecton were chalcopyrite, chalcocite and bornite. Chalcopyrite appears to have formed linings to several large cavities (Green *et al.*, 1887), but today it is only found as minute crystals within clear calcite.

Galena is the most abundant sulphide seen in the presently accessible workings. It is generally massive, although in Water Bank Mine small cubo-octahedral crystals have been found. Green *et al.* (1887) stated that lead generally occurred in the higher workings, near to the surface.

Sphalerite has not been observed underground, but it is fairly abundant on the tips at Water Bank Mine. It was also extracted from the bottom of the Clayton workings (Robey and Porter, 1972).

The chief gangue minerals present are calcite and barite. Fluorspar is generally abundant, but was insufficient for the needs of smelting (Farey, 1811).

Secondary minerals at Ecton are perhaps the most striking. Mawe (1802) gave a vivid description of these:

> "By the decomposition of the copper pyrites on the calcareous spar, arises a beautiful green efflorescence, [malachite], coating the spar, and sometimes appearing to pass into pearlspar.
>
> "Ecton also produces mountain blue [azurite], and mountain green: the former approaching to azure, the latter to a light verdegris colour ... ".

Other minerals recorded at Ecton include cuprite, tenorite, rosasite, chalconthite, limonite, wad, dolomite, cerussite, hydrozincite, celestine, smithsonite, pyrite and arsenopyrite (Sarjeant, 1956; Ford and Sarjeant, 1964; Braithwaite *et al.*, 1964).

Veins

The dominant vein directions are NNW and ENE, with minor east-west and NW trends. The NNW veins are parallel to the fold axes and in many cases they appear to occupy the fractural axial planes of the folds in areas of intense folding. The most important NNW veins are Vivian's, Joan and Water Bank Veins. The last-named, however, differs from the others, and appears to be a series of replacements between the limestone beds parallel to the bedding.

The ENE and NW veins generally occupy fault fissures of small displacement, although the Good Hope Veins fill the fractured axial planes of anticlines.

Pipes

The pipe deposits take the form of vertical or near vertical cavity fillings and replacements. They accounted for the bulk of the output from Ecton in the 18th and early 19th centuries. Vertical pipes are rare elsewhere in the orefield.

Observations of the West Pipe in Clayton Mine have shown that the mineralisation surrounds partly dissolved blocks of limestone, suggesting that solution took place prior to or during mineralisation. The large cavities recorded in the pipes may have formed by the karstification of the limestone by the hydrothermal mineralising solutions.

The locations of the pipe deposits at first sight appear to show no easily discernible controls. However, both the main pipes at Deep Ecton and Clayton Mines lie roughly on the hinge line of the anticlinorium forming Ecton Hill. It appears that this major fold channelled the uprising hydrothermal fluids into its hinge zone; the structurally highest part of the fold.

The position of the main ore deposits at Ecton appears to be related to the structure. The anticlinorium forming Ecton Hill appears to have channelled the uprising hydrothermal fluids into its hinge zone: i.e. the structurally highest part of the fold. In other parts of the orefield, such as at Ashover, similar situations were responsible for the formation of mineral veins above the hinge lines of anticlines. But at Ecton the locations of the main pipe and vein deposits are generally on the limbs of the anti-clinorium, with the majority of known deposits occurring on the eastern limb. Their locations may have been controlled by the degree of folding, which is more intense on the limbs of the anticlinorium. Above the hinge line folding and fracturing is less intense and the uprising hydrothermal fluids were unable to escape: and so they migrated laterally until they reached the areas of more intense folding and fracturing on the limbs, where they were able to rise and deposit their minerals.

The location of individual deposits in the areas of intense folding may have been controlled by the intersection of north-south fractures along the hinges of minor folds and east-west cross fractures, such as the Ecton Vein at Deep Ecton Mine. At Clayton Mine the Ecton Company's plan of 1889 shows that workings in the Clayton Pipe were on both a north-south and an east-west vein.

From the above observations it is possible to predict where undiscovered pipe deposits may occur. On the eastern limb of the anticlinorium places to look for pipe mineralisation are at the intersections of east-west fractures, with the strike extension of the intense folding seen in Deep Ecton and Clayton Mines. Chadwick Mine is at one such intersection, but here the orebody is not very large. On the western limb of the anticlinorium several untried areas exist between Wetton Mill and West Ecton Mine, along the strike of a belt of intense minor folding.

Replacement deposits

Replacement deposits occur adjacent to veins and pipes. A distinctive form of replacement mineralisation constitutes the 'saddles' described by Watson (1860). They are, in fact, replacement deposits along the limbs and hinge zones of anticlines. Replacements along the limbs were termed 'wings' by Watson (1860). The average width of the saddles is about 12 m, with ore extending up to 150 m along strike. Today, observation of these saddles is difficult, as according to Watson, most of them occurred beneath the pipe deposits, and are now below water.

Minor replacement deposits in small anticlines in the Engine Chamber of Clayton Mine may be smaller versions of Watson's saddles. On a larger scale the Water Bank Vein may be a large 'wing' deposit on the northern limb of a large saddle. The Ecton Company's plan of 1889 records a large saddle striking east-west on the 45 fathoms level at Water Bank Mine). The majority of the saddles strike north-south, although others may strike east-west. The intersection of saddles in these two directions was supposed to result in very rich ore.

MINE GEOLOGY

In the time available it was impossible to prepare detailed geological plans of all mines. The work shown in Figs. 4a and 4b was undertaken over a period of 4 days, and should only be regarded as a reconnaissance. Nevertheless, at a quick glance one can easily gain an idea of the complex structure of Ecton Hill.

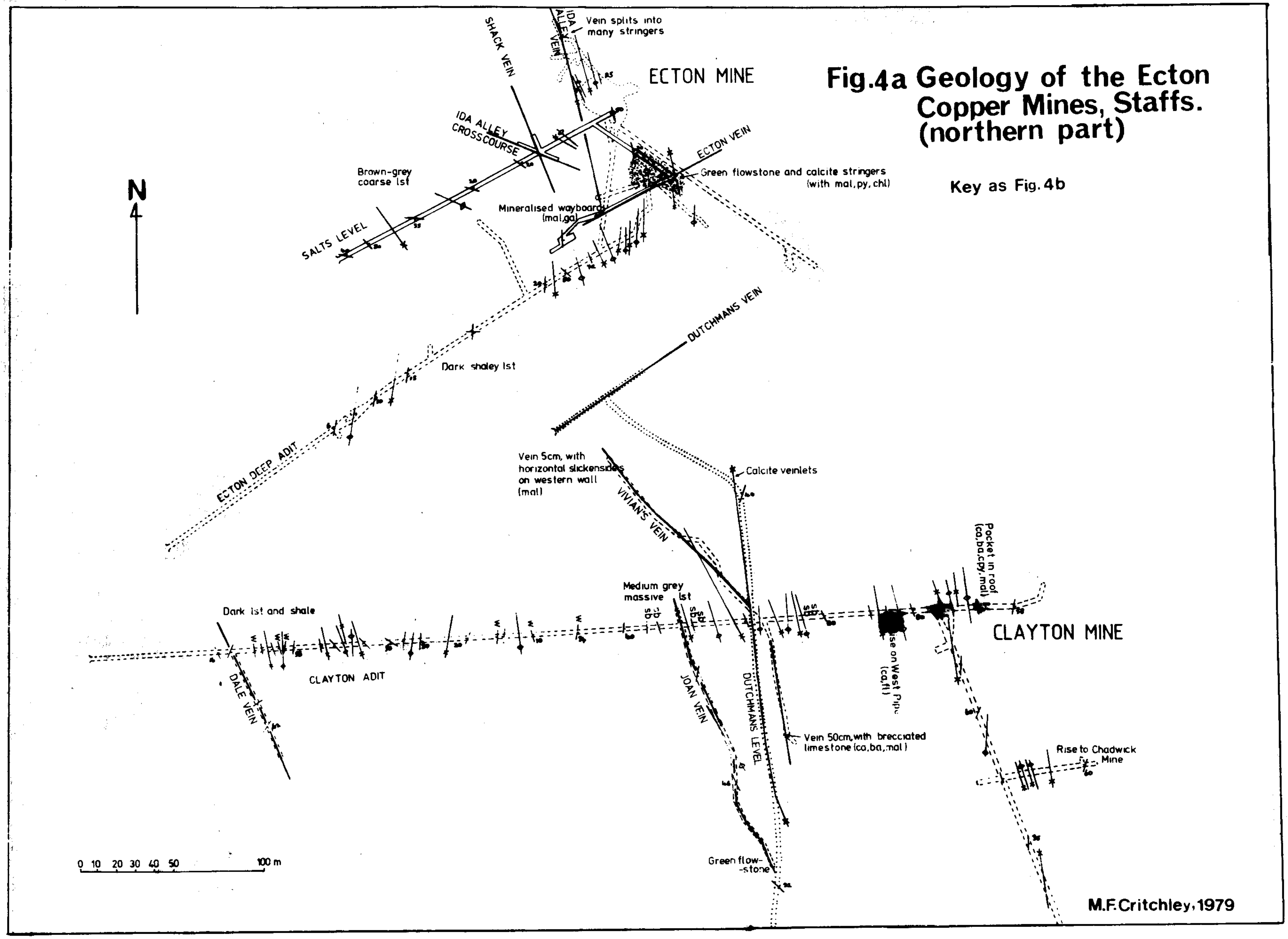


Fig.4a Geology of the Ecton Copper Mines, Staffs. (northern part)

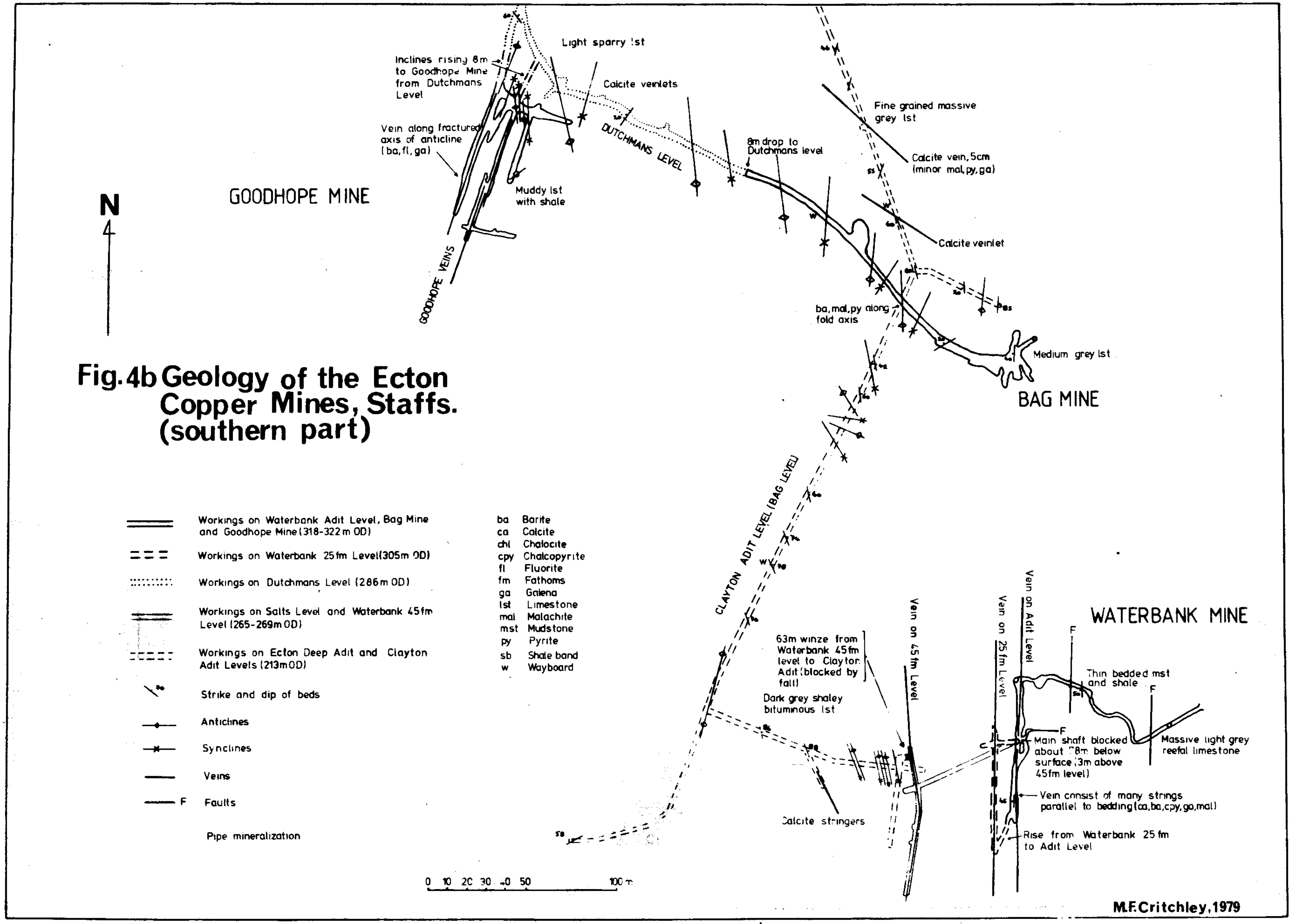
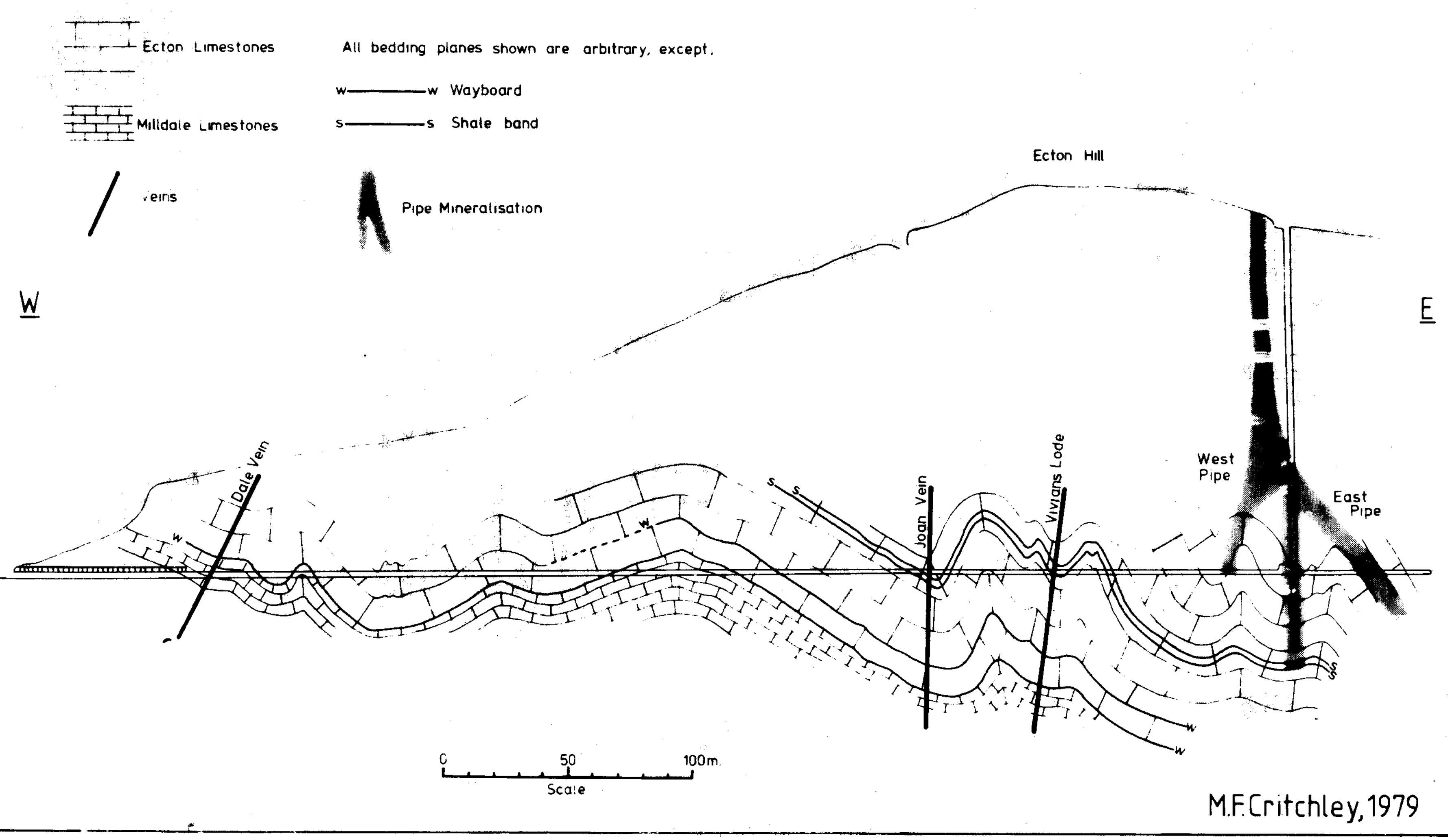


Fig.4b Geology of the Ecton Copper Mines, Staffs. (southern part)

Fig.5 Geological cross-section along Clayton Adit



Deep Ecton

The section exposed in Salts Level shows an increasing easterly dip towards the Deep Shaft, where the dip is sub-vertical; (this sub-vertical dip is also seen in the main workings on the Deep Ecton and Clayton pipes, where it is associated with intense isoclinal folding). Towards its eastern end, Salts Level intersects some minor branch workings on WNW cross vein and the NNW Shack Vein.

Just before the Deep Shaft is reached the level turns southeastwards towards the pipe workings, and thence southwestwards along the Ecton Vein. The Ecton Vein is exposed in the roof of the passage, being about 2 cm wide, and composed of calcite, malachite, pyrite and chalcocite. Following the level southwestwards along the Ecton Vein, a mineralised wayboard is encountered which shows abundant galena,a nd may be related to the Ida Alley Vein seen in the lower workings.

In the lower workings on the Deep Ecton Adit level, attention is focussed on the Pumping Chamber. Here the strata are tightly folded, thinly-bedded, argillaceous limestones and shales. Cross-cuts to the north and west from the chamber give access to the Ida Alley Vein.

Clayton Mine

The Clayton Adit level gives one of the best sections through Ecton Hill. The level commences in the topmost beds of the Upper Milldale Limestones, which consist of dark, fine-grained argillaceous limestones with cherts. Eastwards the level passes through increasingly higher beds of the Asbian (Fig. 5). The lower beds of the Asbian are fairly massive and coarse-grained, but higher up the succession, towards the Engine Chamber, the level passes through more argillaceous strata.

The Bag Level branches southwards from the Engine Chamber, following the strike of the argillaceous limestones exposed in the chamber, and thence southwestwards, down the succession towards the connecting rise to Water Bank Mine (now blocked). Here the strata are shaley and may again represent the top of the Upper Milldale Limestones.

Bag - Good Hope Mines

The Bay and Good Hope workings, originally separate mines, were linked by the Dutchman's Level in the 19th century. Both the mines and the connecting level are above the previously noted workings, and thus cut through the topmost beds of the Asbian succession.

The Bay shaft was sunk on the eastern side of Ecton Hill through light-to medium-grey sparry limestones. These limestones are more pure than usual for near the top of the Asbian, and are probably transitional to the marginal facies further east. Westwards along the Bag workings the strata become the typical argillaceous limestones and mudstones of the upper Asbian, until the 8 m winze is reached, linking the Bay Mine with the Dutchman's Level.

From the bottom of the winze, the Dutchman's Level runs westwards and then northwards through limestones that are generally light in colour and more sparry than those above. These probably represent the middle parts of the Asbian.

Just before the level turns northwards, two steep inclines join the level from the south, and give access to the Good Hope workings. In the Good Hope Mine, the rocks are again more argillaceous, reflecting the higher beds of the Asbian sequence.

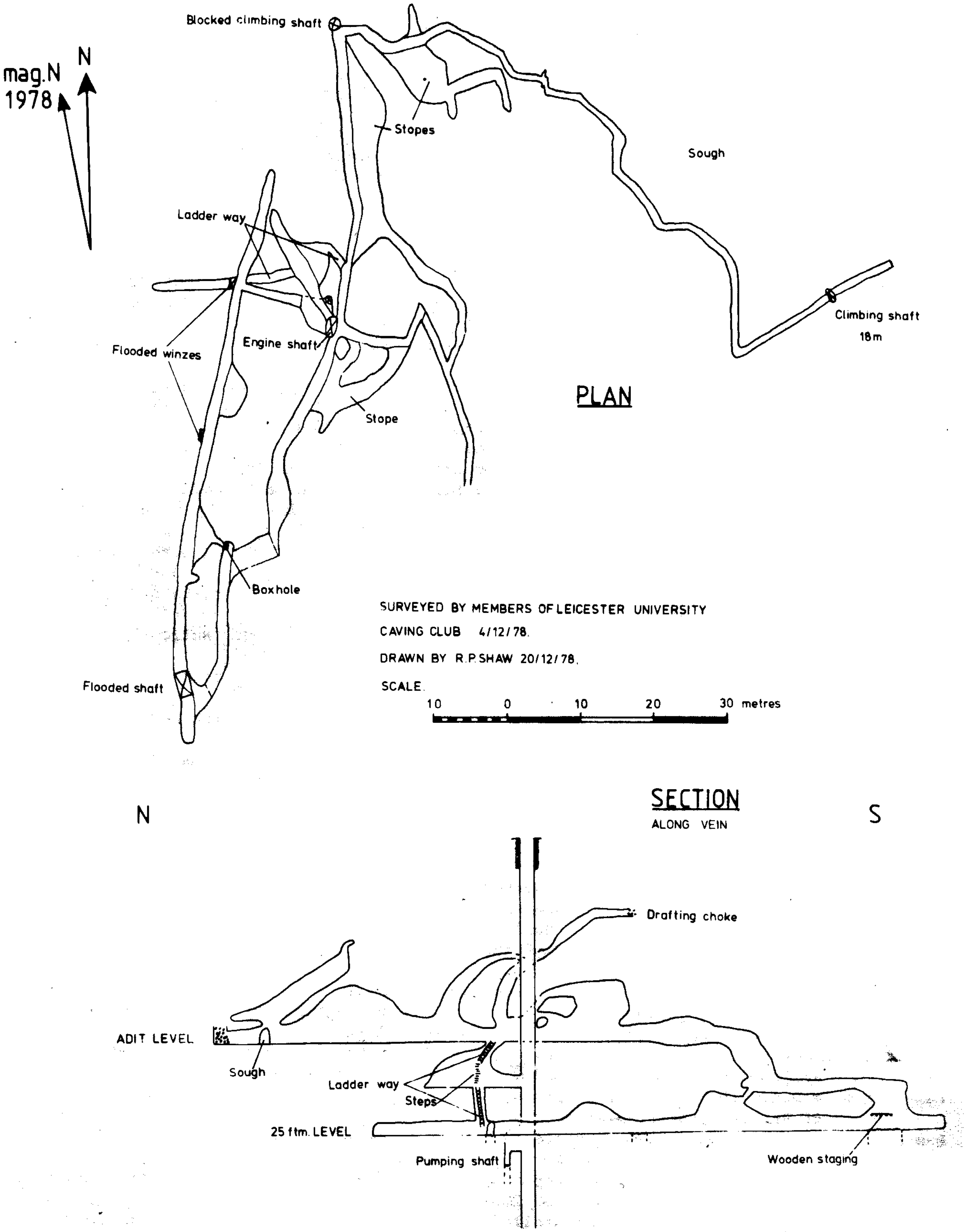
Water Bank Mine

During the present investigation the Water Bank workings were surveyed and this survey is reproduced in Fig. 6. The most convenient means of entry to the mine is via the climbing shaft, near to the sough tail. The climbing shaft is sunk through massive, poorly-bedded, light-grey micritic limestones. These beds are probably a biostrome in the upper Asbian.

Southwestwards from the shaft the sough is low and generally half-full of water. About 12 m from the climbing shaft the massive light-grey limestones are faulted against thin-bedded mudstones and shales to the west. From here the sough follows a sinuous northwesterly course. Just before the sough intersects the main Water Bank Vein, workings in the roof of a small chamber give access to a small, but beautiful rimstone pool.

Workings on the Adit Level along the main vein extend for 80 m to the south, where a winze leads to the 25 fathom level. The Main Engine Shaft intersects the Adit Level halfway along the workings, and can also be reached by a cross-cut from the 25 fathom level. The shaft extends for about 33 m below the 25 fathom level, but is blocked about 3 m above the

Fig. 6. WATERBANK MINE, ECTON.



45 fathom level. Access to the 25 fathom level from the Adit level may also be made via a ladderway from near the Engine shaft.

The vein on the Adit and 25 fathom levels takes the form of replacements parallel to the bedding, linked by small cross-cutting mineral-filled joints.

CONCLUSIONS

The geology of these important mines is both varied and complex. The limited work done underground has given some insight into the problems of the controls of mineralisation, but much more work will be needed to understand fully the controls. In fact it is doubtful whether the problem will be fully solved, as so much of the workings are below water, although it may be feasible to pump out some of the workings; it took several years for the mines to flood when they closed operations.

Nevertheless, the Ecton Copper Mines still provide a site for research, especially in the fields of mineralogy and paragenesis; fluid inclusion and stable isotope studies may prove fruitful.

ACKNOWLEDGMENTS

A study of this type would be impossible without the help of numerous persons. Permission to visit the mines was gratefully received from Mr. G. Cox of Butterton (for Clayton and Deep Ecton Mines), and the farmer at Broad Ecton Farm (for Bag and Water Bank Mines).

Help underground was provided by members of the Sigma Potholing Unit and Leicester University Caving Club, especially Richard Shaw and Pete Wilson.

REFERENCES

Braithwaite, R.S.W., T.B. Greenland & G. Ryback 1964 Celestine at Clayton Adit, Ecton (exhibit note). *Mineral. Mag.*, vol. 33, p. LXXXVI.

Burek, C.V. 1977 The Pleistocene Ice Age and after. Chap. 7 in Ford, 1977, q.v.

Butcher, N.J.D. & Ford, T.D. 1977 Geological Structure. Chap. 8 in Ford 1977, q.v.

Critchley, M.F. 1977 *The geology of the Ecton area, Staffordshire.* Unpub. B.Sc. Thesis, Univ. of Leicester.

Farey, J. 1811 *A General View of the Agriculture and Minerals of Derbyshire.* McMillan.

Ford, T.D. 1972 IN Robey, J.A. & Porter, L. 1972, q.v. pp. 9-15.

Ford, T.D. 1977 *Limestones and Caves of the Peak District.* Geo-Abstracts Ltd., Univ. East Anglia, Norwich. 469pp.

Ford, T.D. & Sarjeant, W.A.S. 1964 The Peak District Mineral Index. *Bull. P.D.M.H.S.*, vol. 2, pp. 122-150.

George, N.T. *et al.* 1976 *A correlation of Dinantian rocks in the British Isles.* Spec. Rep. no. 7, Geol. Soc. Lond. 87pp.

Green, A.H. *et al.* 1887 *Geology of the Carboniferous Limestone of North Derbyshire.* Mem. Geol. Surv. G.B., 2nd Ed., 212pp.

Ineson, P.R. & Mitchell, J.G. 1973 (for 1972) Isotope age determinations on clay minerals from lavas and tuffs of the Derbyshire orefield. *Geol. Mag.*, 109, pp. 501-512.

Institute of Geological Sciences. 1975 1:10 000 geological maps. SKo5NE and SK15NW.

Mawe, J. 1802 *The Mineralogy of Derbyshire.* Phillips, London. 211pp.

Parkinson, D. 1950 The stratigraphy of the Dovedale area, Derbyshire and Staffordshire. *Q.J.G.S. Lond.*, 105, pp. 265-294.

Parkinson, D. & Ludford, A. 1964 The Carboniferous Limestone of the Blore-with-Swinscoe district, northeast Staffordshire, with revisions to the stratigraphy of neighbouring areas. *Liverpool and Manchester Geol. Jour.*, 4 (1), pp. 167-176.

Porter, L. 1969 Ecton Hill - a study of the surface features. *Bull. P.D.M.H.S.*, 4 (2), pp. 156-169.

Porter, L. 1970 Ecton Hill, Part II - Underground. *Bull. P.D.M.H.S.*, 4 (3), pp. 195-216.

Prentice, J.E. 1951 The Carboniferous Limestone of the Manifold Valley region, North Staffordshire. *Q.J.G.S. Lond.*, 106, pp. 171-209.

Prentice, J.E. & Morris, P.G. 1959 Cemented screes in the Manifold Valley, North Staffordshire. *East Midland Geog.*, 2 (11), pp. 16-19.

Ramsbottom, W.H.C. 1973 Transgressions and regressions in the Dinantian: A new synthesis of British Dinantian Stratigraphy. *Proc. Yorks. Geol. Soc.*, 39, pp. 567-607.

Ramsbottom, W.H.C. *et al.* 1978 *A correlation of Siliesian rocks in the British Isles.* Spec. Rep. no. 10, Geol. Soc. London.

Robey, J.A. & Porter, L. 1970 The copper and Lead mines of the Mixon area, Staffordshire. *Bull. P.D.H.M.S.*, 4 (4), pp. 256-280.

Robey, J.A. & Porter, L. 1971 The metalliferous mines of the Weaver Hills, Staffordshire. *Bull. P.D.M.H.S.*, 4 (6), pp. 417-428.

Robey, J.A. & Porter, L. 1972 *The Copper and Lead Mines of Ecton Hill, Staffordshire.* Moreland, Leek, 92pp.

Sarjeant, W.A.S. 1956 The mineralogy of Ecton Hill. *Jour. Univ. Sheffield Geol. Soc.*, 2 (3), pp. 87-92.

Watson, J.J.W. 1860 Notes on metalliferous saddles, or ore-bearing beds in the contorted strata of the Lower Carboniferous of certain parts of Derbyshire and North Staffordshire. *The Geologist*, 3, pp. 357-369.

Worley, N.E. & Ford, T.D. 1977 Mississippi valley type orefields in Britain. *Bull. P.D.M.H.S.*, 6 (6), pp. 201-208.

Received February 1979

Martin Critchley,
Geology Department,
Imperial College,
LONDON. SW7 2BP