THE METALLIFEROUS MINING DISTRICT OF ALDERLEY EDGE, CHESHIRE.

by

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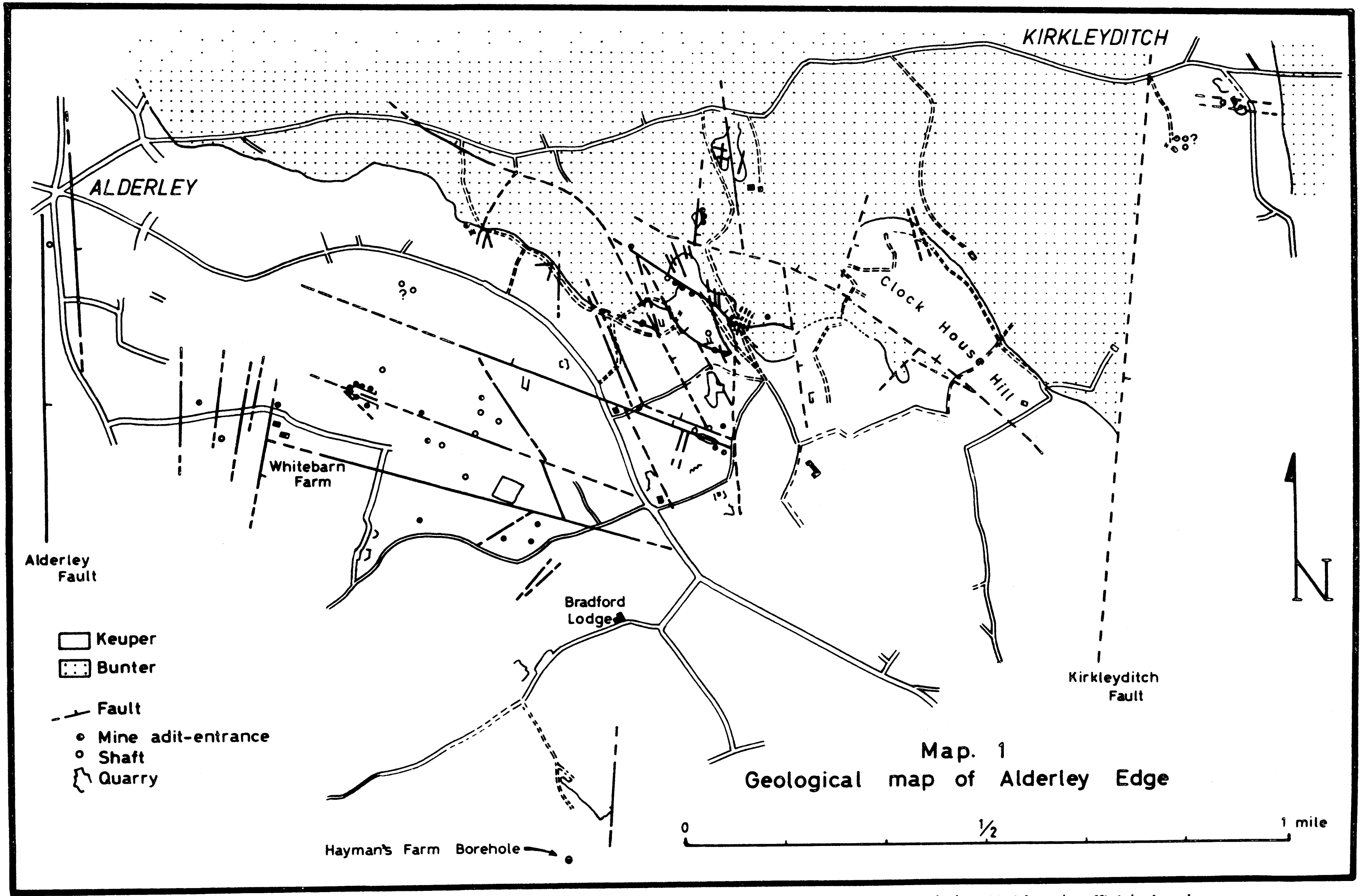
Summary

Surface and subsurface examination of the copper and lead ore deposits of Alderley Edge indicates that the ores possess features suggestive of an epigenetic origin. Copper, lead and cobalt ores, while showing a restriction to certain horizons and lithologies in the Triassic host-rocks, are closely related to the fault system of the area. The geochemistry of the deposit, with a high cobalt: nickel ratio in galena, indicates origin from an acid igneous source. Age-determinations on galena indicate a connection with the Derbyshire ore-field.

Introduction

The mining area of Alderley Edge and Mottram St. Andrew lies in Cheshire, 12 miles south of Manchester (Ord. Surv. 1" map 101; Geol. Surv. 1" map (NS.) 98). Alderley Edge is a striking hill feature rising abruptly from the drift-covered plain to a height of over 600 feet above sea-level. The hill consists of a faulted complex of Triassic rocks, resistant basal Keuper conglomerates constituting a capping. The northern face of the hill corresponds essentially to a series of fault scarps and is abrupt, while the southern side slopes gently down to the level of the plain.



Map 1: Geological map of the Alderley mining district. Area surveyed by the author, 1964. Certain faults added from the official mine plans (Min. of Fuel and Power). Positions of the Kirkleyditch and Alderley Faults from Geol. Surv. Sheet Memoir 98, (1963).

The general geology is indicated on Map. 1.Upper Bunter and Lower Keuper rocks are represented at outcrop. The Bunter series consists of white to red, even-grained, current-bedded sandstones with rare clay intercalations. Faults seen cutting the Bunter carry barytes, and adjacent sandstones are leached of their iron content. The Keuper series consists of a group of conglomerates, sandstones, clayey sands and clays. This series is the main repository for the metallic ores, though copper-ore occurs in the topmost Bunter beds at a few localities. In the Keuper Sandstone, ores tend to be restricted to the more conglomeratic or arenaceous horizons, of which there are three in the sequence.

The main mining area is bounded by the Alderley fault to the west and the Kirkleyditch fault to the east. Between these occurs a complex of north-westerly trending faults which are mostly normal and downthrow to the north-east, with throws averaging about thirty feet. Several are richly mineralized. A number of minor north-south trending faults occur also, but tend to have small throws and are unmineralised except for the presence of barytes.

The main ores are those of copper and lead, but zinc, arsenic, cobalt, nickel, manganese, antimony, silver and gold are also recorded (Dewey and Eastwood, 1925). Mohr (1964) notes the presence of trace amounts of chromium, vanadium, zirconium, strontium and molybdenum. A wide variety of minerals have been formed (Table 1). The issue of the origin of the Alderley ores is confused by the fact that most of the mineral species occurring are secondary types. Certain ores, notably those of lead, are clearly localized near faults. The copper ores are more widespread and give the impression of being a stratiform deposit.

On Alderley Edge the main mines are West Mine (blocked 1961, Map 2); Wood Mine (blocked 1964, Map 3); Engine Vein (Map 4); and the Stormy Point mines (Map 2). No plan is available for the Mottram St. Andrew mine. Surface locations of mine-adit and shaft entrances are marked on Map 1. Map 2 shows the extent of the mine-workings for which plans are available, accompanied by a.section showing their distribution in relation to the ore-bearing horizons. These horizons are the topmost Bunter sandstones and three groups of conglomerates and sandstones in the Lower Keuper. The Keuper horizons are herein referred to, in ascending sequence, as the Engine Vein, Wood Mine, and West Mine Beds after the principal mine which worked each horizon. In the plan of the mines prepared by Dickinson in 1877, three ore-bearing horizons are indicated as occurring throughout the main mines. The section of Map 2 shows that entirely different horizons were worked in each of the main mines. The ore-bearing conglomerates and sandstones are separated by barren series of clayey sandstones and clays.

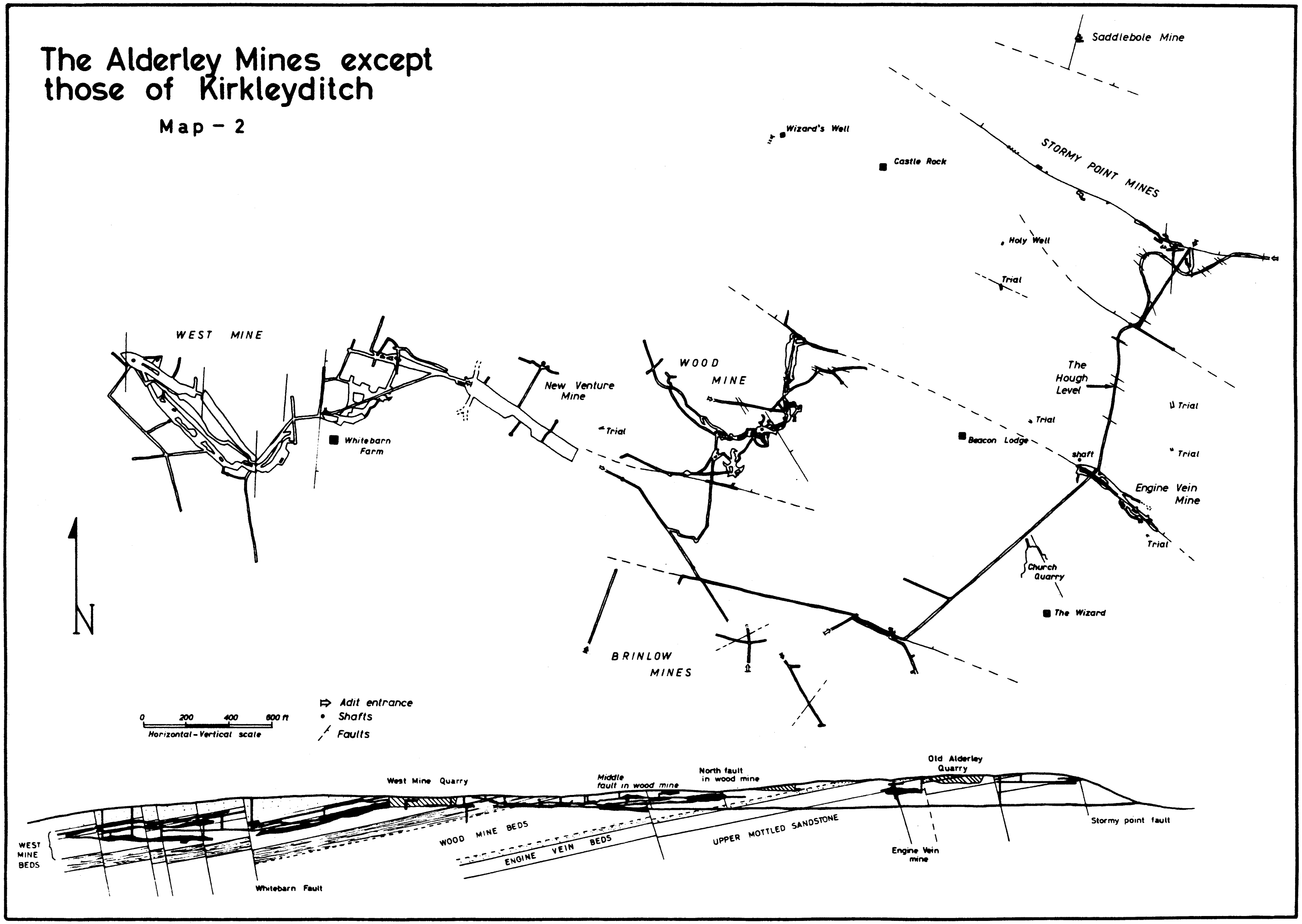
At Mottram St. Andrew, two miles east of Alderley Edge village, the productive beds are equivalent to the Engine Vein Beds.

Similar ore deposits are known in Triassic rocks at Beeston, Bickerton and Peckforten in Cheshire; Grinshill, Pim Hill, West Felton and Hawkstone in Shropshire; and Cannock in Staffordshire. Occurrences of copper ores in rocks of New Red Sandstone age are also known in Worcestershire, Nottinghamshire, Somerset and Devon (Dewey and Eastwood, 1925)

History of Mine-Working.

The area may have been worked in pre-Roman times and was certainly the site of mining activity in Roman times (Roeder, 1901). The first working to be dated with any degree of precision is the section of the Hough Level between Dicken's Wood and Engine Vein. Holland (1813) states that this was driven about 1708.

Copper and lead were being worked in 1755 by Charles Roe of Macclesfield. When Roe transferred his interest to the Parys Mountain area of Anglesey about 1770, he was followed at Alderley by a succession of owners who worked the mines for copper and lead until about 1810. During the period 1810 to 1830 cobalt ore was mined on a small scale.



Map 2: Map of the mine-workings in the main mining area at Alderley, with a section indicating the relations of the mine workings to ore horizons in the Triassic rocks. Data from author's surveys and from official mine plans (Min. of Fuel and Power).

In 1857 James Mitchell of Bristol (Henderson, 1860) obtained a mining lease and worked the West Mine until the expiry of the lease in 1877. Working commenced in Wood Mine in the early 1860's. Between 1857 and 1877 West Mine and Wood Mine yielded 170,000 tons of ore from which about 3200 tons of copper metal was extracted; an average yield of about 2.1%. The main production of this period occurred between 1858 and 1873. From 1873 until 1877 production was halved. A description of the processing methods used at this time is given by Dewey and Eastwood (1925).

The mines were disused from 1877 until 1902 when a new lease was granted. However, production at this period was negligible, about 35 tons of ore being won annually up to 1915 (Mohr, 1964). Mining ceased in 1919 and has not been renewed, though interest revives periodically.

The Mottram St. Andrew occurrence was known at least as early as Roman times. Working was renewed about 1807 (Roeder, 1901) but soon ceased. About 1865 the Magnesium Metal Co. re-opened the mine at Kirkleyditch for a short period and mined lead, copper and cobalt ores. This mine has now been disused for nearly a century and is flooded.

History of Research.

General accounts of the Alderley desposits have been given by Holland (1813), Henderson (1860), Hull (1864), Hull and Green (1866) and Greenwell (1866). Roscoe (1868-9; 1876) described the occurrence of vanadium ore at Mottram, suggesting that it was present in vanadinite and two new minerals, mottramite and roscoelite. More recently it has been considered that the vanadium ores of Mottram are not indigenous to that locality but are derived from ore delivered there from Pim Hill, Shropshire, for smelting.

Hunt (1884) ventured the hypothesis that the widespread copper deposits of the Edge were formed by the solution of minerals at Engine Vein, followed by natural filtering of the solutions through the sandstones, largely subsequent to exposure of the ore-body by mining.

Rudler (1905) held views of favouring a syngenetic origin for the ores, believing that they were deposited contemporaneously with the sediments in which they occur.

Greenwood (1921) stated that the Alderley copper ores are definitely secondary and originated by the leaching of minerals in superincumbent strata which have been removed by denudation.

Dewey and Eastwood described the workings and ore-bodies in moderate detail (1925). These authors favoured a syngenetic origin for the Alderley deposit and suggested that detrital sulphide grains from an easterly or southerly source were incorporated in the sediments during deposition and were subsequently converted to carbonates and oxides by the action of meteoric waters in the zone of oxidation. Dewey later reiterated his views (1935) and stated that the concentration of ores along the faults is not due to primary mineralization of the faults, but to migration of ore minerals from the country rock to them.

Chesworth (unpublished thesis, 1960) carried out a surface geochemical study of a small portion of the Edge, plotting geochemical anomalies for lead, copper and minor elements.

Moorbath (1962) published a model age for galena from Alderley, dating the ore at 210±60 m.y. (Lower Permian to Upper Jurassic; Holmes, 1959).

Trotter (in Taylor, Price and Trotter, 1963) regarded the ores as associated with Tertiary faulting and invoked an epigenetic origin for the deposit.

Mohr (1964), in a detailed work on the Alderley and other Red Bed ore deposits, proposed a complex combination of epigenesis and syngenesis to account for conflicting features displayed by these

ORE		LOCALITY					
ELEMENT	MINERAL	WEST MINE	NEW VENTURE LEVEL	WOOD MINE	ENGINE VEIN	STORMY POINT	MOTTRAM St.ANDREW
Pb + Cu, As, Ag, V	GALENA	●	●	●	●	●	●
	CERUSSITE	●	●	●	●	●	●
	PYROMORPHITE				●	●	●
	ANGLESITE				●		
	LINARITE				●		
	CALEDONITE				●		
	VANADINITE						?
	MOTTRAMITE						?
Zn	SPHALERITE				●	●	
Cu + As, Fe.	MALACHITE	●	●	●	●	●	●
	AZURITE	●	●	●	●	●	●
	CHALCOPYRITE				●	●	
	BORNITE				●	●	
	CHRYSOCOLLA			●	●	●	
	CHALCOCITE				●		
	COVELLITE				●		
	PISANITE				●		
	ENARGITE				●		
	OLIVENITE				●		
	LIROCONITE				●		
	LIBETHENITE				●		
Mn, Co + Ni, As.	ASBOLITE	●	●	●	●	●	●
	ERYTHRITE				●	●	
Fe	PYRITE				●	●	
GANGUE	BARYTES	●	●	●	●	●	●
	WITHERITE				●		
	CALCITE				●		

Table 1: Mineral species recorded from Alderley Edge with location of occurrences where known (sources cited in text).

occurrences.

The author has mapped accessible mines, topographically and geologically, and examined sections of ore-bodies revealed in the mines. The majority of the observations made in this paper are drawn from sections in Wood Mine and Engine Vein Mine. Where necessary, evidence has been drawn from records of mines closed prior to 1962. Mineral identifications, except where otherwise stated in the text, are by the author. A summary of the mineral species, recorded as having been found at Alderley, is presented in Table 1.

Description of the Ores.

The main surface showings of ore are at Engine Vein and Stormy Point.

(i) Copper ores :

The principal copper ore at Alderley is malachite, which is the most widespread of all the ores (Map 5). It occurs in the form of disseminations in the arenaceous divisions of both the Bunter and the Keuper series. The ore is mainly developed in the topmost 20 feet of the Bunter and at three levels in the Keuper series. The disseminations are richest immediately above clay bands in the sequence (Map 4, points I, II; text-fig. 2A). In this position at the base of the arenaceous units, the concentrations of ore follow the general dip of the beds, but higher in the units they tend to follow structures in the host rocks such as current-bedding (Map 3 point III; text-fig. 1C). Malachite is concentrated around clay pellets in conglomeratic portions of the Keuper series and is also concentrated along some fault zones (e.g. Engine Vein fault in the Engine Vein openworks) and in joint fissures. Redeposition of copper minerals on the mine walls is a common phenomenon, especially near faults (Map 3, point VIII).

Azurite and chrysocolla occur in lesser amounts than malachite and have a more restricted occurrence. Both appear to be commonest near to faults. Azurite is moderately abundant at Engine Vein (Map 4) in the wall-rock immediately adjacent to the fault. In Wood Mine it is rare but sometimes occurs associated with malachite ore (Map 3, point VI).

Sulphide ores of copper are rare but include chalcopyrite, bornite, covellite and chalcocite (Greenwood, 1919). These minerals are restricted in occurrence to certain faults, notably the Engine Vein fault and the Stormy Point fault where they are present in the fault breccia. The copper sulphide ores are often associated with lead ores, especially galena, along the faults. At Engine Vein, copper and iron sulphides occur sporadically as small flecks in masses of galena which are present in the fault breccia.

Other copper minerals recorded are only of minor importance. Copper combines with arsenic in liroconite (Geological Survey collection) and also in arsenates (Dewey and Eastwood, 1925), probably olivenite and enargite. Copper occurs with lead in linarite, with iron in pisanite (Chesworth, 1960) and as the phosphate, libethenite (Berruti <u>in</u> Hull and Green, 1866).

A peculiar occurrence of azurite is seen at two localitites, Engine Vein (Map 4; points III, IV) and at the openworks 300 yards to the north. The mineral occurs as small spheres scattered through a grey clay. This occurrence appears to be restricted to the immediate neighbourhood of faults and to a grey clay lithology. The grey clay in which the azurite spheres are found passes into a red clay at a short distance from the fault at Engine Vein (Map 4, point V; text-fig 2C).

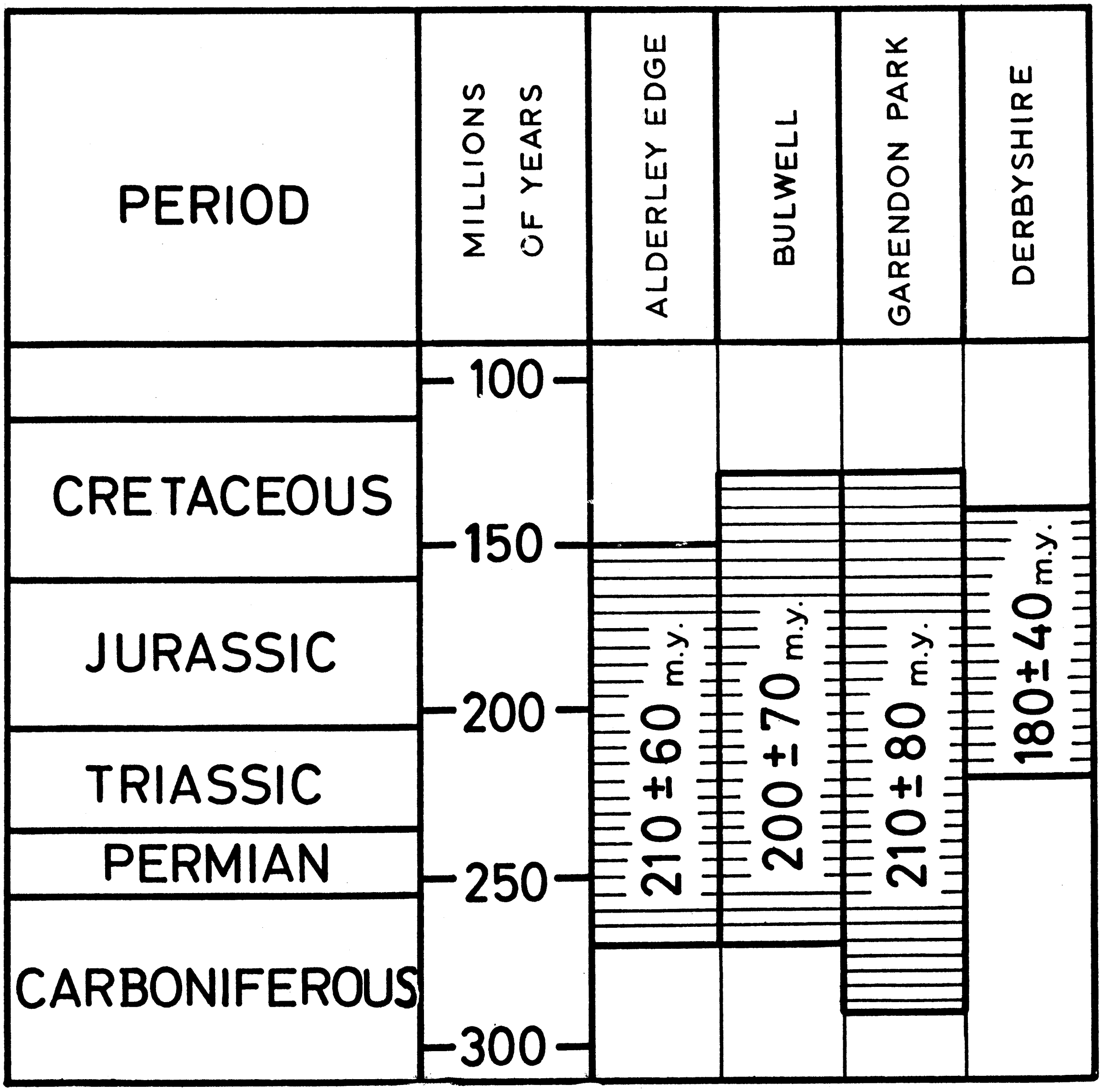


Table 2: Comparison of lead-age determinations for galena samples from Permian and Triassic rocks of the Midlands (data from Moorbath, 1962).

(ii) Lead ores :

The main lead ores are cerussite and galena. Both ores occur in masses in fault breccia zones in Wood Mine (Map3; points V, VII; text-figs ID and 2A) and at Engine Vein and Stormy Point. They also form disseminations in neighbouring sandstones. The lead ores appear to be restricted almost entirely to the Keuper series; only at one locality, alongside the fault in Engine Vein, have they been found in Bunter rocks.

Disseminations of galena sometimes follow current-bedding laminae in a similar manner to the copper ores.

Dewey and Eastwood (1925) reported that some masses of galena showed cores of sphalerite and calcite. An analysis of lead ore quoted by them indicated the presence of silver, copper, arsenic, zinc, iron, aluminium, nickel, cobalt, manganese and sulphur in addition to lead.

Pyromorphite is moderately common at Alderley. It forms masses associated with galena and cerussite in fault breccias at Engine Vein and Stormy Point and is also present as disseminations in sandstones in the neighbourhood of these faults. Anglesite and caledonite are recorded from Engine Vein (Eagar, Broadhurst and Jackson, 1959).

The lead ores are always associated with a barytes gangue which forms crystalline masses in the fault breccias and veins, impregnations and crystal rosettes in the adjacent country rocks. It is abundant in both the Bunter and the Keuper rocks along and near faults. Many small fractures in the area carry small amounts of barytes, especially in the Stormy Point district (Map 5). Greenwood (1919) records witherite.

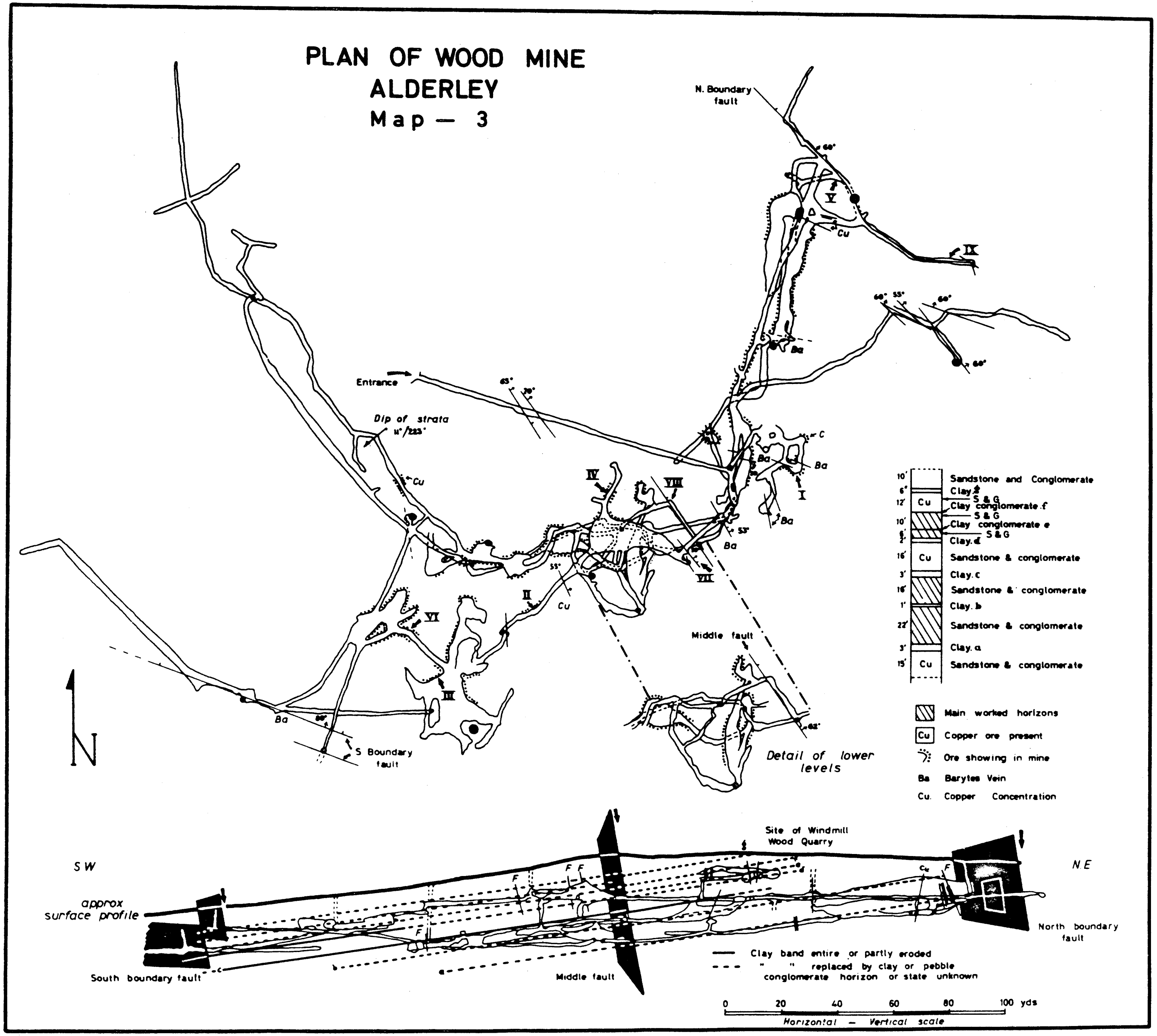
(iii) Manganese, cobalt and nickel ores:

Manganese, cobalt and nickel occur almost exclusively in the form of "wad", a complex secondary mineral consisting of oxides and hydroxy-oxides of the metals. Asbolite is a cobalt-rich form of "wad" and appears to have a wide distribution at Alderley. Asbolite forms large segregations, vein-like masses and spots in the host rocks, both Bunter and Keuper. The mineral is concentrated in arenaceous rocks near faults in all the mines. The rocks in which the ore occurs are typically free from iron-staining. Asbolite is often closely associated with malachite and galena. Sometimes the disseminations are concentrated on current-bedding laminae.

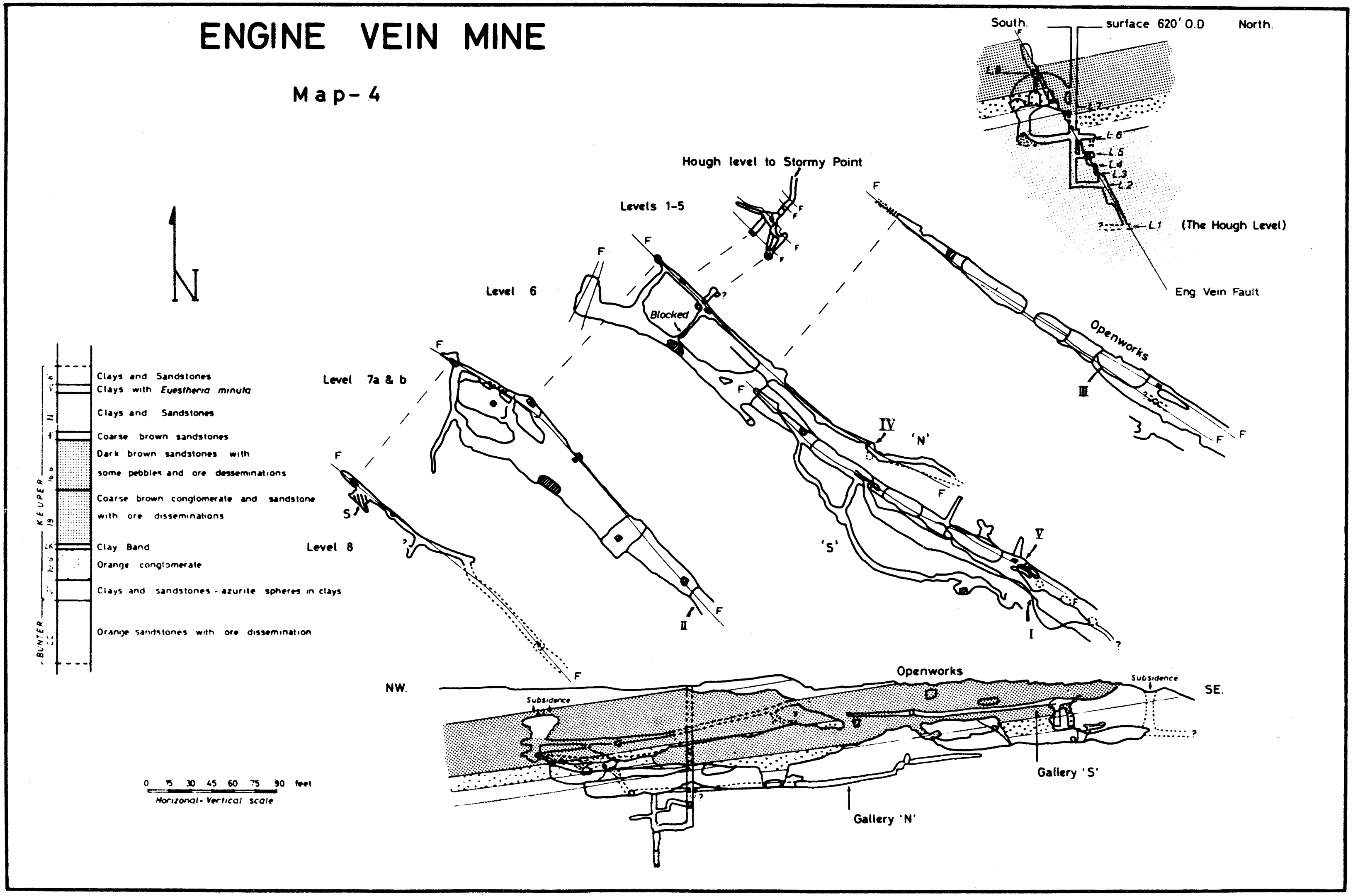
Several analyses presented by Mohr (1964) indicate that cobalt is more abundant than nickel in the Alderley ore-deposits. Galena, probably a primary ore, from Engine Vein, showed a cobalt: nickel ratio of 50 : 1 (cobalt 500 p.p.m., nickel 10 p.p.m.) Among secondary minerals analysed, asbolite from Wood Mine had a high cobalt : nickel ratio while in malachite, nickel predominated over cobalt.

West Mine and Wood Mine both worked ore-bearing conglomerates and sandstones in the Keuper (Map 2 and section). Both these mines were worked mainly for copper ore and developed as a ramifying series of passages in the cupriferious horizons. Small amounts of lead ore were won from the neighbourhood of faults. The form of the copper ore-concentrations in Wood Mine is shown by Map 3 to have been highly capricious. Masses of workable ore appear to have occurred randomly in the arenaceous horizons although the distribution of these ores shown on Map 5 indicates some restriction to the faulted areas. The Northern Boundary Fault of Wood Mine should have caused a repetition of the cupriferous beds but trials run northwards across the fault only enter barren strata. A similar situation occurs at the southern boundary of the mine.

Engine Vein Mine (Map 4) worked the considerable concentrations of lead ore which are associated with the Engine Vein fault at that point. Copper ore was also worked but apparently only on the up-throw side of the fault. There is evidence that the occurrence of copper ore is richer downdip from the fault



Map 3: Map, section and simplified succession of the Wood Mine Beds (Keuper), Wood Mine, Alderley. Data from author's survey.



Map 4: Map, section and simplified succession of the Engine Vein Beds (basal Keuper) and topmost Bunter beds, Engine Vein Mine, Alderley. Data from author's survey.

than on the up-dip side. Dewey and Eastwood(1925) state that workings 50 yards north of Engine Vein had been driven for 100 yards along a fault with cupriferous strata to the south and a barren conglomerate to the north of the fault. The conglomerate mentioned must have been a member of the Engine Vein series which were worked only a short distance to the south. Ore disseminations do not continue far enough north to appear in equivalent strata exposed in the Old Alderley Quarry, 150 yards north of Engine Vein. This evidence suggests that copper mineralization is localised about Engine Vein and related in some way to the fault at that locality.

At Stormy Point several small mines (Map 2) were mainly concerned with the extraction of lead ore from the Stormy Point fault. A little copper ore occurs in the Engine Vein Beds and in the topmost Bunter, as at Engine Vein, while lead ores accompanied by barytes are developed along the fault. The occurrence is generally poorer than at Engine Vein.

Few records exist of the Mottram Mine and the workings are now inaccessible. The ore-body appears to have been of a twofold nature; a conglomerate horizon which outcropped in the Kirkleyditch quarry and which was extensively worked downdip and a lode-form ore-body which was probably a mineralized fault. The conglomerate is equivalent to part of the Engine Vein Beds. Ore samples yielding up to 22% copper are reported to have come from the "lode" whilst 3% copper ore was fairly common at Mottram. These figures indicate the occurrence to have been richer than those in the main Alderley mines where average ore yielded 2% copper.

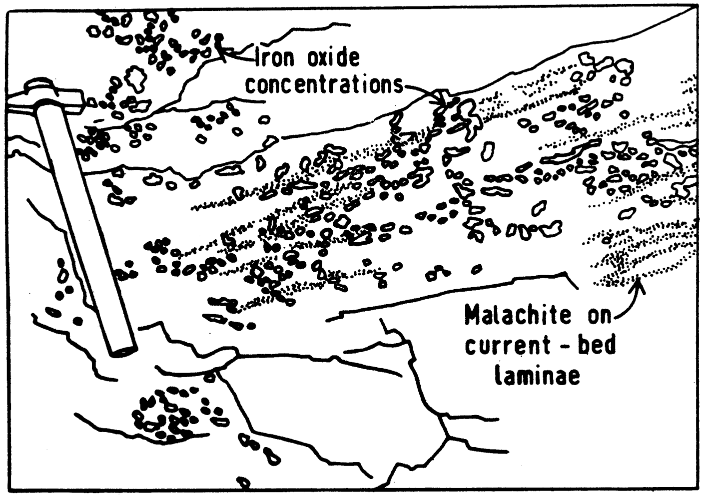
Origin of the Ores

Both syngenetic and epigenetic origins have been advocated for the Alderley ore deposits. In recent years the syngenetic views of Dewey and Eastwood (1925) have been countered by the epigenetic theory of Trotter (1963). Mohr (1964) advances a theory proposing a combination of epigenesis and syngenesis.

From considerations of the stratigraphical and geographical distribution of the mineral deposits and the composition of the mineral assemblage, it appears that a simple epigenetic origin is the most likely.

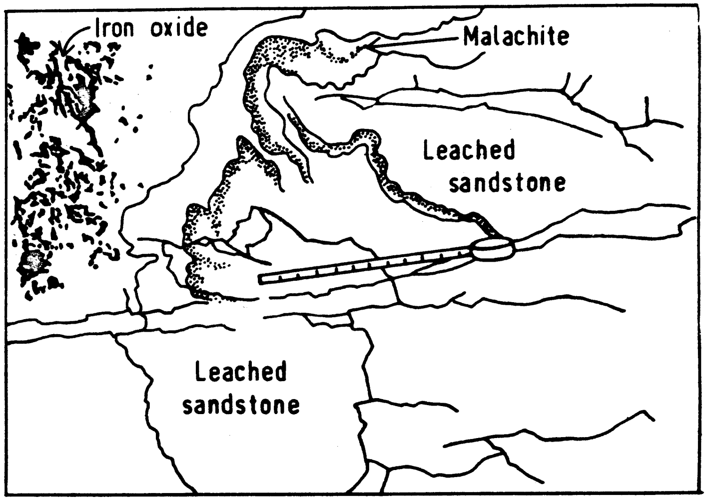
(a) Distribution: The ore-occurrences plotted on Map 5 show that there is a significant association of the lead and copper mineralization with the fault system of the area. This is most apparent in the case of the lead ores and their attendant barytes which are seen to be restricted in their occurrence to the immediate vicinity of faults. Most of the faults which lack metallic ores are mineralized by barytes alone. The copper ores are more widespread than the lead ores but show a similar restriction to the faulted area, in particular, there appears to be an absence of copper ore in the Engine Vein Beds in the area between the Stormy Point and Engine Vein faults although ore occurs in the neighbourhood of these faults. It is significant that the occurrences of sulphide minerals are entirely on, or very close to, fault planes whilst it is the secondary species, especially carbonates, which are the most widespread. It has been mentioned previously that there is apparently a richer occurrence of secondary copper ore down-dip from the Engine Vein fault than on the up-dip side of the fault, indicating migration of the secondary ores down-dip from a primary ore-body on the fault. It may be inferred from the evidence presented on Map 5 that the copper ores show a greater dispersion from the main mineralized faults in the higher ore-bearing horizons (Wood Mine and West Mine Beds) than is seen in the Engine Vein and topmost Bunter beds, though a drilling programme would be necessary to prove this.

At Alderley the ores are restricted to the topmost Bunter and three horizons in the Keuper Sandstone. At West Felton, Salop, a similar deposit occurs in association with faults which bring the Keuper Waterstones into contact with Keuper Marl. At Cannock, Staffordshire, Bunter rocks are mineralized. The mineralization of the Triassic rocks is only seen in faulted areas at the Cheshire and Shropshire localities.

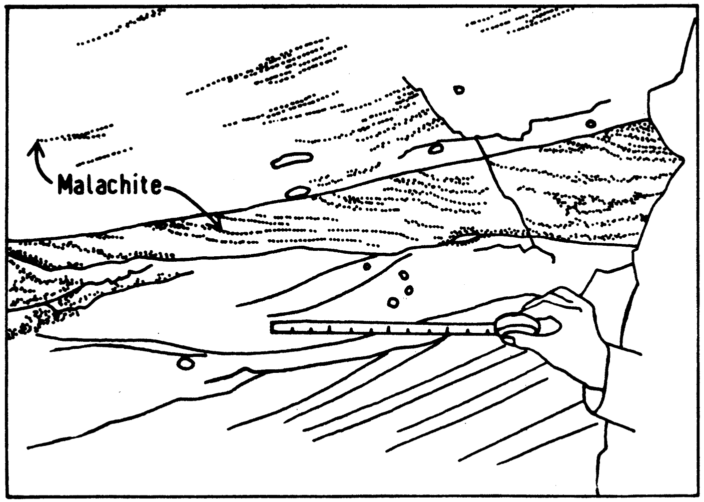


A: Malachite ore, Wood Mine, Alderley. (Map 3, 1).
Malachite occurring in white sandstone, iron-staining concentratrated into small spots in the rock.

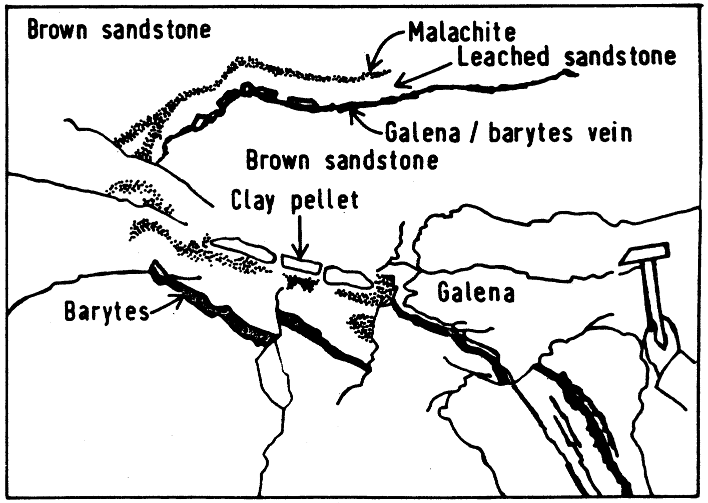
All figures drawn from photographs



B: Malachite ore, Wood Mine, Alderley. (Map 3, II).
Malachite occurring in white sandstone surrounded by heavily iron-stained sandstone. Scale - 1 foot.

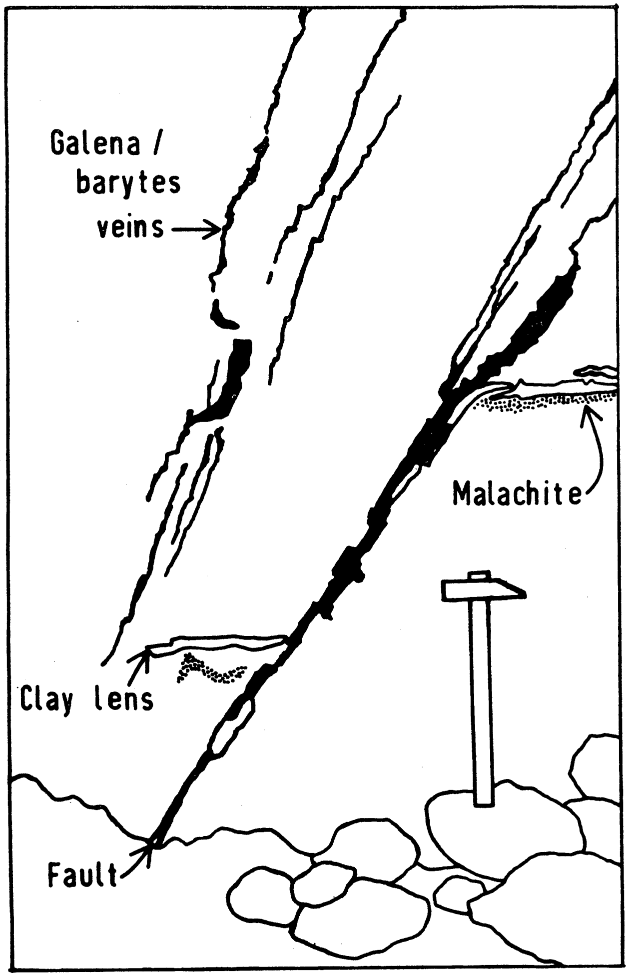


C: Malachite ore, Wood Mile, Alderley. (Map 3, III).
Malachite disseminations concentrated along current-bedding laminae and sharply restricted to a particular unit. Scale - 1 foot.

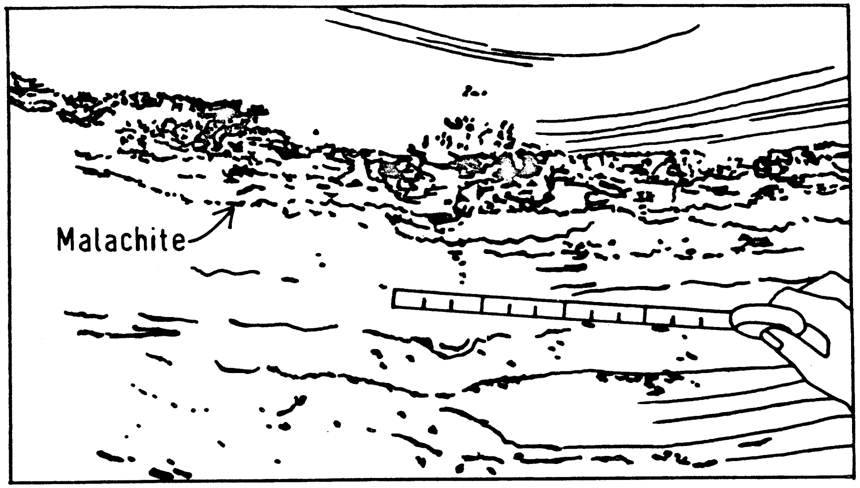


D: Malachite, galena and barytes, Wood Mine, Alderley. (Map 3, V). Galena and barytes veins along the North Boundary Fault separated from malachite by a narrow zone of leached sandstone.

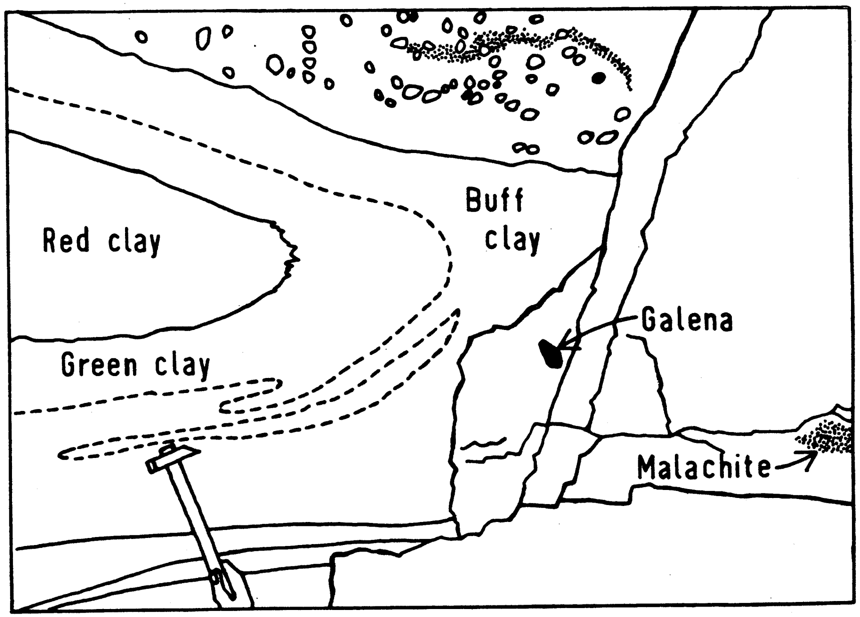
Text-fig. 1



A: Mineralization on the Middle Fault, Wood Mine, Alderley. (Map 3, VII). Galena and barytes veins developed along the fault plane. Malachite disseminations concentrated about clay flakes in the Keuper host rocks.
All figures drawn from photographs



B: Malachite concentrations associated with a mud-cracked clay band; the malachite (full black), occurs between the clay flakes. Upper Bunter, Engine Vein, Alderley. (Map 4, 1). Scale - 1 foot.



C: Basal Keuper clay band showing alteration of colour against the Engine Vein Fault. Downthrow side to left of fault. Engine Vein mine, Alderley. (Map 4, V.)

Text-fig. 2

(b) The mineral assemblage: The bulk of the mineral species recorded from Alderley (Table I) are the products of oxidation processes acting on pre-existing primary ores. The small amounts of sulphide ores present probably represent the remnants of the primary ores. Many of the rarer mineral species recorded, assuming correct identifications were made, are those which characterize the zone of secondary enrichment of copper sulphide lodes (e.g. chrysocolla, libethenite and olivenite). Anglesite, linarite, pyromorphite and vanadinite are minerals which are typical of the oxidised zones of lead ore-bodies.

The association of lead and a little zinc with barytes, as seen at Alderley, is suggestive of an epigenetic assemblage. The recognition that the bulk of the minerals are secondary and that remnants of the primary sulphide ores are restricted to the faults supports this hypothesis for both the copper and lead minerals.

The high cobalt : nickel ratio (50:I) shown by galena from Engine Vein (Mohr, 1964) is important since it is a feature of the geochemistry of ore-bodies whose source was an acid igneous mass (Davidson, 1962). Such a source body could supply the combination of ores noted at Alderley and account for the abundance of arsenic present.

While certain occurrences of ore (e.g. text-fig. IC) appear to indicate that the minerals were deposited contemporaneously with the sediment, others (e.g. text-fig. IB) show that there has been migration of mineral-bearing fluids through the sediments after their deposition. In the case of the copper ores, only the carbonates are seen accentuating the sedimentary structures in the manner shown (text-fig. IC); but in the case of the lead ores, galena sometimes occurs in this manner. The sulphides are mainly restricted to the faults, however.

There are two main objections to the acceptance of a syngenetic origin for the Alderley ores.

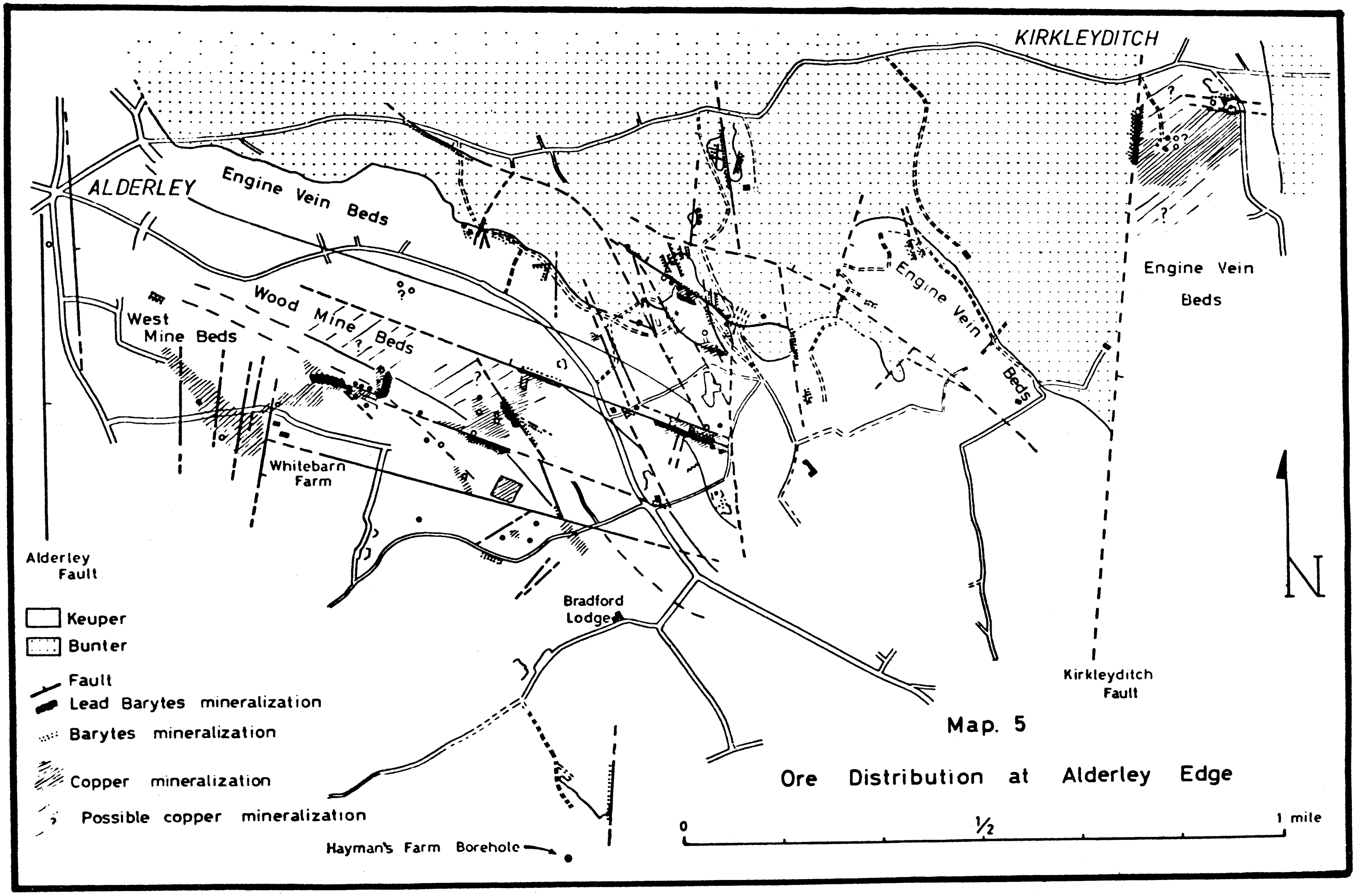
(i) The lack of a source for the ores in Triassic times. Current-bedding in the ore-bearing horizons indicates that the sediments were derived from the east and south-east. Derivation from this direction suggests the Derbyshire mineral field, where lead is important but copper insignificant, as the source for the ore minerals. Lead-age determinations by Moorbath (1962) suggest that the Derbyshire mineralization did not occur until the period between the Mid Trias and Upper Jurassic. This deposit is therefore unlikely to have been in existence to act as a source for the Alderley deposit.

(ii) The composition of the mineral assemblage is not what might be expected if the minerals were derived from pre-existing mineral veins by weathering and erosion. While the copper ores are readily converted into the carbonate state in which they are easily transportable, the alteration of galena is hampered by the formation of a surface coating of cerussite. Therefore, in a deposit derived from lead and copper lodes by weathering, only negligible amounts of lead ore would be expected, contrary to the situation obtaining at Alderley.

The situation where cobalt predominates over nickel has never been recorded in sedimentary ore deposits (Davison, 1962). It is concluded that the high ratio of cobalt to nickel in galena from Alderley (Mohr, 1964) indicates an epigenetic origin. The reverse situation in malachite (Mohr, 1964), where nickel is more abundant than cobalt, is probably attributable to the secondary nature of the malachite in which the ratios of the minor elements need not reflect in any way their initial relations in the primary ore.

Summary

An epigenetic origin from an acid igneous source is suggested for the mineral deposits of Alderley Edge and occurrences of similar type in Cheshire and Shropshire. The evidence for such an origin is as follows:



Map 5: Ore distribution in the Alderley mining area superimposed on a geological map of the area. Mineral occurrences partly partly inferred from records in the case of the Kirkleyditch Mine and the West Mine, Alderley. Other occurrences from author's survey.

(i) The close association of sulphide ores with faults.

(ii) The distribution of carbonate ores only in the faulted areas.

(iii) The restriction of mineralization to arenaceous rocks except near faults. (text-fig. 2C).

(iv) The richer occurrences of ore down-dip from certain faults.

(v) The lack of concentrations of ore in old stream channels in the sediments.

(vi) The irregular occurrence of the ores, both stratigraphically and geographically, indicating that exhalative syngenesis was not the formative process.

(vii) The high cobalt : nickel ratio found in the sulphide ore.

(viii) The lack of a suitable source for the ores if formed by a syngenetic process.

(ix) The mineral composition of the Alderley assemblage.

Conclusions.

It is concluded that the Alderley and similar ore deposits in Cheshire and Shropshire had an epigenetic origin from an acid igneous mass. Lead-age determinations for deposits in the Midlands (Moorbath, 1962) suggest some degree of contemporaneity in the times of formation of the galena at Alderley, Cheshire; Bulwell, Nottinghamshire; Garendon Park, Leicestershire; and the main Derbyshire ore-field (Table 2). Deposits of comparable age and mineralogy occur in Permian and Triassic rocks surrounding the ore-field of Derbyshire. Ford (1960) has reviewed the evidence which suggests a granitic source for the Derbyshire lead veins.

The almost complete restriction of the metallic ores to the Keuper rocks may be related to the appearance of numerous clay bands in the sequence, these tending to trap mineral-bearing solutions.

The age of the ores is possibly Jurassic. Moorbath's age determination on galena gives a considerable degree of freedom but the ores cannot have been emplaced in their present location until the Upper Triassic. If the other similar occurrences in the region are considered it becomes apparent that, in some areas, emplacement must have followed deposition of the Keuper Marl since that series is cut by faults with which the ores are associated. Emplacement of the ores was, therefore, either contemporaneous with, or shortly after, faulting in the Jurassic.

The Alderley ores lie in the zone of oxidation and have been considerably altered and undergone some redistribution by ground water. The primary ores are represented by sulphides which occur sporadically on the faults.

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