THE LANCASHIRE & NORTH STAFFORDSHIRE GROUPS OF THE GEOLOGISTS ASSOCIATION - JOINT EXCURSION TO ALDERLEY EDGE SATURDAY 21st AUGUST 1999

Excursion leader: David B. Thompson (formerly of the University of Keele)

Meet at 10.00 a.m. in the western part of the National Trust Car Park, 100m E of the Wizard Restaurant, on the top of Alderley Edge (grid ref. SJ 859773). Vehicles will be parked here all day but lunch will be taken away from the vehicles. Secure locking of the cars is recommended. A packed lunch and drinks are needed; the leader regrets that one of the drawbacks (the only one?) of an excursion to Alderley Edge over the years is a lack of convenient hostelries within striking distance of the meatier parts of the geology. The excursion will involve walking over modestly rugged ground for most of the day but will not involve great distances - only 4km or so. The pathways may be muddy in places if the weather is/has been wet; occasional steep gradients up and down will be experienced for short distances. Collecting and hammering is not permitted on National Trust property. No hazardous exploits will be attempted but members are reminded of their duty of care towards the safety of others besides themselves.

Lying within the wider extensional Permo-Jurassic Cheshire Basin (286-200Ma = million years old), the Alderley Edge area consists of a series of escarpments and dip slopes which have been fashioned by differential erosion from mineralised sandstone units of the Sherwood Sandstone Group (Lower Triassic; age c.248-243 Ma) which lie in a N-S 3km-wide block (horst) cutting the Wilmslow anticline (upfold). The whole belongs to the Wem-Red Rock Fault (=fracture) zone, an inherited ancient Palaeozoic lineament (line of fractures) c.600-500Ma on the NE of the basin. The latter stages of the evolution of the Edge relate to it being covered, and then exposed, during the passage of the Devensian (last) ice sheet (25000-13000 years ago). During the Holocene (13000 years-present), the area was occupied by Mesolithic (c.8000 years) and ?Neolithic peoples and by Bronze Age (2000-1000yrs), Roman and 17th-19th century copper miners.

The excursion is designed to introduce members to the rock succession (stratigraphy) and sedimentary origins (sedimentology) of a sequence of rock units of river and wind-blown (fluvial and aeolian) origins, largely of Lower Triassic (Upper Scythian 245-243 Ma) to Middle Triassic (Anisian c.243-238 Ma) age:

(i) the Wilmslow Sandstone Formation (WSF) (more fluvial at the base; more aeolian at the top);
(ii) the rock units (members) within the Helsby Sandstone Formation (HSF):

- * the Engine Vein Conglomerate Mbr (EVCM) at the base followed upwards by:
- * the Hayman's Farm Mbr (both somewhat ephemeral braided river units;
- * the Beacon Lodge Mbr (largely aeolian);
- * the Wood Mine Conglomerate or Pebbly Sandstone Mbr (WMCM) (fluvial and equivalent to the Delamere Pebbly Sandstone in basinwide terms);
- * the West Mine Sandstone Mbr (WMSM) (largely aeolian; contemporaneous with the spectacular Frodsham Mbr) and
- * the Nether Alderley Sandstone Mbr (NASM) (fluvial; of great sinuosity and steadier discharge; once regarded as the top of the Helsby Sandstone but perhaps equally validly the lateral equivalent of the lower parts of the Tarporley Siltstone Formation (TSF; the base of the Mercia Mudstone Group, MMG, basinwide).

The possible presence of a major period of erosion, uplift and ?folding in the sequence, and therefore gaps in deposition of the Helsby Sandstone at around 243Ma) will be discussed. This includes the suggestion of of the presence of an angular unconformity (?equivalent to the Hardesgen unconformity of the southern North Sea and Northern Germany) at the base of the Engine Vein Conglomerate at Castle Rocks or the base of the Wood Mine Conglomerate near Church Quarry.

Almost contemporaneous (synsedimentary) faulting (fracturing of the rock sequence) has affected the whole of the Basin and probably the Styal-Wilmslow-Alderley area. Certainly the extensional (i.e.normal) Alderley Fault, downthrowing west on the west of the Alderley block (horst), is large with a displacement, or throw, of up to c.1000m. The Kirkleyditch Fault, downthrowing east on the east of the horst, is a less fundamental but still large fault dipping (antithetically) towards the basin margin to the east. Within the block (horst), minor faulting is along N-S, NW-SE, and particularly WNW-ESE, lines, these being some of the most mineralised directions.

Although poorly exposed at the surface compared with underground, the area is famous because of its primary and secondary Cu-Pb-Zn-Fe-Co-Ni-As-Ba sulphide, sulphate (SO_4) and hydroxy-carbonate CO_3 (OH) mineralisation, and its copper, lead and cobalt mines developed in the Wilmslow Sandstone and the EVCM, WMCM and WMSM members of the Helsby Sandstone. Traces of hydrocarbons had been found associated with these minerals. The sources of the heavy metals are likely to have included the Carboniferous sandstones and black shales/coals (aged 360-286Ma) buried beneath the basin bottom of the Permo-Triassic red-bed succession which has been buried deeply enough (at a temperature gradient of c.30 degrees Celsius per Km depth) to undergo hydrocarbon generation. The sulphur present in the mineralised areas has the signature of Permian (255-248Ma) or Upper Triassic (238-225Ma) evaporites (beds of rock salt and gypsum). Fluid inclusions trapped in the mineralising barite ($BaSO_4$) deposits indicate the presence of low-temperature basinal brines and temperatures of origin of greater than 60 degrees Celsius. The brines and heavy metal solutions have migrated up, and laterally across, major faults and joints (cataclastic fracture zones = CFZs) and updip into the porous-permeable trap provided by the Wilmslow anticline, the Alderley block and the porous-permeable WSF-HSF succession. The mineral solutions have been baffled by many fracture zones (CFZs), but they have generally ponded and crystallised in the top of the block beneath a regional seal provided by the upward increase in clay and silt (argillaceous) components of the NASM, TSF and the overlying Mercia Mudstone Group. In addition the mineralisation is found below and above local mudstone beds in any part of the succession and preferentially on one side of many CFZs. The dating of the galenas by the Pb-Pb method has yielded mean dates of 180ma. By analogy with the East Irish Sea Basin, hydrocarbon generation is likely to have taken place between 200 and 60Ma. Mixing of the mineral solutions is envisaged to have taken place along major conduits (fracture zones) during episodes of seismic pumping associated with the incidence of frequent earthquakes. The likely major mineralisation pathways and sites, marked by the reduction in colour of the original red beds, are a matter for discussion. Unroofing of the trap took place during inversion (uplift) of the rock successsion sometime in the Tertiary period (65-2 Ma) probably starting 60 million years ago.

Reference will be made throughout the excursion to the wider interdisciplinary research findings of the Alderley Project funded by the Leverhulme Trust on behalf of the Manchester Museum and the National Trust.

SOURCES

Ordnance Survey sheets 1:50000 Manchester (101); 1:25000 SJ87/97 Macclesfield & Alderley Edge, 1:10560 or 1:10000 SJ 87NW & NE; Geological Survey sheets 1:63360 or 1:50000 Stockport (98) Solid or Drift; 1:10560 SJ87 NW & NE.

CARLON, C.J. 1979. The Alderley Edge Mines. Altrincham, Sherratt & Sons 144pp.

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EAGAR, R.M.C. & BROADHURST, F.M. (eds) 1991 The geology of the Manchester Area. Geologists' Association Guide No.7. London, Geologists' Association 118pp.

EVANS, D.J., REES, J.G. & HOLLOWAY,S. 1993 The Permian to Jurassic stratigraphy and structural evolution of the central Cheshire Basin. Journal of the Geological Society of London 150, 857-870.

MEADOWS, N.S., TRUEBLOOD, S.P., HARDMAN, M. & COWAN, G. 1997 Petroleum Geology of the Irish Sea and Adjacent Areas. Geological Society Special Publication 124. London, Geol. Soc., 447pp.

ROWE, J. & BURLEY, S.D. 1997 Faulting and porosity modification in the Sherwood Sandstone at Alderley Edge, northeastern Cheshire: an exhumed example of fault-related diagenesis. Pp.325-352 in Meadows et al. q.v.

TAYLOR, B.J., PRICE, R.H. & TROTTER, F.M. 1963 Geology of the Country around Stockport and Knutsford. London, HMSO for the British Geological Survey. 183 pp.

THOMPSON, D.B. 1970a The stratigraphy of the so-called Keuper Sandstone Formation (Scythian-?Anisian) in the Permo-Triassic Cheshire Basin. Quarterly Journal of the Geological Society of London 126, 151-181.

______ **1970b** Sedimentation of the Triassic (Scythian) red pebbly sandstones in the Cheshire Basin and its margins. Geological Journal 7, 181-216.

______ **1985** Field Excursion to the Permo-Triassic of the Cheshire, Irish Sea, Needwood and Stafford Basins. Poroperm Excursion Guide 4. Chester, Poroperm-Geochem 172pp.

______ **1991** Itineraries VII to XI. Triassic rocks of the Cheshire Basin. Pp. 57-81 in Eagar, R.M.C. & Broadhurst,F.M. (eds) q.v.

WARRINGTON, G. 1965 The metalliferous mining district of Alderley Edge, Cheshire. Mercian Geologist 1, 111-129.

______ **1980** The Alderley Edge mining district. Amateur Geologist 8, 4-13.

______ **1981** The Copper Mines of Alderley Edge and Mottram St. Andrews, Cheshire. Journal of the Chester Archaeological Society 64, 47-73.

Itinerary.

Meet at the **National Trust Car Park** immediately east of the Wizard. Introduction to the Permo-Jurassic Basins. (see figures, pp. 1-5).

1. Walk to **Castle Rocks**. Aeolian Wilmslow Sandstone Formation (WSF) overlain unconformably (?) by fluvial channelised Helsby Sandstone Formation (HSF). This is the Engine Vein Conglomerate Member some 30m thick (EVCM). Examine the base and top of the outcrop. Mesolithic, ?Neolithic site. (Figs, pp.5-9, 11).

2. Walk 100m westwards to **Wizards "Well" Quarry**. Three units of fluvial HSF (EVCM) separated by two different mudstone units. The site of a footprint find. (Figs, p.6)

3. Walk 50m westwards to **Wizards "Well"** to examine the basal mudstone and first unit of the HSF (EVCM), the structure and the indicators of mineralisation/mining. Also the "Well". (Figs, p. 5).

4. Return eastwards via Castle Rocks and walk towards the **Alderley Reservoir,** observing the nature of the mappable WSF/HSF junction. Discuss the sediments of structures once seen (1910) in the reservoir excavation.

5. Identify and seek the location of **an un-named exploratory adit** in the WSF. (Figs, p. 5).

6. **Alderley Beacon**. WSF nearby and loose blocks of mineralised HSF form the mound.

7. Walk NE to an **un-named quarry**. Distinguish WSF(?) or HSF(?) and hypothesise the structure of the area. Revise the map, Figs p. 5.

8. Travel northwards for 75m to **the Holy Wells**. WSF overlain by HSF (EVCM) with a strong basal mudstone. Mineralisation. The Holy Well fault? as the possible continuation of the fault of the Cobalt Mine to the south. Revise the map Figs, p. 5. The rock fall of 1740.

9. Clamber steeply down and then up-hill to **Twin Shafts** on the WNW trending Stormy Point mineralised fault zone. WSF beneath HSF (EVCM). Mine spoil.

10. Follow the Stormy Point Fault eastwards, observing changes of structure and sediments (WSF & HSF (EVCM)) across **Stormy Point**. Mine spoil. See the locality from which sedimentary micas were collected for age dating (Fitch, Miller, Thompson 1966). See the detailed map, Figs p. 4.

11. If time permits, traverse rapidly northwards across **Glaze Hill** to **Saddlebole** (a smelter hearth?) to locate an outlier of HSF (EVCM) on WSF (and revise the map, Figs p.5). See the need for the WNW Edge Fault. Observe the ? mine trials. Return to Stormy Point.

12. Continue eastwards along the Stormy Point Fault to mineralised **Doc Mine** (WSF overlain by HSF (EVCM)) and **Pillar Mine** (in WSF alone). The best and most abundant mine spoil. (See Figs pp. 4-5). Locate the **entrance to the Hough Level,** cut in the 18thC and underlying most of the mined area of the horst.

13. Walk southwards across the **Opencast Canyon** (WNW mineralised fault), passing through **Old Alderley Quarry.** Water fleas (Euestherias) found by C.E. De Rance in the late 19thC; Brockbank 1891) and **close by the North Engine Vein Quarry.** All this area is developed in HSF (EVCM) which is repeatedly uplifted on the southern sides of the many faults. (Figs, p.5 and the cross-section on p. 11).

14. Reach **Engine Vein Mine** (scarcely a vein but an area of sandstones (WSF & HSF) impregnated by Cu, Pb, Zn, Fe, Co, Ni mineralisation). (See Figs, pp.10-13). Analyse the openworks in the HSF (EVCM) and locate the places where Warrington (1963) found two horizons of Euestheria minuta var. Brodieana and plant spores. Locate Bronze age mining pits, a copper smelting site dated 2000 and 1800-1600 B.C. by radiocarbon, a Roman shaft with wood dated A.D. 5 & 75 and coins c.330-340 A.D. It is reccomended that on a future occasion - a public Open Day - members should permit themselves a short visit into the stopes and former opencast area of the Mine by courtesy of the Derbyshire Caving Club (Stephen Mills and Doug Kidd are suggested as suitable leaders). Such a visit would locate: (i) the fault zone and its galena impregnations; (ii) the WSF (fluvial cross-bedded ripple-marked mudcracked horizons as well as aeolian horizons; (iii) the basal

mudstone of the HSF with azurite spheres; (iv) the pebbly HSF with pods of Galena and Cu-Fe-Co-Ni sulphides; (v) Roman and subsequent shafts.

15. Walk WNW along the Engine Vein Fault to **near Beacon Lodge** and locate the thin aeolian Beacon Lodge Sandstone Member of the HSF (12m thick in the Hayman's Farm borehole to the south of the area) alongside an adit.(Figs, p.5).

16. Traverse across a ridge to overlook and then enter **Church Quarry** which displays the lowest units of the Wood Mine Conglomerate Member of the HSF (c.40m thick and comprising c.10 fluvial cycles). A large copper mine was developed in these rocks in the area to the south of the Alderley-Macclesfield Road (see Figs, p.5).

17. Walk past the **Wizard Inn** to locate the main shaft/headworks of the former well developed in the waters of the Cobalt Mine. Pass on to see the main entrance shaft of the Cobalt Mine close to the entrance to the car park. The mine operated 1806-17 (Bakewell 1813). It is developed largely along a NNW trending fault (? the Holy Well Fault which crosses Engine Vein) which has little expression on the ground. It continues south into Finlow's Wood.(Figs, p.5).

18. If time permits, walk down **Artists Lane,** turning into **Cow Lane** and **Brynlow Dell** to locate the smash zone of a WNW fault possibly **the Southern Boundary Fault** of Wood Mine around the site of the ponds, and and a parallel fault - **the Brynlow Fault** - to the south of the latter which lies in a visible fault complex. (Figs, p.5 & 12).

19. Walk down **Brynlow Dell** identifying the incidence of drainage adits and mine trials on both south and north and the presence in the cliffs of the partly aeolian West Mine Sandstone Member (WMSM) of the HSF (c. 17m thick). These beds are likely to be the lateral equivalent of the thicker more spectacular Frodsham Sandstone Member which is present across the whole of north and central Cheshire and much of the East Irish Sea Basin. (Figs, pp.4,5,13).

20. Climb out onto **Artists' Lane**, identifying the top of the WMSM and the base of the Nether Alderley Sandstone Member (NASM) of the HSF (here represented by the Brynlow Conglomerate Bed) (Figs, p.5). This is a finer and more argillaceous member which, with the impersistent mudstone bands in the more porous rocks below, begins to form the upwards regional seal of the former hydrocarbon and mineral trap within the Alderley Horst. (Figs, pp.3,13).(Figs, p.3,13).

21. If time permits walk WSW down past the **Brynlow and Topps Quarries** of the NASM (Figs, p.5), turning northwards to cross the south of Wood Mine (p.12) and the eastern parts of West Mine and the As-rich minespoil of the latter. Retrace one's steps to the car park, having walked over the top of the north part of Wood Mine (p.12) and the sites of the major copper, lead, cobalt processing works of the period 1860-75. (Figs, p.13).

DBT

(1)

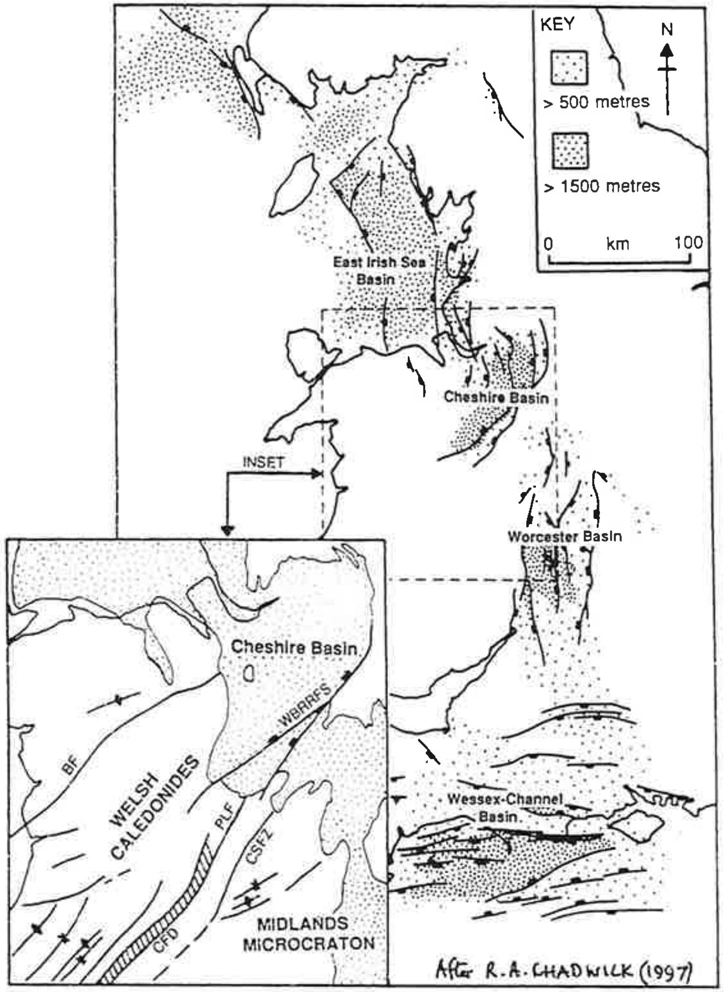
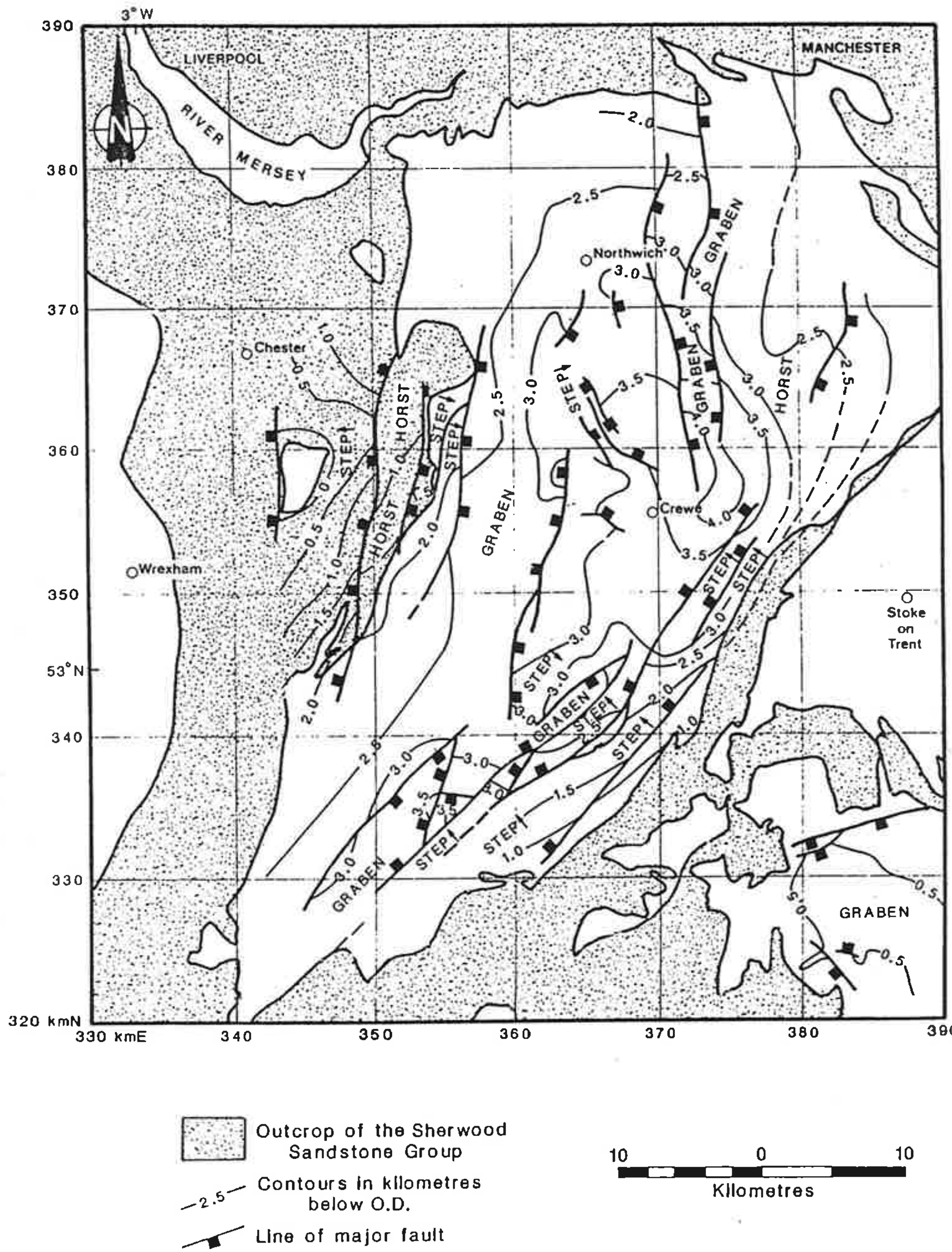


Fig. 1. The Permo-Triassic rift basins of southern Britain (stipple ornament denotes thickness of preserved Permo-Triassic strata). Inset shows Cheshire Basin in relation to outcropping basement structures. BF, Bala Fault; PLF, Pontesford–Linley Fault; CFD, Clun Forest Disturbance; CSFZ, Church Stretton Fault Zone; WBRRFS, Wem–Bridgemere–Red Rock Fault System.

Figure 5E Structure contour map of the base of the Permo-Triassic in the Cheshire Basin (after Gale et al 1984)



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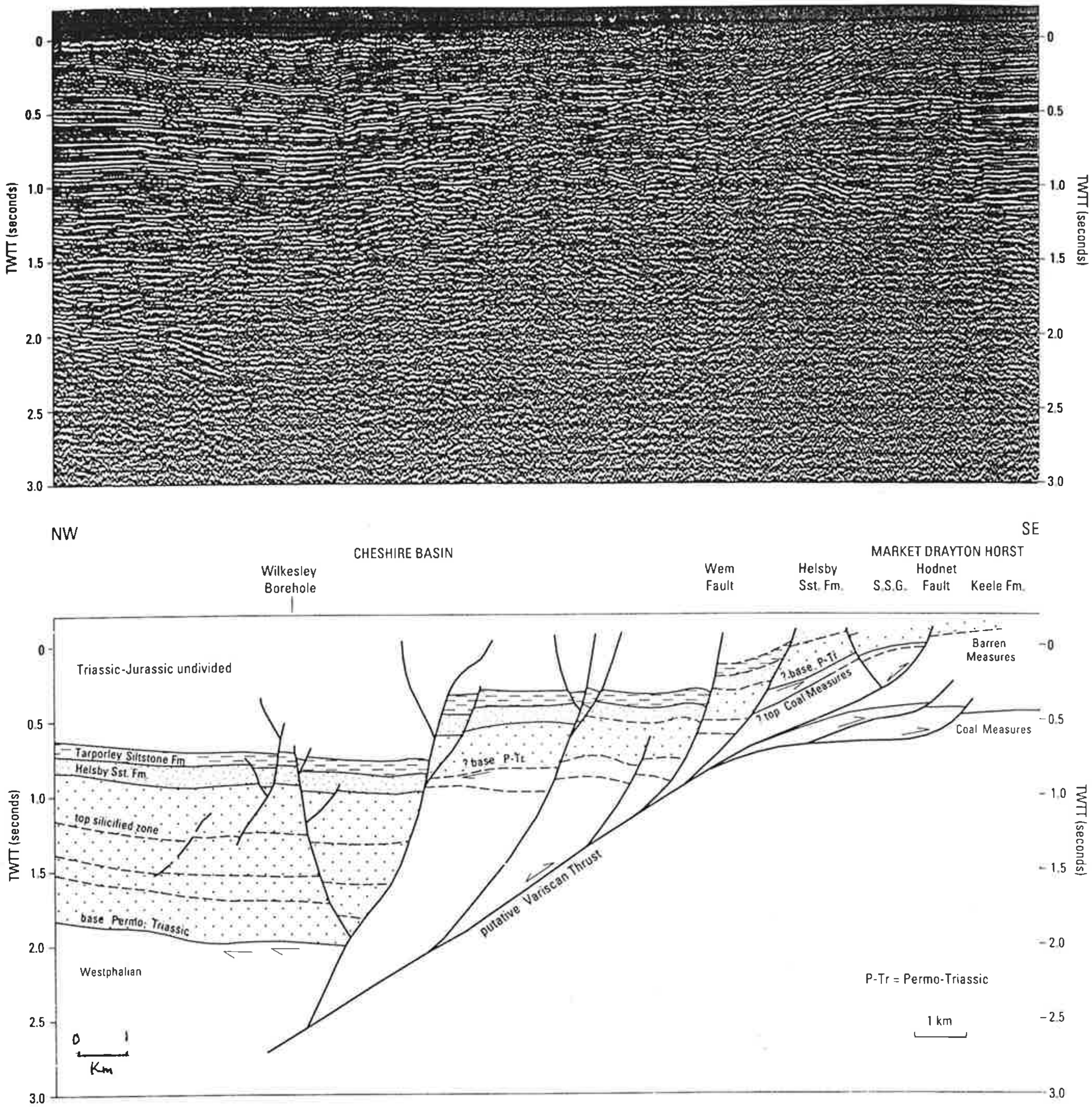


Fig. 9. Seismic reflection line and line drawing illustrating the nature of the eastern margin of the Cheshire Basin onto the Market Drayton horst. Syn-sedimentary normal faults of Permo-Triassic age developed as a result of, and detach onto, a putative re-actived Variscan compressional structure (thrust). Note in this area, the major thickening of the Sherwood Sandstone Group and Permian formations appears to occur across a fault (the Bridgemere fault; Rees & Wilson pers. comm.) to the west of the Wem fault. (After Evans et al 1993)

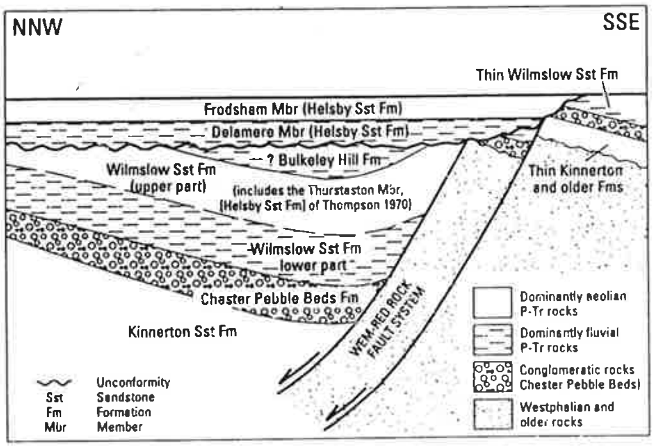
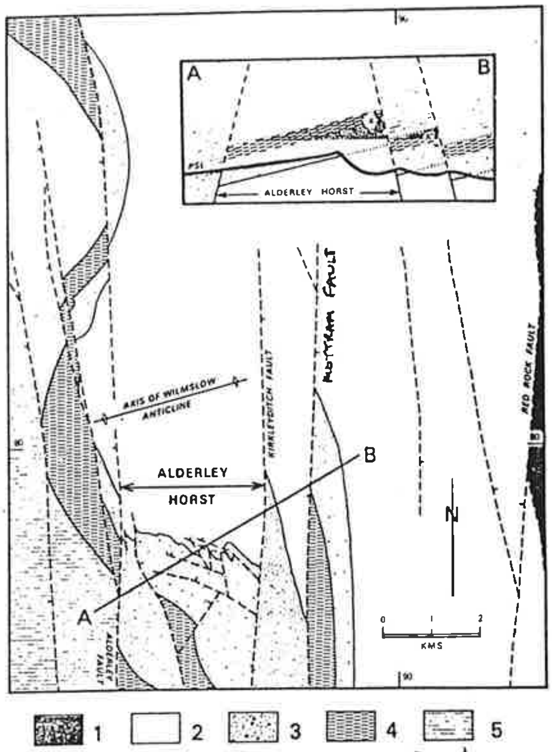


Fig. 10. Interpretive sketch section illustrating the relationship of strata to the intra-Triassic unconformity recognized in the seismic reflection data. (After Evans et al 1993).



(From Warrington 1980b)

Fig.1 Outline structure and solid geology of the Alderley area (based, with permission, upon Institute of Geological Sciences 1:50000 Sheet 98, Stockport; 1977).
Key to ornament: 1 - Carboniferous, 2 - Bunter, 3 - Keuper Sandstone, 4 - Waterstones, 5 - Keuper Marl.
Inset: schematic section, on line A - B on the geological map, showing potential structural traps for hydrocarbons and other fluids beneath a cap-rock of Keuper Marl (See appendix 1 for recent changes in the names of 2 to 5) in the Alderley horst (X) and an adjacent faulted block (x[1]); PSL - present surface level (shown by thick line), all features in the section above that level have been removed by erosion and are projected from the geological map.

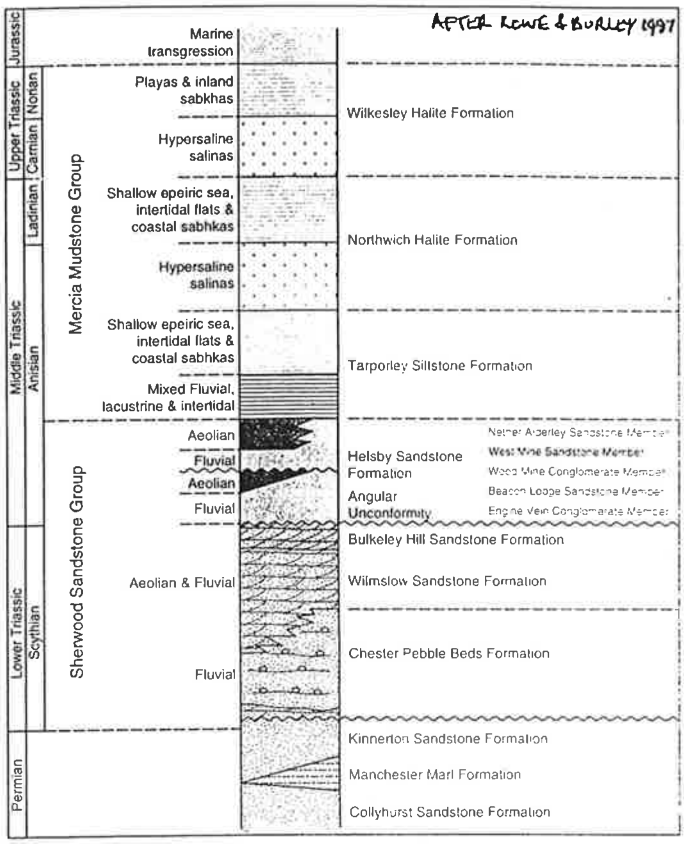


Fig. 2. The stratigraphy and interpreted depositional environments of the Permo-Triassic succession in the northeast of the Cheshire Basin (based on Evans *et al.* 1993, Thompson 1970, 1985, 1991, Warrington and Thompson 1971). The local sub-divisions of the Helsby Sandstone Formation at Alderley Edge are indicated.

Period	Stage	Group	Former nomenclature 1860 – 1980		Formations and members with thicknesses & abbreviations used in the text: Cheshire Basin generally	Alderley – Styal area	Sedimentology and palaeoenvironment
JURASSIC					LOWER & MIDDLE LIASSIC-Jur. c.600 m	Eroded	Shallow marine
TRIASSIC	Rhaetian	Penarth	RHAETIC BEDS			Eroded	Shallow marine, evaporitic in part
TRIASSIC	NORIAN	MERCIA MUDST GROUP MMG	UPPER KEUPER MARL	KEUPER	UNNAMED MUDSTONE FM c.300 m	Eroded	Hypersaline, lagoonal, Sabka, continental
TRIASSIC	CARNIAN	MERCIA MUDST GROUP MMG	UPPER KEUPER Saliferous Beds	KEUPER	WILKESLEY HALITE FM c.400 m	Eroded	Salinas with marine feed
TRIASSIC	LADINIAN CARNIAN	MERCIA MUDST GROUP MMG	MIDDLE KEUPER MARL	KEUPER	UNNAMED MUDSTONE FM c.400 m	Eroded	Hypersaline, lagoonal, continental
TRIASSIC	LADINIAN ANISIAN	MERCIA MUDST GROUP MMG	LOWER KEUPER Saliferous Beds	KEUPER	NORTHWICH HALITE FM c.300 m	? Solution breccia	Salinas with marine feed
TRIASSIC	ANISIAN	MERCIA MUDST GROUP MMG	LOWER KEUPER MARL	KEUPER	UNNAMED MUDSTONE FM c.300 m	UNNAMED MUDSTONE FM	Hypersaline, lagoonal, continental
TRIASSIC	ANISIAN	MERCIA MUDST GROUP MMG	WATERSTONES	KEUPER	TARPORLEY SILTSTONE FM. TSF c.120 m	TARPORLEY SILTSTONE FM. TSF c.120 m	Fluvial, intertidal, marine, hypersaline, lagoonal
TRIASSIC	SCYTHIAN	THE SHERWOOD SANDSTONE GROUP	LOWER KEUPER SANDSTONE	KEUPER	HELSBY SANDSTONE FM. HSF 100 - 150 m; Frodsham Soft Sst Mbr FSSM c. 30 m; Delamere Pebbly Sandstone Member. DPSM c. 30 m; Thurstaston Soft Sst. Mbr. TSSM c. 30 m with Thurstaston Hard Sst. at base c. 3 m	HELSBY SANDSTONE FM HSF c.132 m; Nether Alderley Sst. Mbr NASM c. 38 m with Brynlow Conglom. at base c. 3 m	Fluvial moderate sinuosity
						West Mine Sandstone Mbr. WMSM c.17 m	Aeolian dominates fluvial
						Wood Mine Conglom. Mbr WMCM c. 40 m	Fluvial, low sinuosity
						Beacon Lodge Sst. Mbr 12 m	Aeolian dominates fluvial
						Engine Vein Conglom Mbr. EVCM 30 m	Fluvial; low-sinuosity, ephemeral
TRIASSIC	SCYTHIAN	THE SHERWOOD SANDSTONE GROUP	BUNTER UPPER MOTTLED SANDSTONE	BUNTER	WILMSLOW SST FM WSF c 300 m	WILMSLOW SST. FM WSF c 300 m	Aeolian dominates fluvial at top; Aeolian-fluvial; Fluvial dominates aeolian at base
?	SCYTHIAN	THE SHERWOOD SANDSTONE GROUP	BUNTER PEBBLE BEDS	BUNTER	CHESTER PEBBLE BED FM. CPBF c 200 m	CHESTER PEBBLE BED FM CPBF c 200 m	Fluvial, low-sinuosity, braided, very high discharges
PERMIAN Upper	ZECHSTEIN 1 & ?2		MANCHESTER MARL	BUNTER	MANCHESTER MARL FM in the north 0-100 m; KINNERTON AND COLLYHURST SANDSTONE FM IN THE NORTH = BRIDGNORTH SST. IN THE SOUTH c 350 m	STOCKPORT & MANCHESTER MARLS 40-100 m	Marine with dwarfed restricted fauna, salinas with marine feed some intertidal; Aeolian inland sand
PERMIAN Lower			BUNTER LOWER MOTTLED SANDSTONE FM	BUNTER		COLLYHURST SANDSTONE FM 150-275 m	Sea with dunes draa and dry interdunes

Table 4
Stratigraphy and sedimentology of the Cheshire Basin:
(after Thompson, 1966b, 1970a, Warrington & Thompson, 1971, and Warrington, *et al.* 1980)

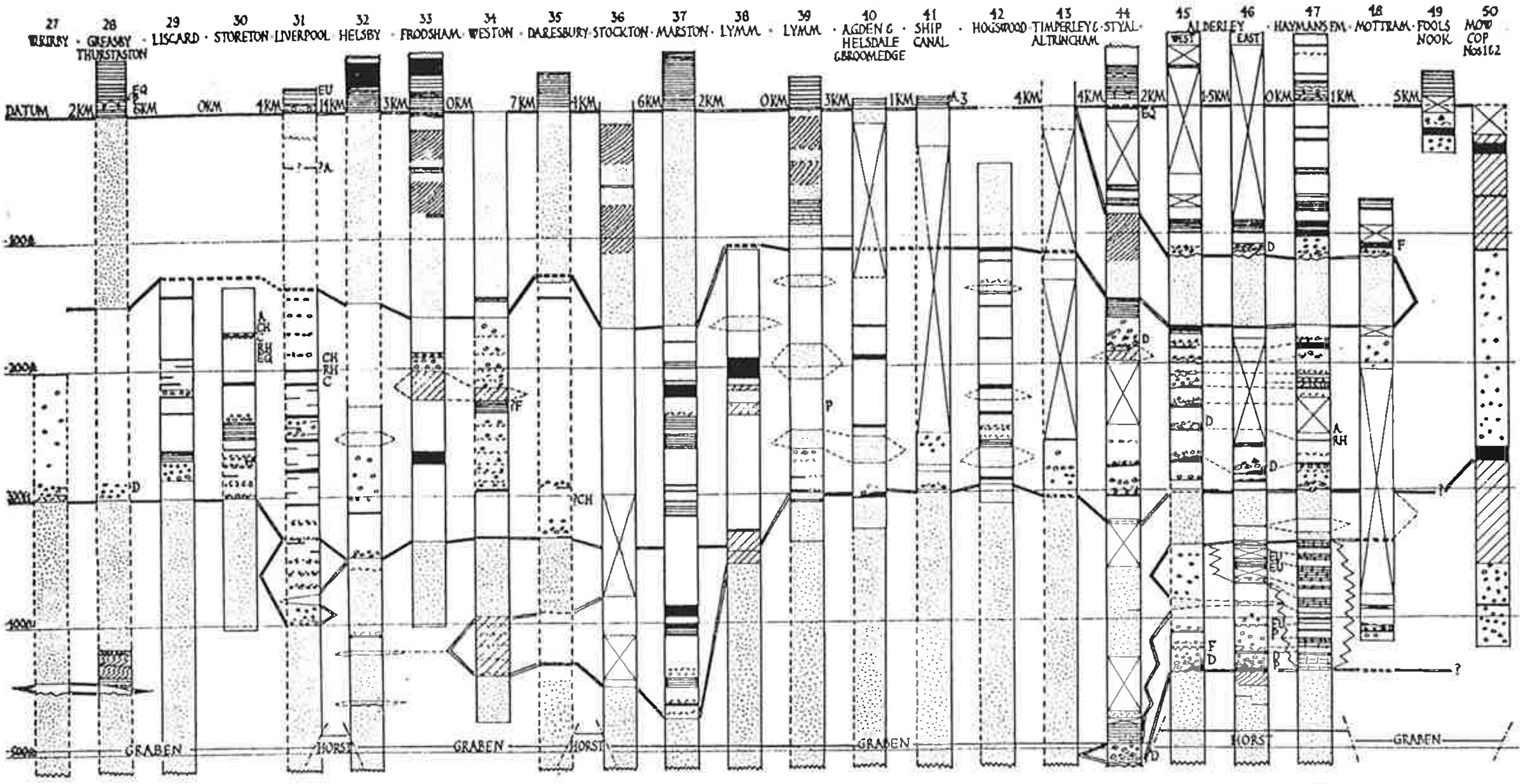


FIG. 5. Correlation diagram for the ~~Keuper~~ HELSBY Sandstone Formation. The numbers placed before localities are utilized in Figs. 3, 6, and 7. Doubt about the correct identification of a facies indicated by cross-hatching.

(27) West Kirby. From Morton (1891) and Rice (1938, 1939A, B). Data in outline only.

(28) Greasby. From Morton (1891), but especially Rice (1938, 1939A, B) and Wedd *et al.* (1923). Interpolation of data from Thurstaston by the author. Data in outline only. (From Thompson 1970 a).

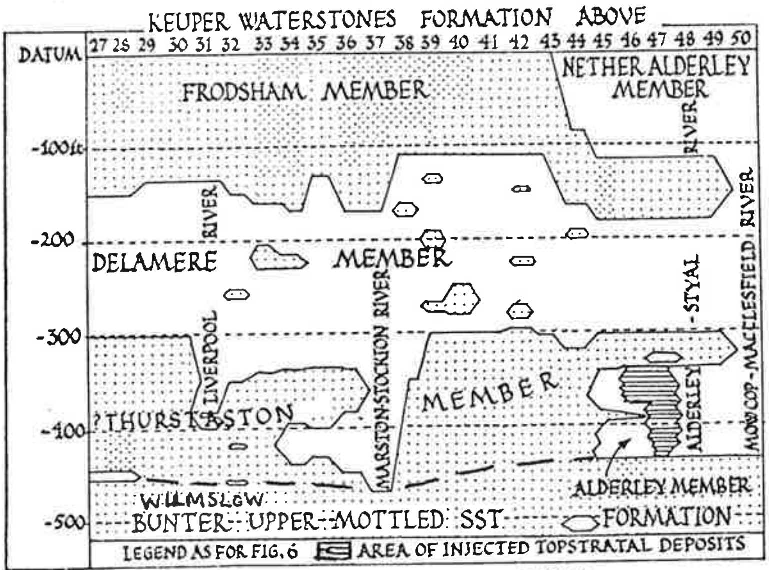
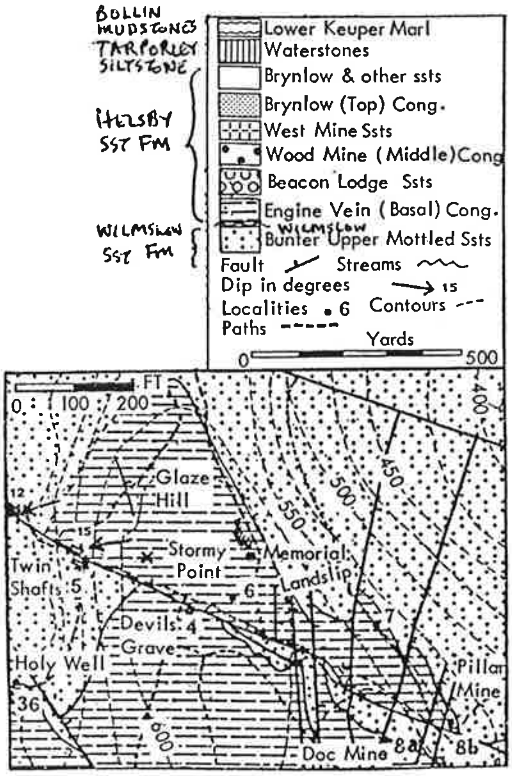


FIG. 6. Outline environmental interpretation of the ~~Keuper~~ HELSBY Sandstone Formation defined in Fig 5 with names of Members proposed in this paper. Names of local groups of beds, e.g. in the Alderley Succession, Engine Vein Conglomerate, Beacon Lodge Sandstones, Wood Mine Conglomerates, West Mine Sandstones in the Keuper Sandstone Formation; Finlows Sandstone in the Keuper Waterstones Formation (Warrington 1965; Thompson, thesis, 1966), are necessary for local description and mapping, but are not included here. For ease of drafting, full names of Members defined are not given, but are included in Table 1.

KEY: FLUVIAL   FLUVIAL & AEOLIAN + UNDETERMINED   AEOLIAN



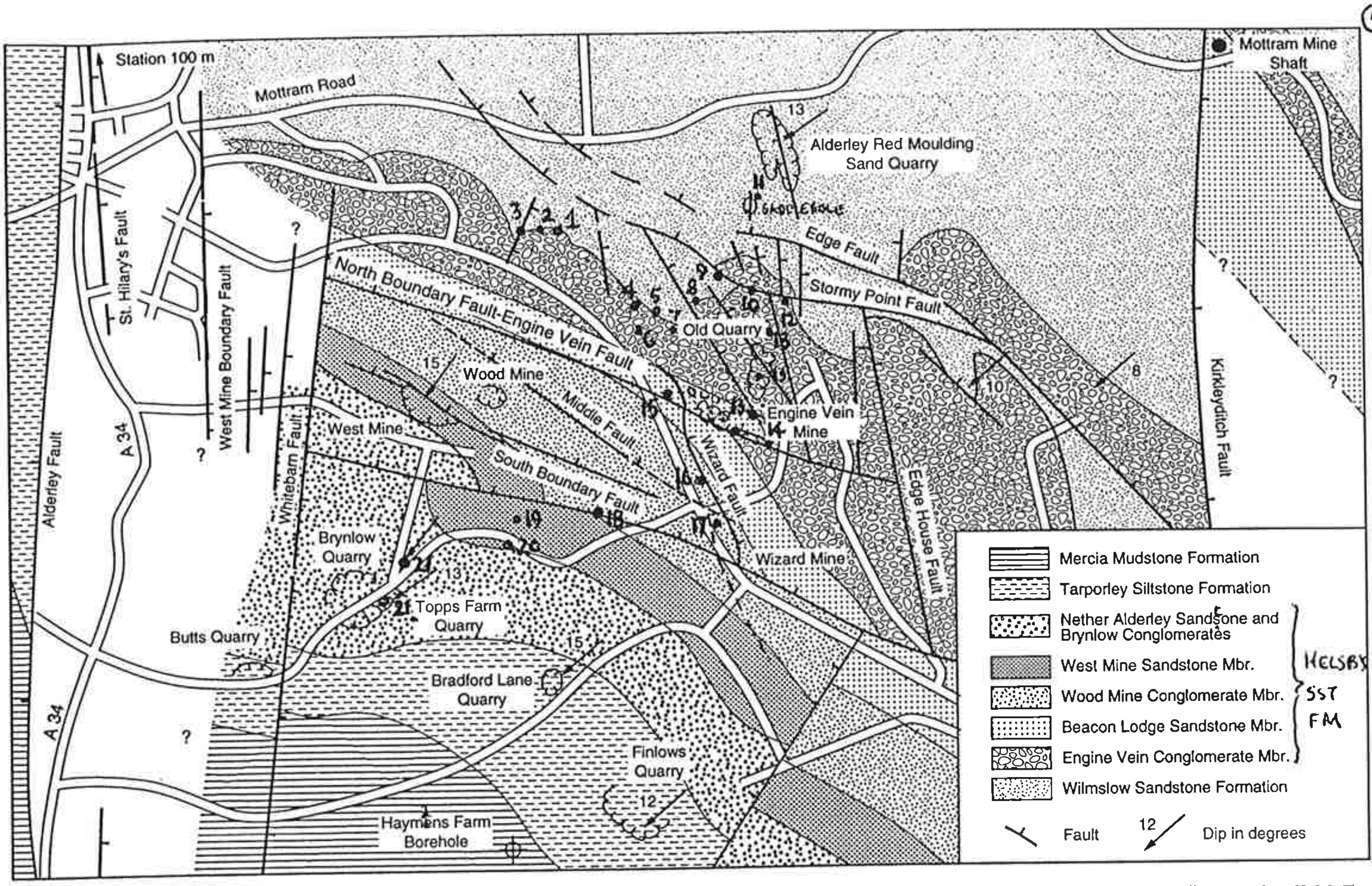
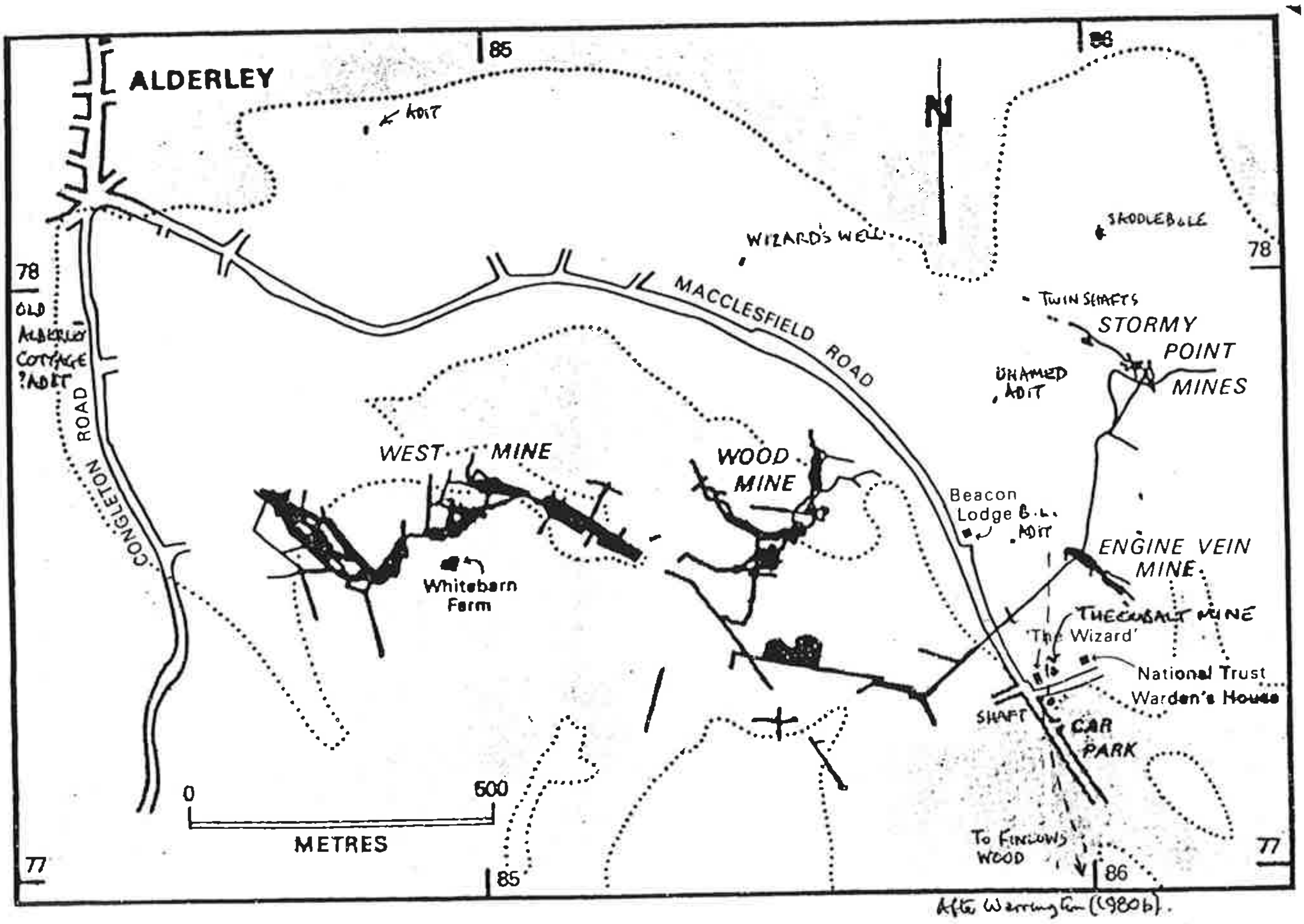


Fig. 3. Geological map of the Alderley Edge area detailing the location of faults and mine workings mentioned in the text (based on the BGS 1:10560 6" maps of D. F. M. Trotter and Thompson 1970, 1991, with modifications and additions). (After Rowe & Burley 1997) Locations to be visited are ringed.



After Warrington (1980b).

Fig. 2. Distribution of known mine workings at Alderley Edge (based upon Warrington, 1965) in relation to principal roads and other relevant surface features and to the areas of solid outcrop and of masking superficial deposits; mine workings shown in full black, margin of areas of solid outcrop dotted and areas masked by superficial deposits shaded.

(6)

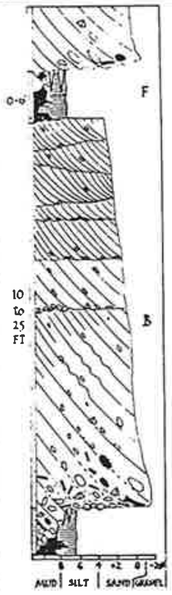
RARE VARIANTS	SEDIMENTS, STRUCTURES, ORGANISATION TYPE FEATURES	MAIN FACTS	FOSSILS	INTERPRETATION
		Channeling.		
Syneresis cracks, ripple marks small-scale cross strata, erosion channels. Some bands rubbly: some eroded with isolated posts only extant. Possible to detect initial dip at times.		Red micaceous laminated or blocky well-sorted or poorly-sorted silty mudstones often with mudcracks. Bands lensing or wide-spread.	Drifted or indigenous Euestherias.	VERTICAL ACCRETION DEPOSITS OF THE TOPSTRATUM within low sinuosity river plain. Low flow ripple bedded and tranquil flow laminated sediments deposited in upstream and downstream cut off channels, swales after high stage. Period of exposure and dessication allows mudcracks and ? dreikanter to form. Some bands extend across whole riverplain. Soil profiles develop in sand ?
		Sharp flat upper surface: at times irregular.		Relatively sudden cessation of flood and bed load traction.
Ripple mark of linguoid type at top of coset. Trough cross-strata: grouped. Intraset crossbeds and argillaceous bottomsets in BPB. Traces of laminated or rubbly 'marl' between sets. Hetero-lithic foresets. Lenses of pebbles on erosion planes. Some deep channeling within the coset. Some cycles of only one set. Lower parts at times non-bedded: some beds of loosely cemented conglomerate. Structureless sandstone over flute casts. $CaCO_3$, SiO_2, Fe_2O_3 cemented bands and nodules.		Red,? secondarily buff or grey coarse to medium grained angular, ill-sorted sandstone, pebbly sandstone or rare con-glomerate. Intraformational mudstone and siltstone galls, mudballs, armoured mudballs, especially at the base. Rolled dreikanter. Trough to lenticular planar large scale sets of cross-strata are ubiquitous. Foresets poorly defined and thicker at base, well defined and often laminated at the top. Set thickness often, but not always, decreases upwards: grain size likewise. Extraformational pebbles: disc and spheroid shape: of quartz, quartzite, porphyry, felsite, tuff, chert, sandstone, mudstone. Fe_2O_3 and SiO_2 cement.	Derived corals, crinoids, algae. (Carboniferous) ?Drifted plants.	CHANNEL FILL OF DOWNSTREAM AND LATERAL ACCRETION DEPOSITS. Lateral and vertical scour in sand and gravel gives rise to building of channel bars and point or lateral bars which are built of more or less lunate mega-ripples which migrate across the bar surface. Sand and pebbles travel as bedload, fine sand, silt and clay by-pass. Occasional lag surfaces develop on top of bars. Local channels cut through the bars by shift of the anabranches of low sinuosity braided streams. Rare flow across the foresets: surges of flow may deform sets: high flow may lead to loss of definition of bedding. Flow generally in upper low flow regime. The flood tears vegetation from place: the 'marl' of swales, cut-off channels, and the topstratum, ripped up and carried in bedload, being swiftly buried, rounded or picking up pebbles as armour.
Channeling into the surface below: terraced margins: flute brush, prod, groove, pot hole marks. Corrasion furrows.		Scoured surface. Erosion surface cut in hydroplastic under-surface.	Chirotheroid, Rhynchosauroid Chelonoid footprints	Erosion by high flow regime currents across whole plain. Erosion greatest where current centered in channels. Flow through swale fill cut off channels at high stage cuts sole structures in hydroplastic deposits, which may have been trodden by early reptiles.

Fig. 7. The miocycle B'BF in BPB and LKS. Erosion of F, as at the base, would result in a cycle B'B.

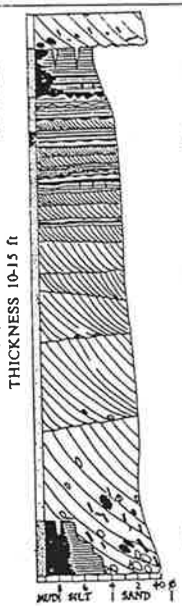
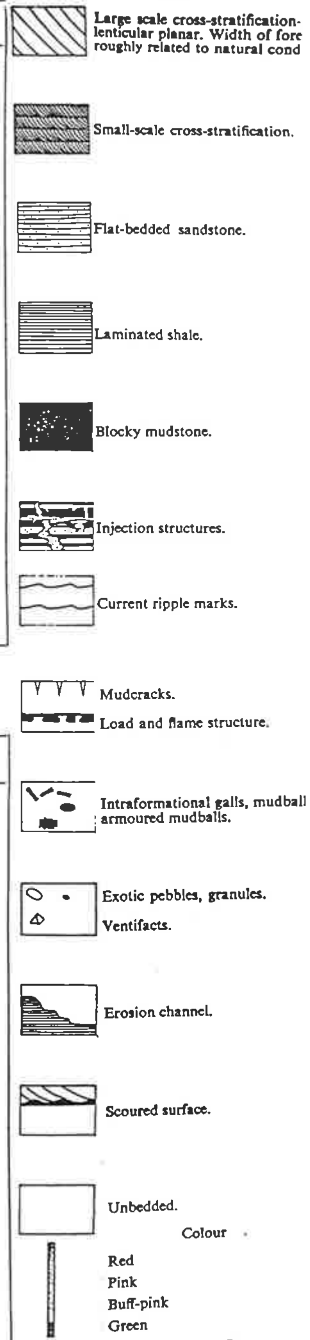
RARE VARIANTS	SEDIMENTS, STRUCTURES, ORGANISATION TYPE FEATURES FACIES	MAIN FACTS	FOSSILS	INTERPRETATION
		Scoured surface		
Symmetrical, asymmetrical, interference and flat-topped ripplemarks. Load-flame structures, convolution. Injection structures. Intraformational faulting. Slump structure. Wavy laminae-in-phase. Sole marks. Channel cut and fill. Mudcracks, mudcurls. Rainprints. Marl draped against foresets. Thin gravel bands. Geodes with calcite.		Deep chocolate red occasionally green laminated or occasionally blocky interlaminated shale, mudstone, siltstone and fine-grained sandstone. Flat bedding and ripple bedding. Occasional thin coarse sandstones with pebbles and galls. Mica common. Inter-granular clay (illite, kaolinite) and sericite. Red and green galls.	Footprints: Rhynchosauroides spp. Chirotherium spp. ? Chelonia Euestheriae Tracks of ? gastropods, worms, ? arthropods. Worm casts, burrows. Voltzia, Equisetales, Dictyophyllum	FLUVIAL RIVERPLAIN TOPSTRATUM. Mainly VERTICAL ACCRETION DEPOSITS following high stage overbank flood. Cessation of floods less sudden than in case of ABF. BF type cycle. Dessication is known, but generally tranquil flow conditions dominate and alternate with low flow ripple-inducing currents. Possible that rivers are now more meandering and less braided. During drier periods semi-aquatic reptiles scutter across muddy surface, and burrow for food. Worms and gastropods graze and wander across the levees. Areas with stands of conifers, horse-tails, possibly ferns.
Grouped sets of trough cross-bedding: deformed cross-bedding: elastic and fluid. Lenses of white calcite cement.		Pink-red micaceous fine and medium grained sandstone tending towards coarse sandstone at base. Intraformational clasts, galls, mudballs. Occasional pebbles at base. Mica common at some horizons. Fe_2O_3 and SiO_2 cement.		CHANNEL FILL AND LATERAL ACCRETION DEPOSITS: building of bars and migration of megaripples in upper low flow regime. Fluctuating strong currents, for short periods in the high flow regime at the base, otherwise steady flow of diminish-ing strength and depth of water. Bed load material becomes finer with time, but rare lag gravels at base.
Mudballs. Armoured mudballs. Rolled ventifacts. Lag gravel, thin and very rare. Groove and prod marks.		Channels. Scoured surface.		Stream cuts through vertical accretion deposits after shifting channel or cutting laterally: in places scours hydroplastic sediment surface.

Fig. 8. The miocycle of the type BCDF, BCD, CDF which is present in the upper LKS.

(From Thompson 1970 b)



(6)

6B

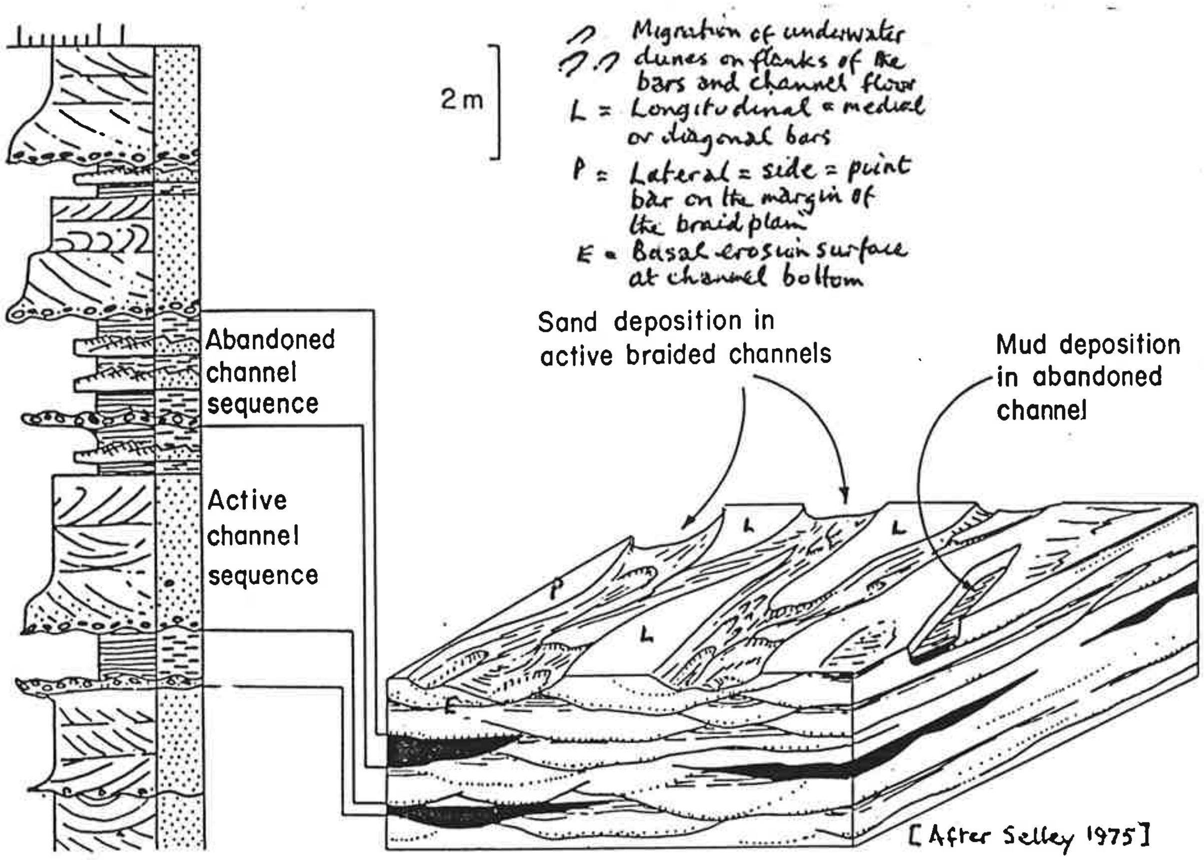


Fig. 101. Physiography and facies of a braided alluvial channel system. Sedimentation occurs almost entirely in the rapidly shifting complex of channels. Silts are rarely deposited in abandoned channels. A flood plain is absent.

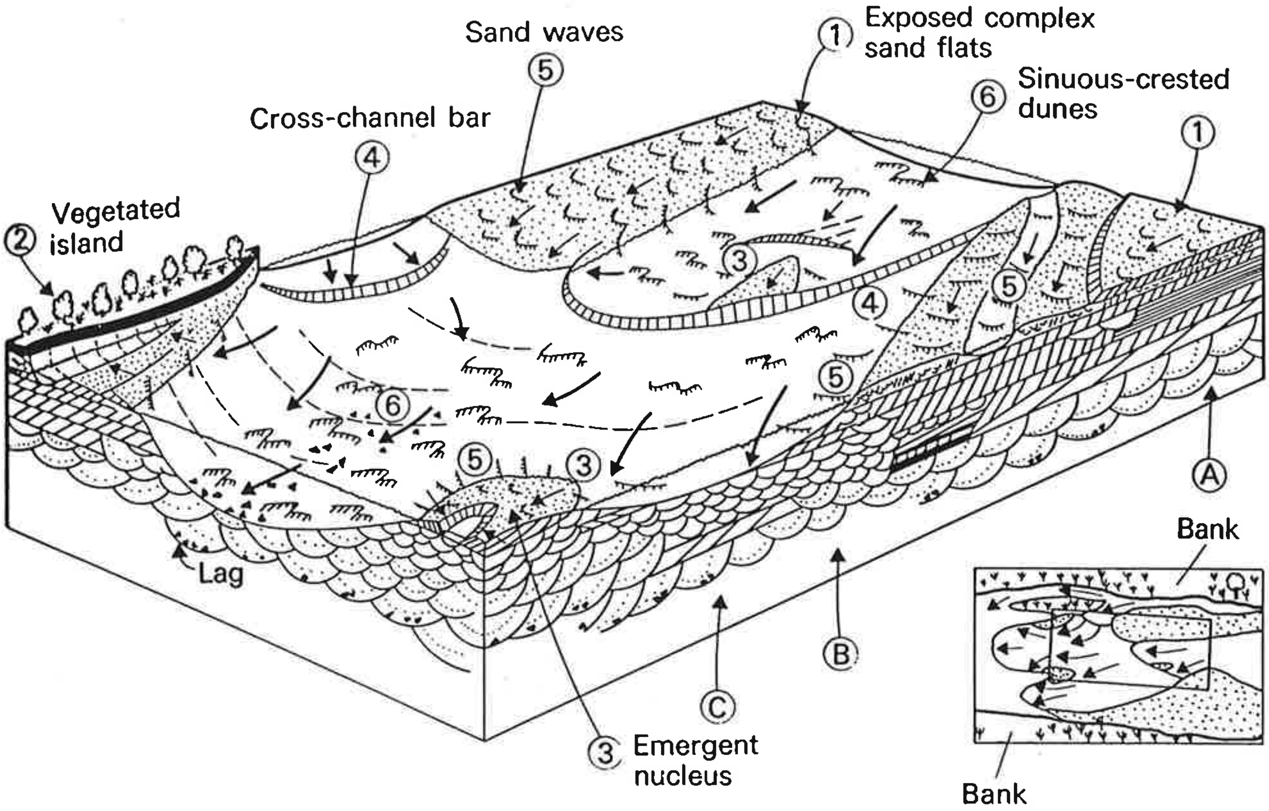


Fig. 3.10. Composite block diagram of the major morphological elements of the South Saskatchewan River, Canada, showing the predicted sequences of internal structure generated in different parts of the channel. Numbers refer to various examples of the same feature. A is the sequence typical of a major sandflat, B is transitional and C is the sequence generated by a channel setting. Inset shows the variations in direction of local flow and in the orientation of cross-channel bars (after CANT & WALKER 1978).

Figure 22. Field diagram of channel fill at Castle Rocks, Alderley Edge. (After Thompson 1985)

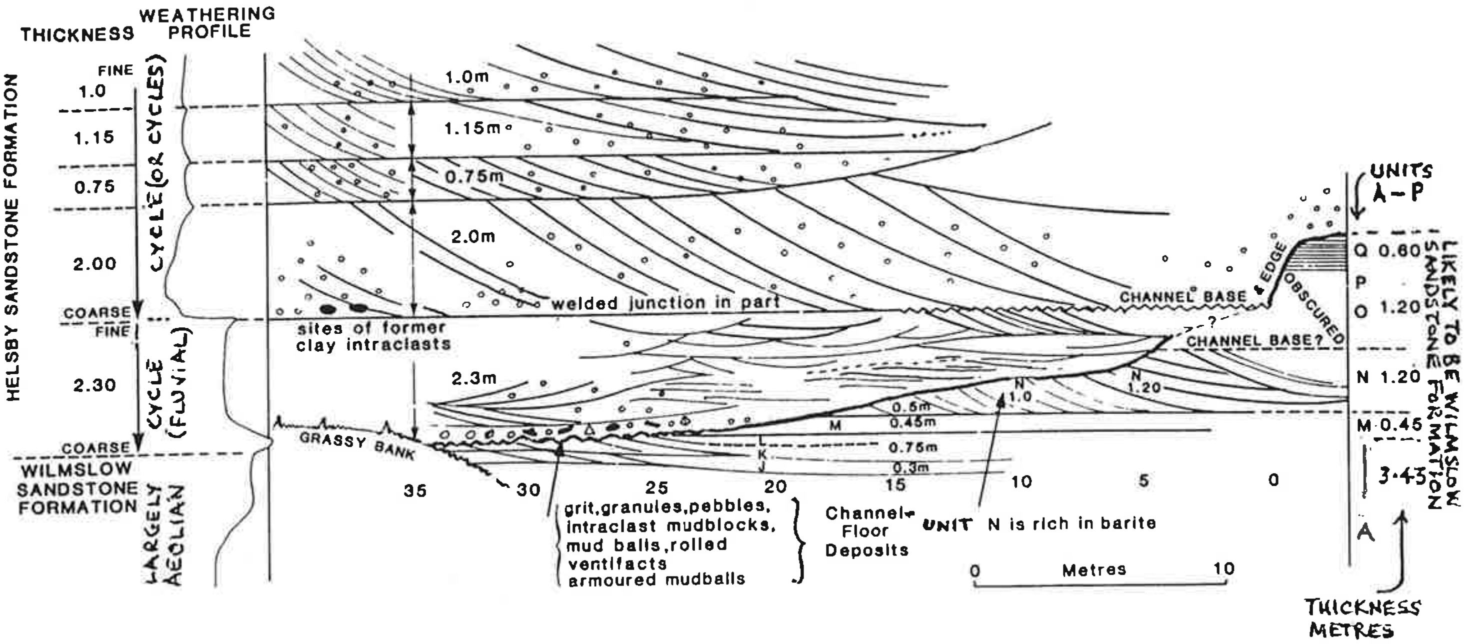


Figure 21. Graphic log of Wilmslow Sandstone and Helsby Sandstone junction at Castle Rocks, Alderley Edge. (After Thompson 1985)

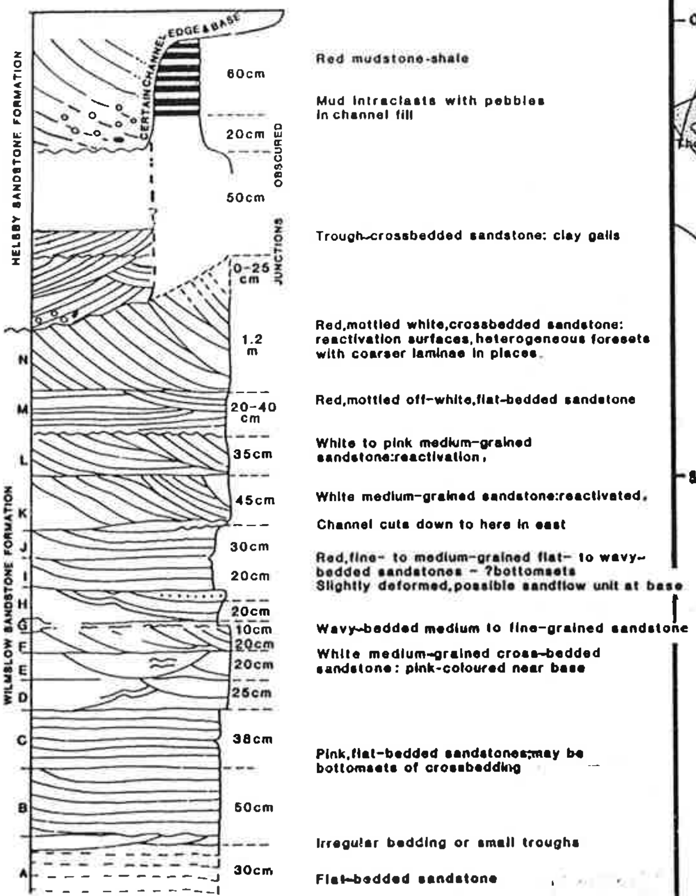
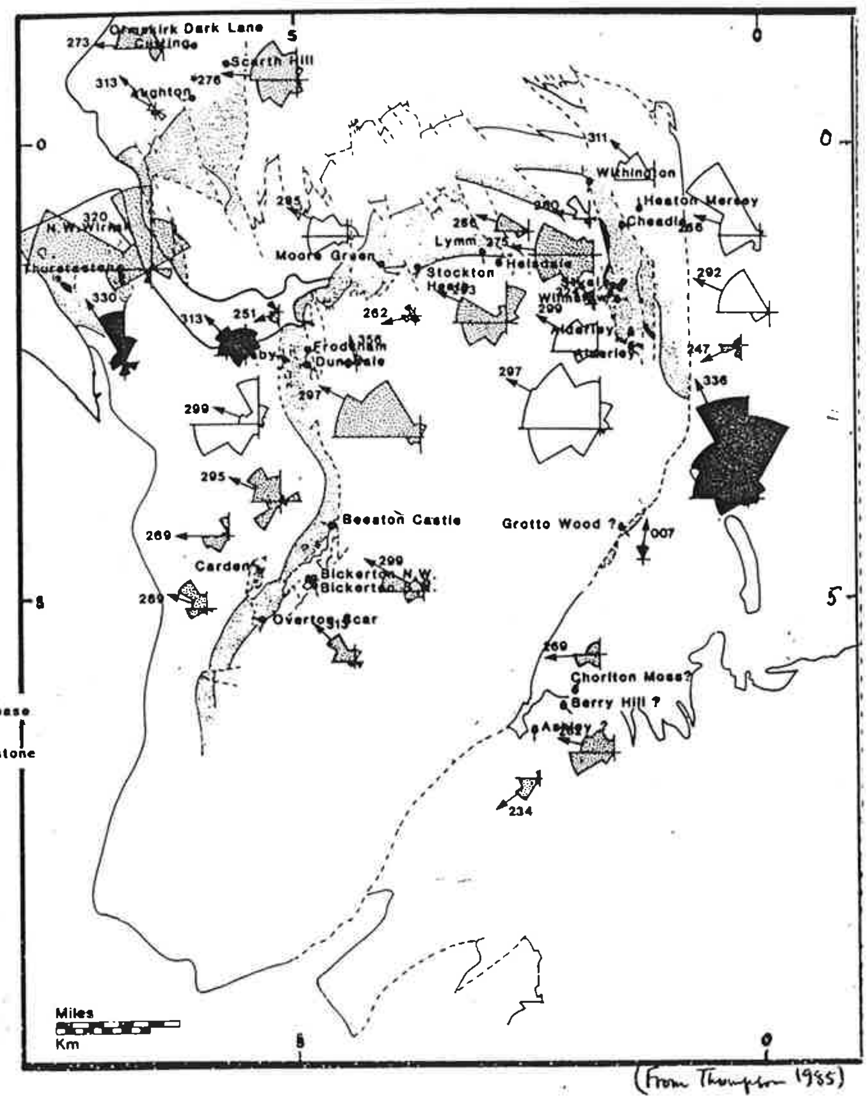


Fig. 9. Palaeocurrents: Wilmslow Sandstone Formation and Helsby Formation (part).



OUTCROP & DATA OF ALDERLEY CONGLOMERATE MEMBER (LKS)

OUTCROP OF THURSTASTON MEMBER (UMS & LKS)

PALAEOCURRENT DATA OF WILMSLOW SANDSTONE (UMS)

234 VECTOR MEAN

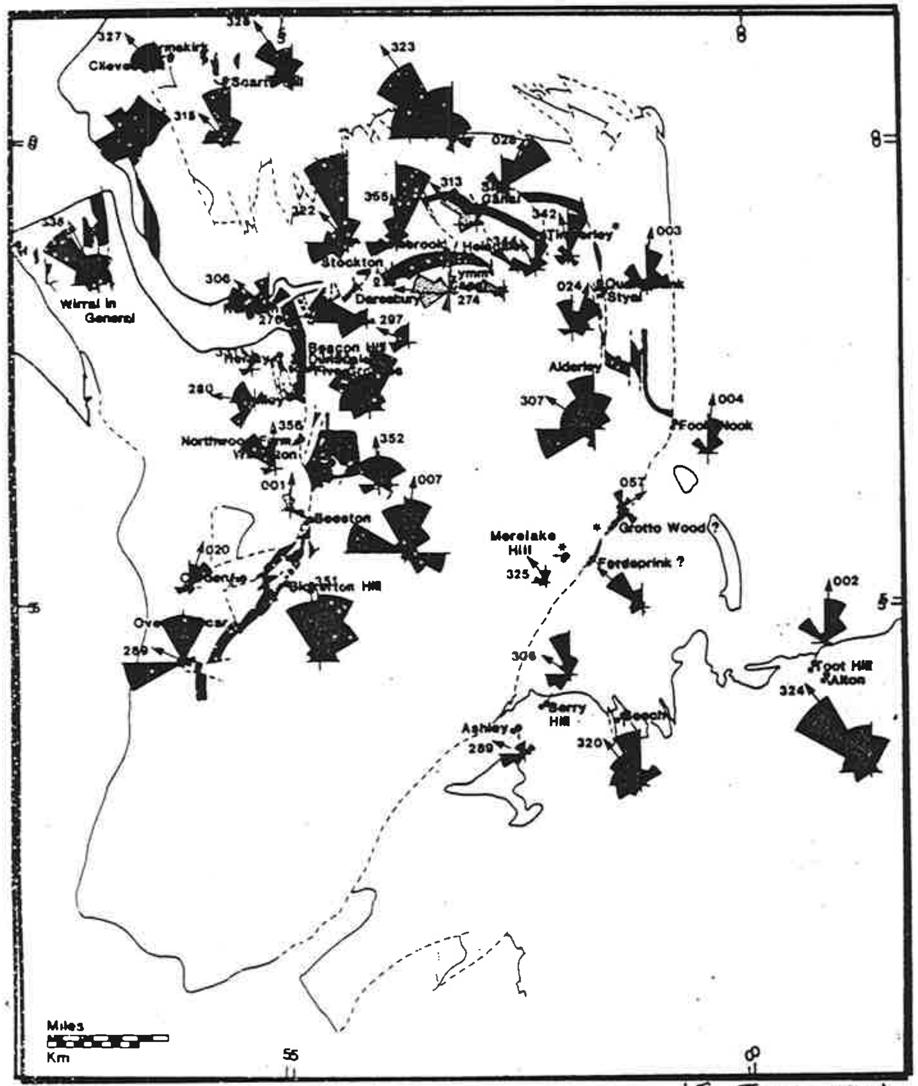
EDGE OF BASINS

FAULTS

(UMS) UPPER MOTTLED SANDSTONE (BUNTER) (LKS) LOWER KEUPER SANDSTONE

• Statistics for the vector mean not significant at the 95% level.

Figure 10. Palaeocurrents: Helsby Sandstone Formation.



(From Thompson 1985)

OUTCROP OF DELAMERE PEBBLY SANDSTONE MEMBER (PALAEOCURRENT DATA)

PALAEOCURRENT DATA FOR INTERBEDDED SOFT SANDSTONE

* Statistics for the vector mean not significant at the 95% level.

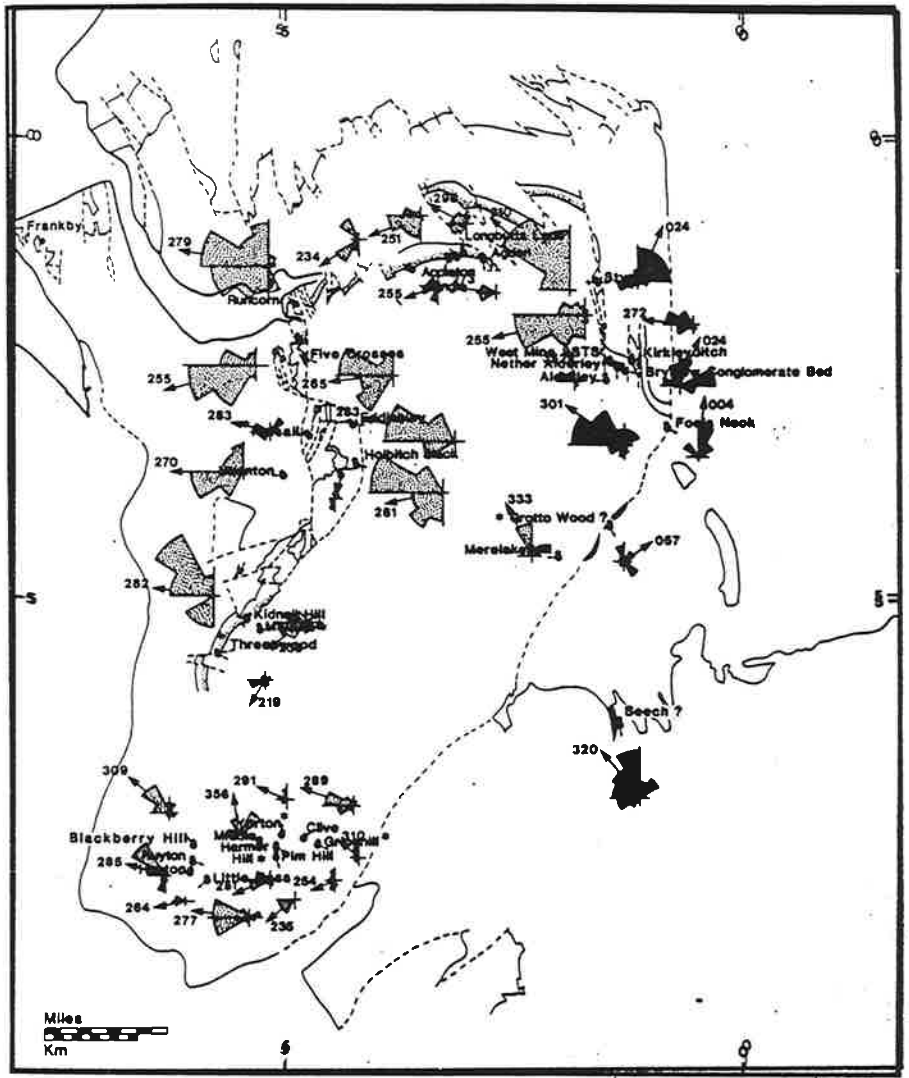
234 VECTOR MEAN

—— EDGE OF BASINS

---- FAULTS

Figure 11. Palaeocurrents: Upper Part of Helsby Sandstone Formation and Tarporley Siltstone Formation.

(8)



(From Thompson 1985)

OUTCROP & DATA FOR FRODSHAM SOFT SANDSTONE MEMBER (LKS)

OUTCROP & DATA OF NETHER ALDERLEY RED SANDSTONE MEMBER (LKS)

DATA FOR MALPAS SOFT SANDSTONE (KW)

234 VECTOR MEAN

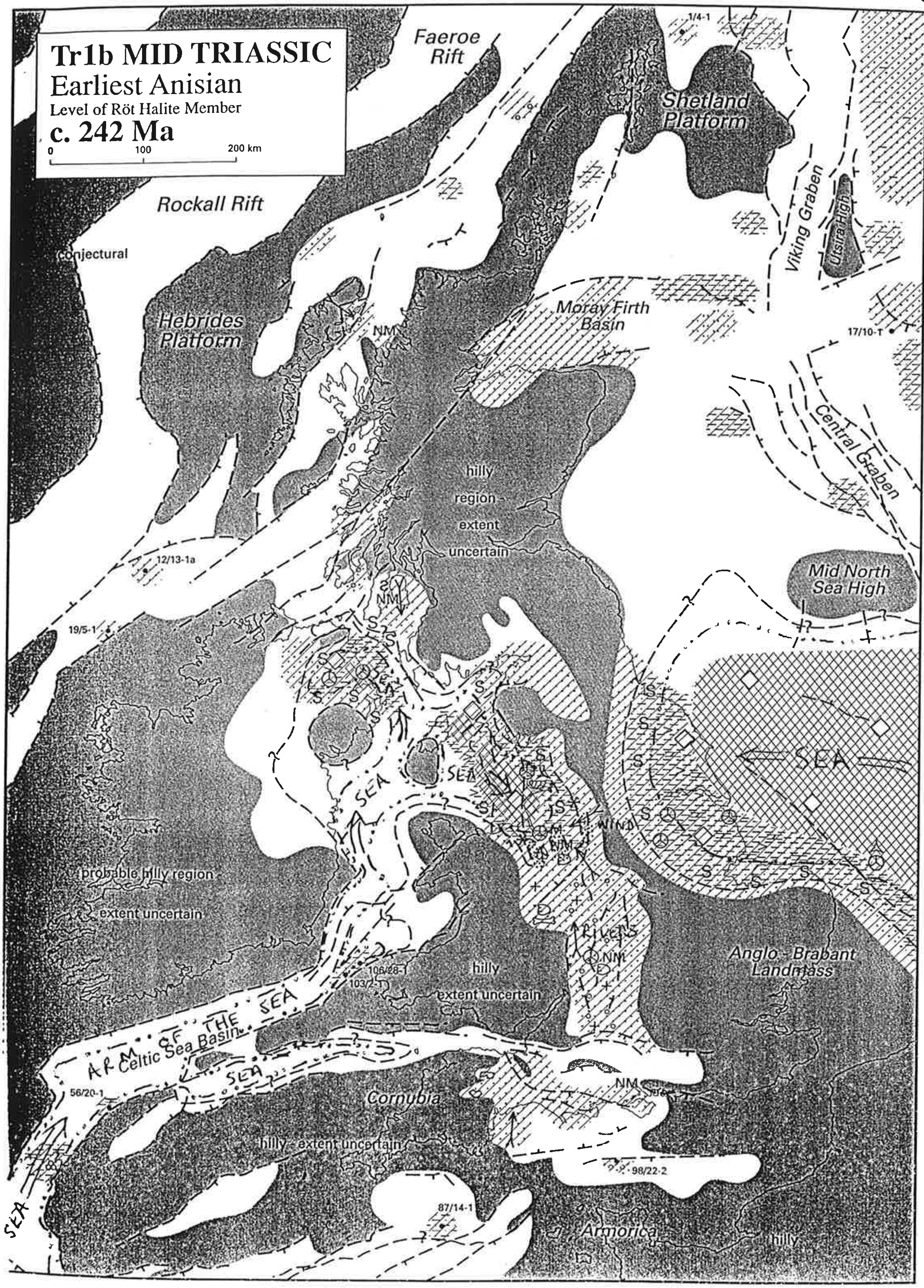
—— EDGE OF BASINS

---- FAULTS

(LKS) LOWER KEUPER SANDSTONE (KW) KEUPER WATERSTONES

* Statistics for the vector mean not significant at the 95% level.

(8)



COASTLINE SHOWN AS -·-·-·-

[After Warrington in Cope et al 1992]

KEY TO THE SYMBOLS ON THE PALAEOGEOGRAPHY ON PAGE 9A

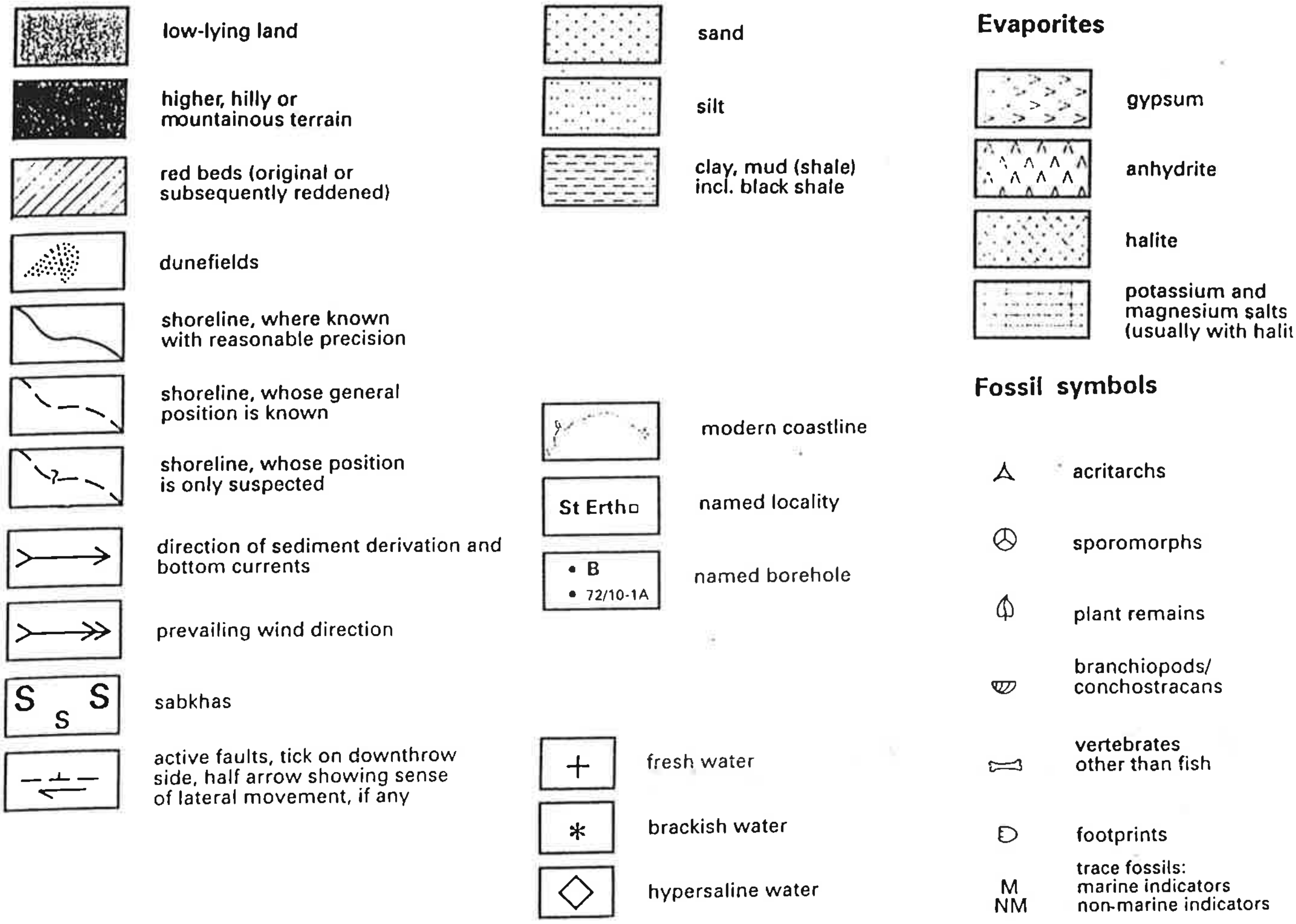
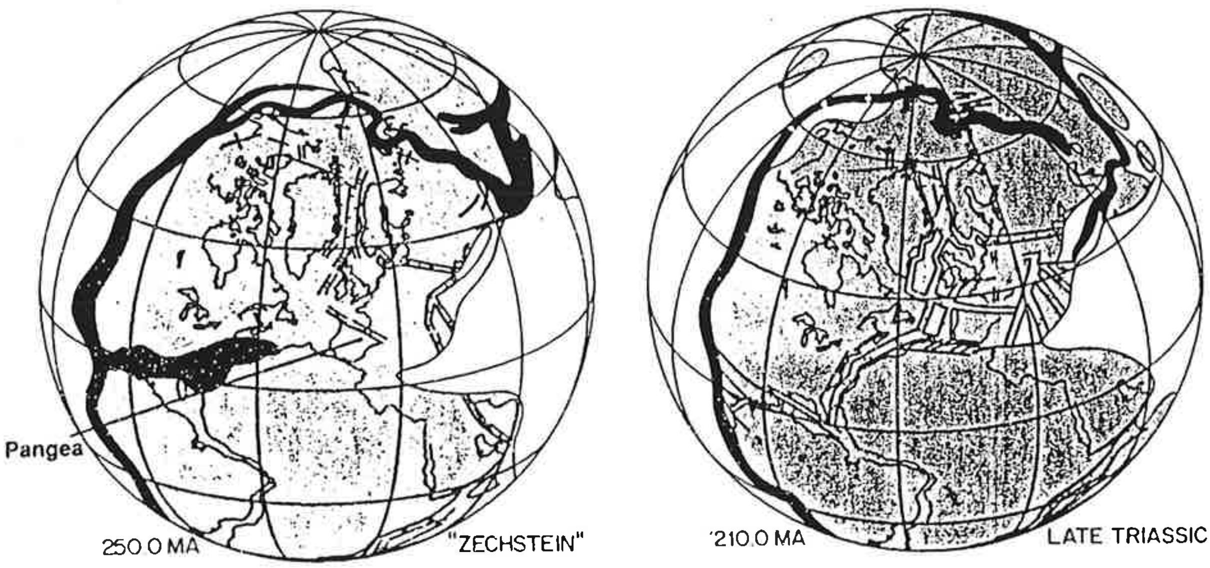


Figure 7b The general disposition of the fragments of our present landmasses at 250 and 210 mya, showing that there was then only one continent - Pangea (after P.A. Ziegler 1993 with the kind permission of the Geological Society of London).



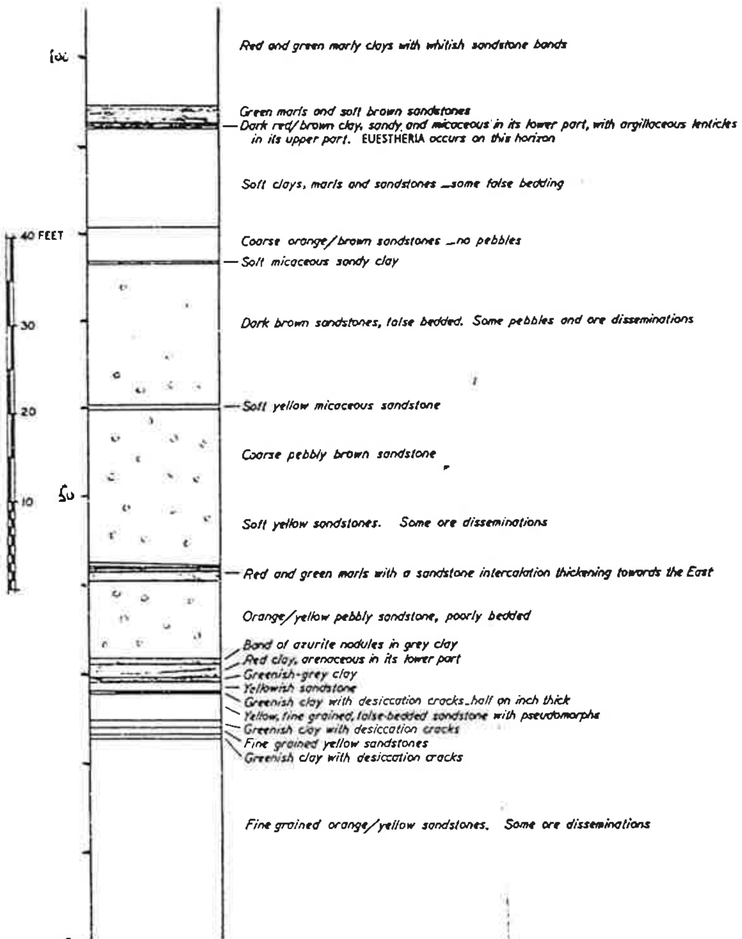


Fig. 1.—The Keuper Sandstone succession exposed in the openworks of the Engine Vein Mine, Alderley Edge.

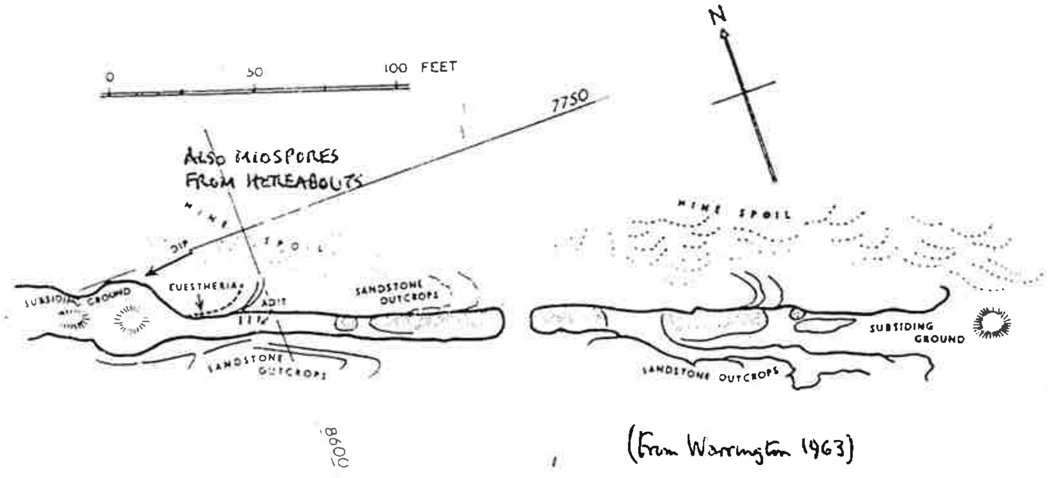
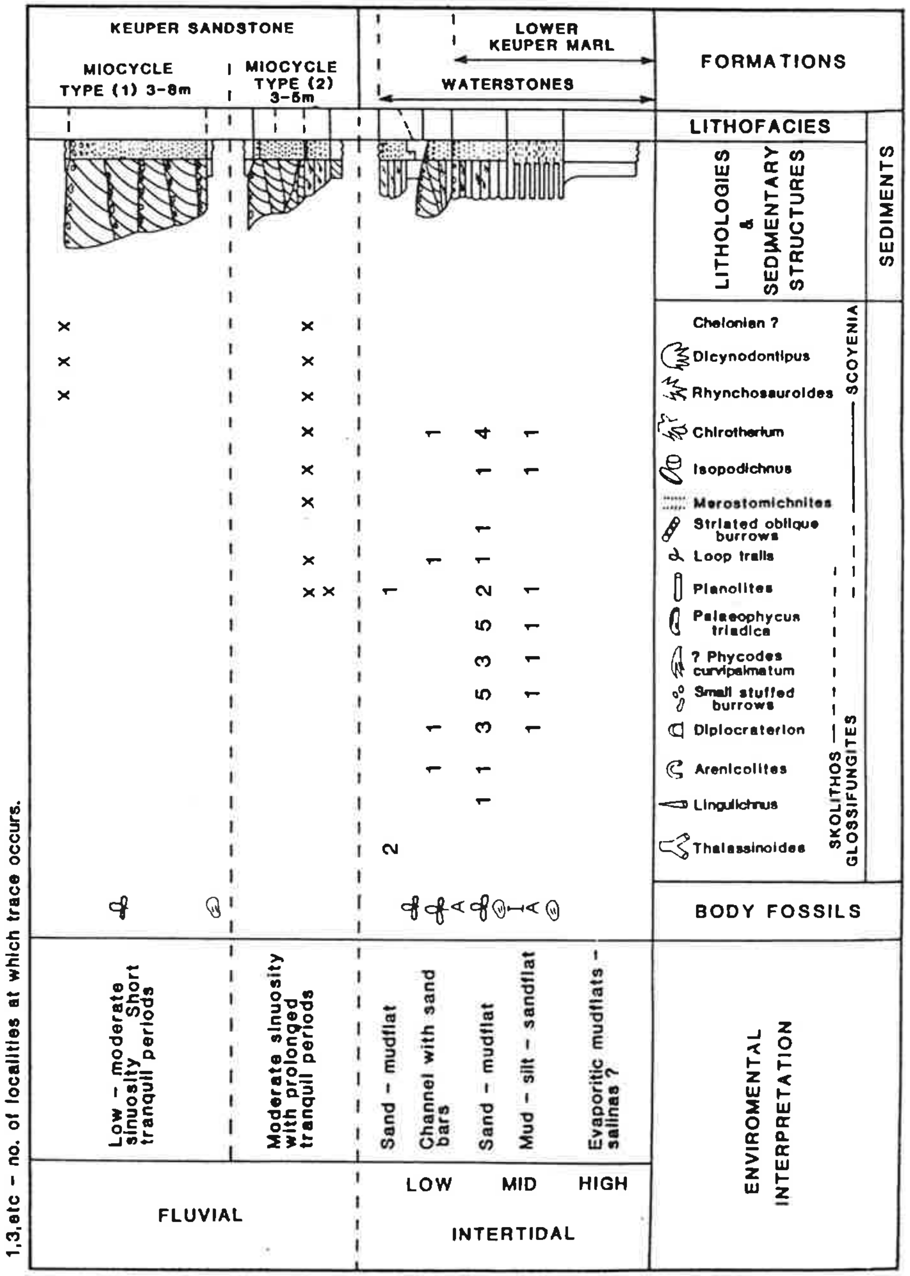


Fig. 2.—Sketch-map of openworks of the Engine Vein Mine, Alderley Edge.

(10)

Figure 19. Distribution and environmental interpretation of lithofacies, trace fossils, and body fossils from the "Keuper" Sandstone, Waterstones and Lower Keuper Marl (Scythian-Anisian) in the Cheshire Basin (after Pollard 1981).
(& Thompson 1985)



(10)

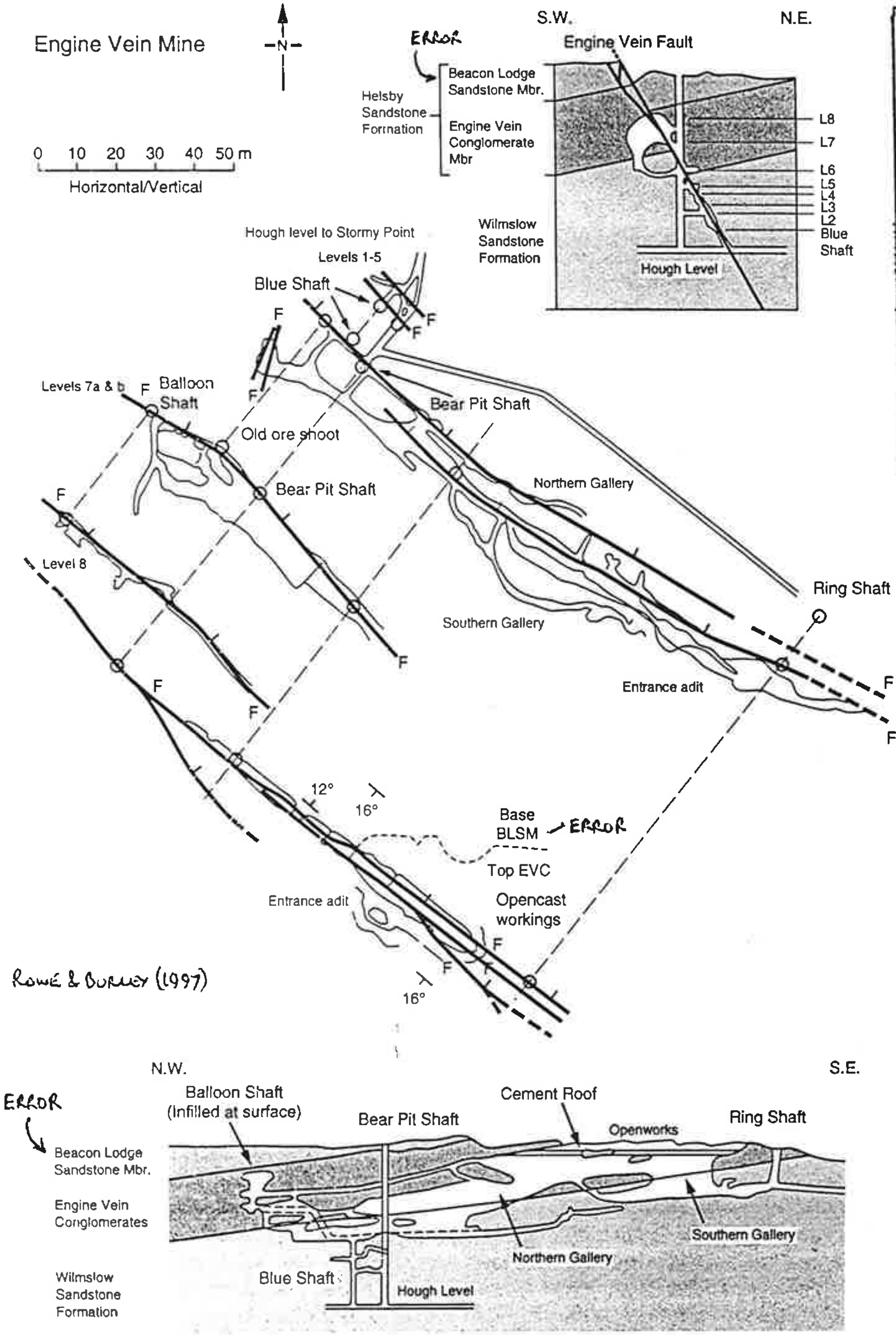
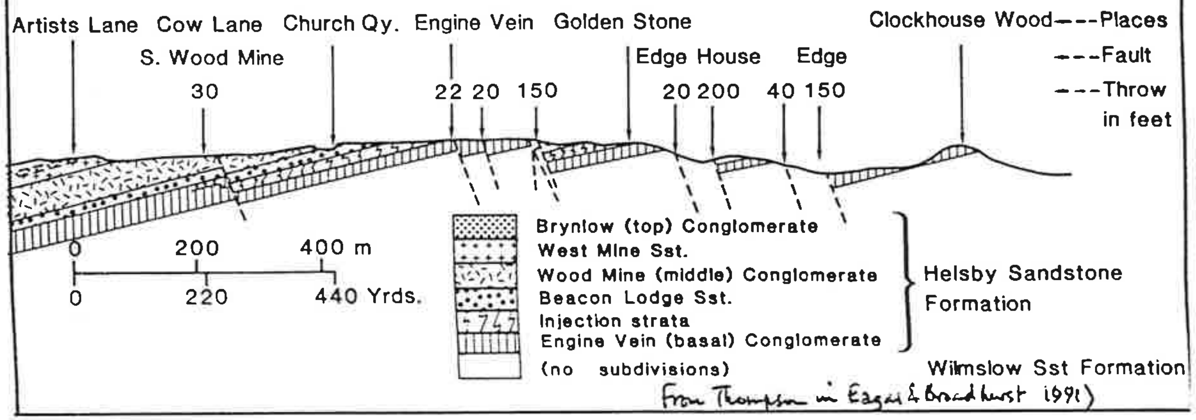
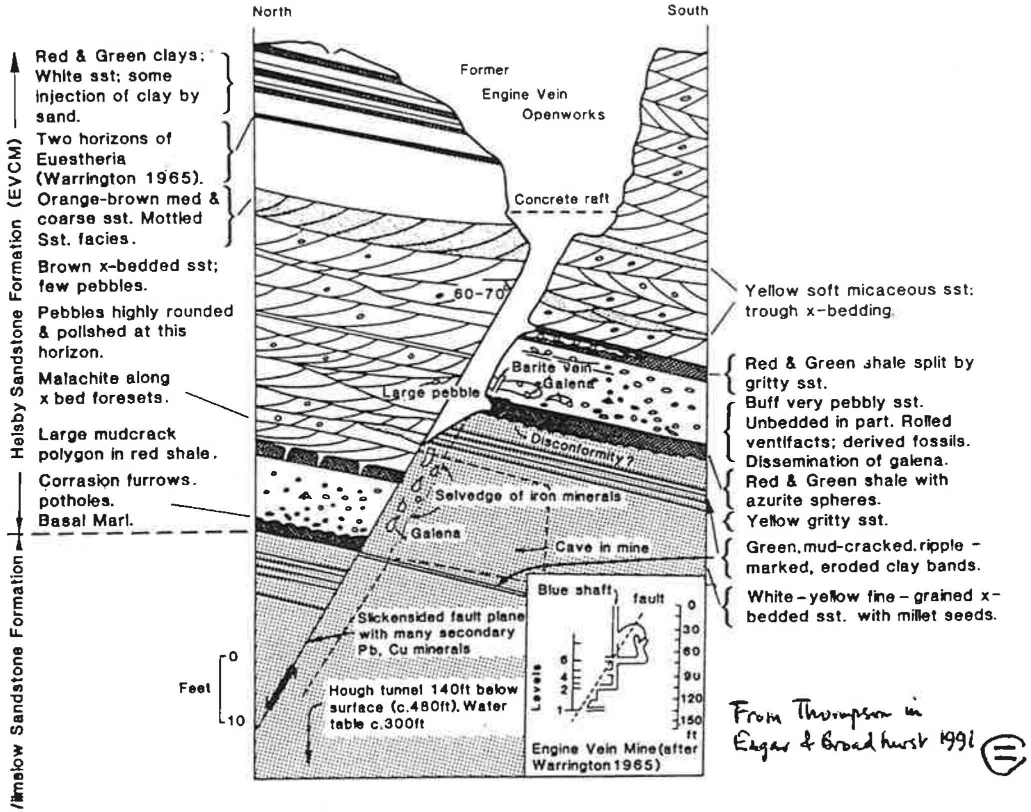


Fig. 5. Map and sections (dip and strike) of the Engine Vein Mine showing the relationship of the mine workings to stratigraphy and faults. Distribution of mine workings taken from original mine plans and the authors' surveys.

Figure 13. Section across Alderley Edge.





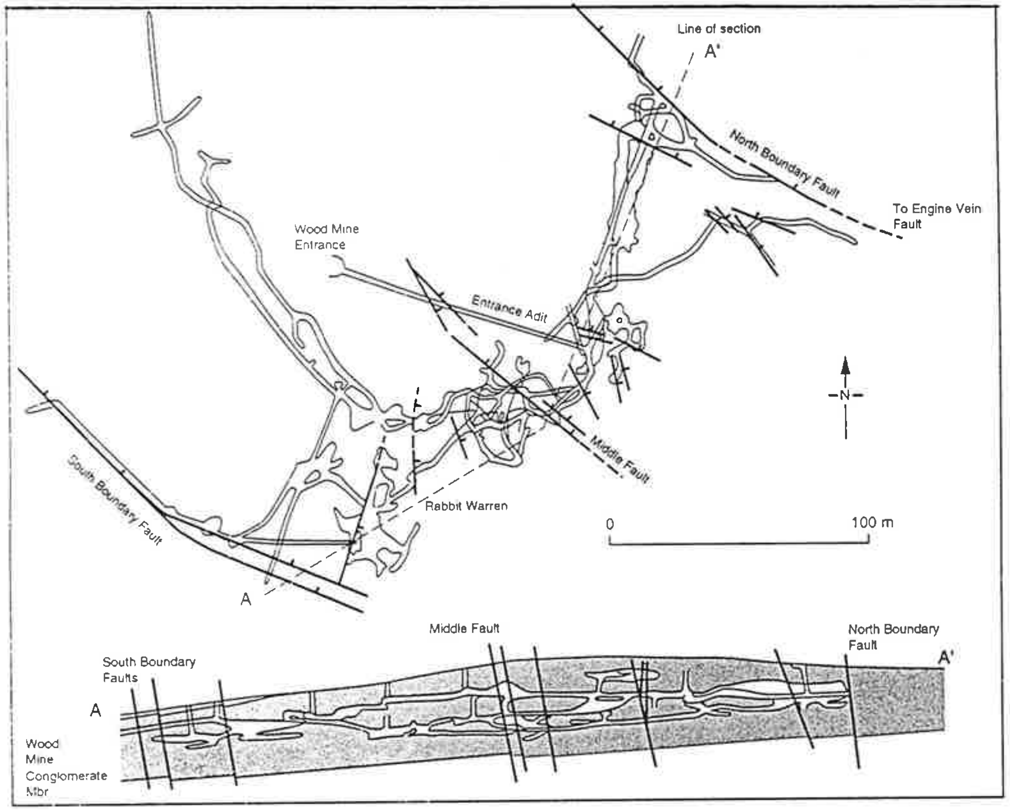


Fig. 7. Map and dip cross-section of Wood Mine (adapted from Warrington, 1965 with additions) showing the main faults in relation to the mine workings. (After Rowe & Burley 1997)

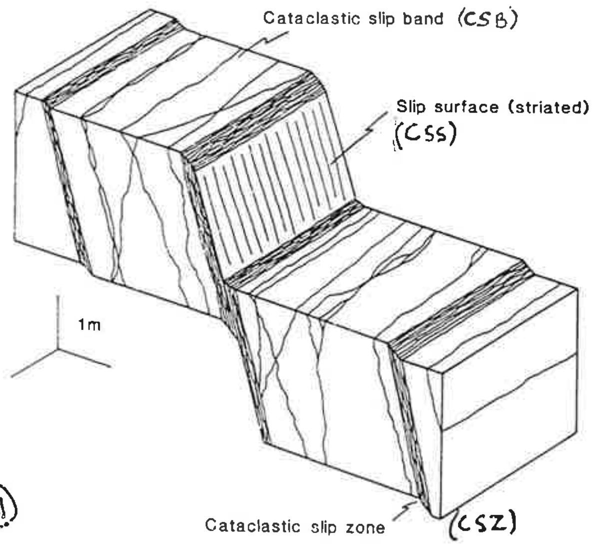
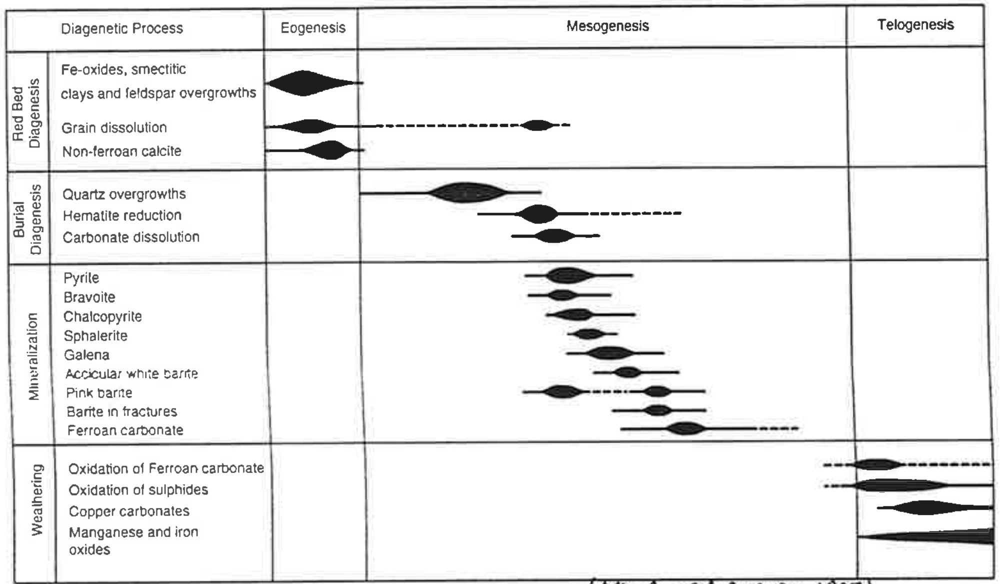


Figure 7 Schematic diagram depicting the relationships between cataclastic slip bands, cataclastic slip zones and slip surfaces. Thicknesses of individual bands are exaggerated. Shear displacements on individual bands are below the resolution of the diagram (After Fowles & Burley 1994)

(21)

Table 4. Scheme for the main diagenetic reactions occurring in red bed formation

Detrital supply Wedepohl (1978)	Early diagenesis - dissolution	Authigenic precipitation	Cementation	Mineralization
Silicates				
Quartz	Si	Quartz		Barite
K-feldspar (Cu $\bar{x}$ 5ppm; <20ppm)	K Al Si Ba Pb	K-feldspar		Galena
Plagioclase (Cu $\bar{x}$ 62ppm; <840ppm)	Ca Na Al Si	Plagioclase		Pyrite
Ferromagnesians (Cu $\bar{x}$ 100ppm;<11,600)	K Na Ca Fe Mg Al Si Cu U			Cu - sulphides
Pyroxene Cu $\bar{x}$ 100 <1000			Gypsum/Anhydrite	
Biotite Cu $\bar{x}$ 100 <11600			Calcite	
Evaporites - Gypsum Anhydrite ?Ba			Dolomite	
Clays				
Illite	K Al Si	Illite		
Smectite	Na Ca Al Fe Si	Chlorite		
Chlorite (Cu $\bar{x}$ 100ppm; <400ppm)	Fe Mg Al Si			
Kaolinite (Cu $\bar{x}$ 23ppm; <226ppm)				
Oxides				
Goethite		Hematite		
Titanomagnetite (Cu $\bar{x}$ 76ppm; <800ppm)	Fe Ti V Mn Co Cu Ni			Co, Ni, Fe -sulphides
TiO_2		Anatase		
CONDITIONS	pH =7, Eh +ve NEUTRAL OXIDISING		$CO_3^{=}$ $SO_4^{=}$ FROM EVAPORITES	pH <7, Eh -ve ACID REDUCING



(After ROWE & BURLEY 1997)

Fig. 12. Interpreted paragenetic sequence combining early diagenesis, burial diagenesis, mineralization and Recent weathering effects for the sediments of the Sherwood Sandstone Group at Alderley Edge.

(12)

(13)

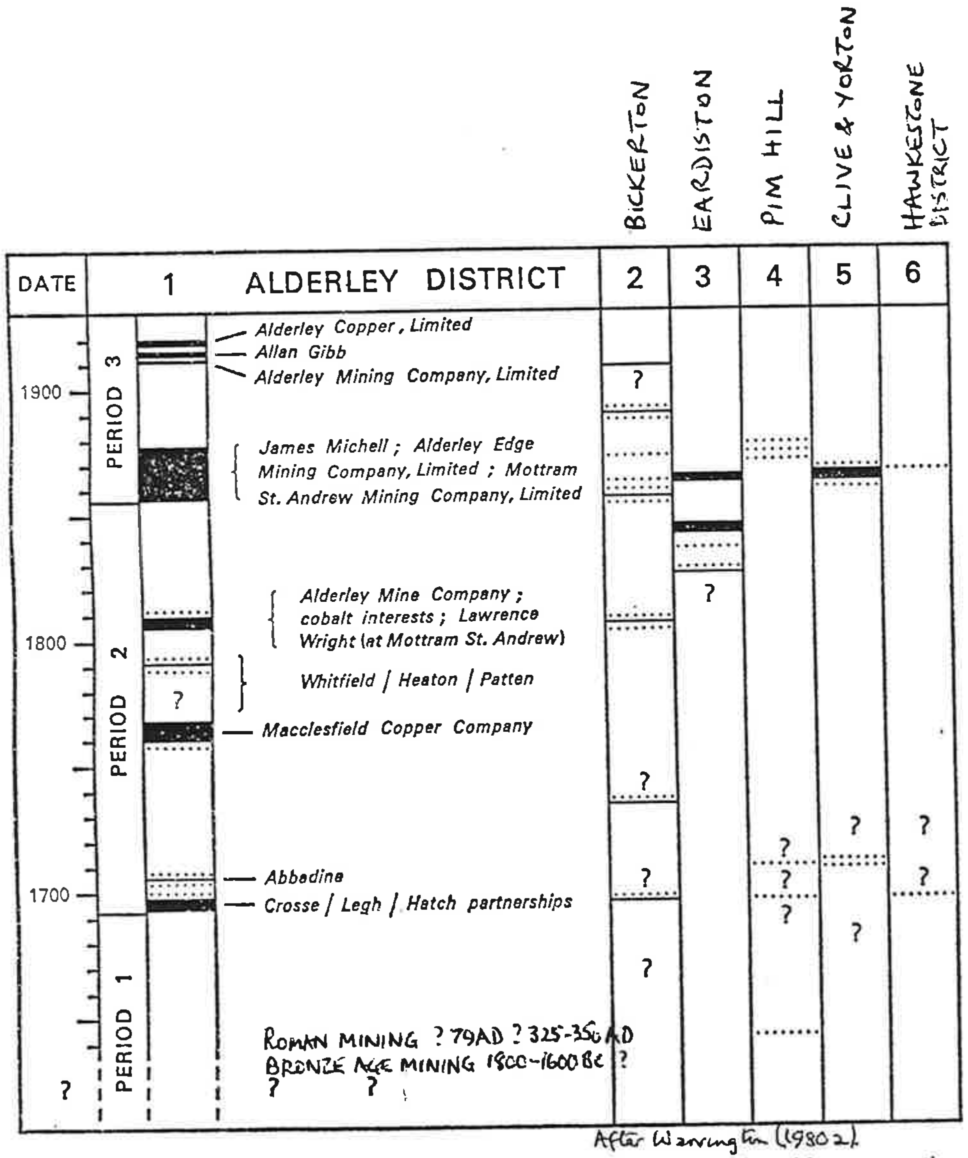


Fig. 3 — Chronology of mining activity in the Alderley district (1), with comparative summaries of activity in other non ferrous mining districts (2-6) in Cheshire and northern Salop (localities as in Figure 1). (Based upon Warrington, 1980b, Fig. 1, p. 10, and *J. Shrops. Caving Min. Club* (for 1980), 1981, p. 13)
Full black — periods of documented activity. Stipple — periods (approximate) of inadequately documented activity. ? — periods during which mining may have taken place.

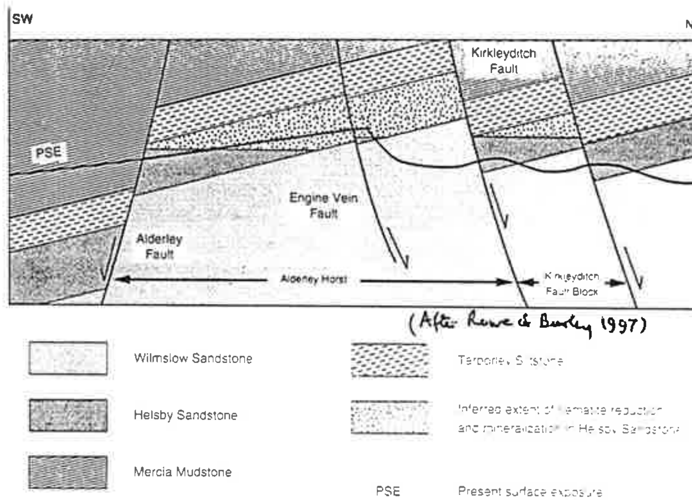


Fig. 4. Geological cross-section aligned SW–NE through the Alderley Horst illustrating the projected trap structure prior to present exhumation (based on Warrington, 1980). The Kirkleyditch Fault Block is shown mineralized to spill point, assuming fault-seal against the Tarporley Siltstones of the Mercia Mudstone Group.

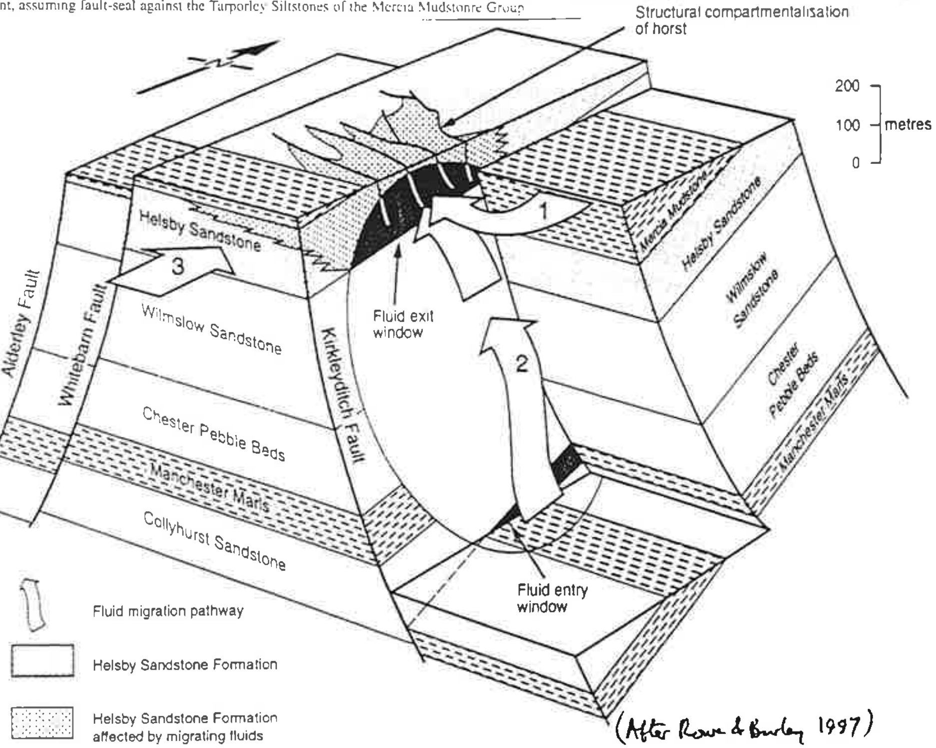


Fig. 14. Conceptual model of the probable fluid migration pathways responsible for the mineralization at Alderley Edge. Migration pathway 1 is for cross-formational flow of a saline, sulphate-rich chloride brine expelled from the MMG in the Kirkleyditch Fault Block. Pathway 2 is for overpressure valving of fluids from deeper stratigraphic horizons in the Kirkleyditch Fault Block. Example of a sulphate-rich chloride brine sourced from the Mancheter Marls is shown, but a similar vertical migration route is possible for a reducing fluid expelled from the underlying Carboniferous. Pathway 3 represents a regional flow of reducing fluid through the uppermost sandstones of the Sherwood Sandstone Group, sourced from the Carboniferous juxtaposed across the Red Rock Fault to the south. In all cases the fluids are trapped and ponded on the crest of the Alderley Horst. Fluid entry window and fluid exit window concepts based on Knipe (1993). Vertical exaggeration ×2.

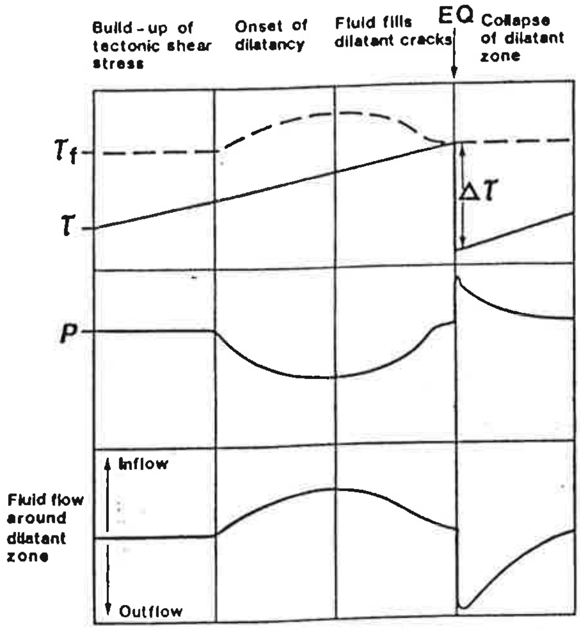


FIG. 2. Synoptic diagram of the seismic pumping process (modified from Scholz *et al.* 1973). (After Sibson 1975.)

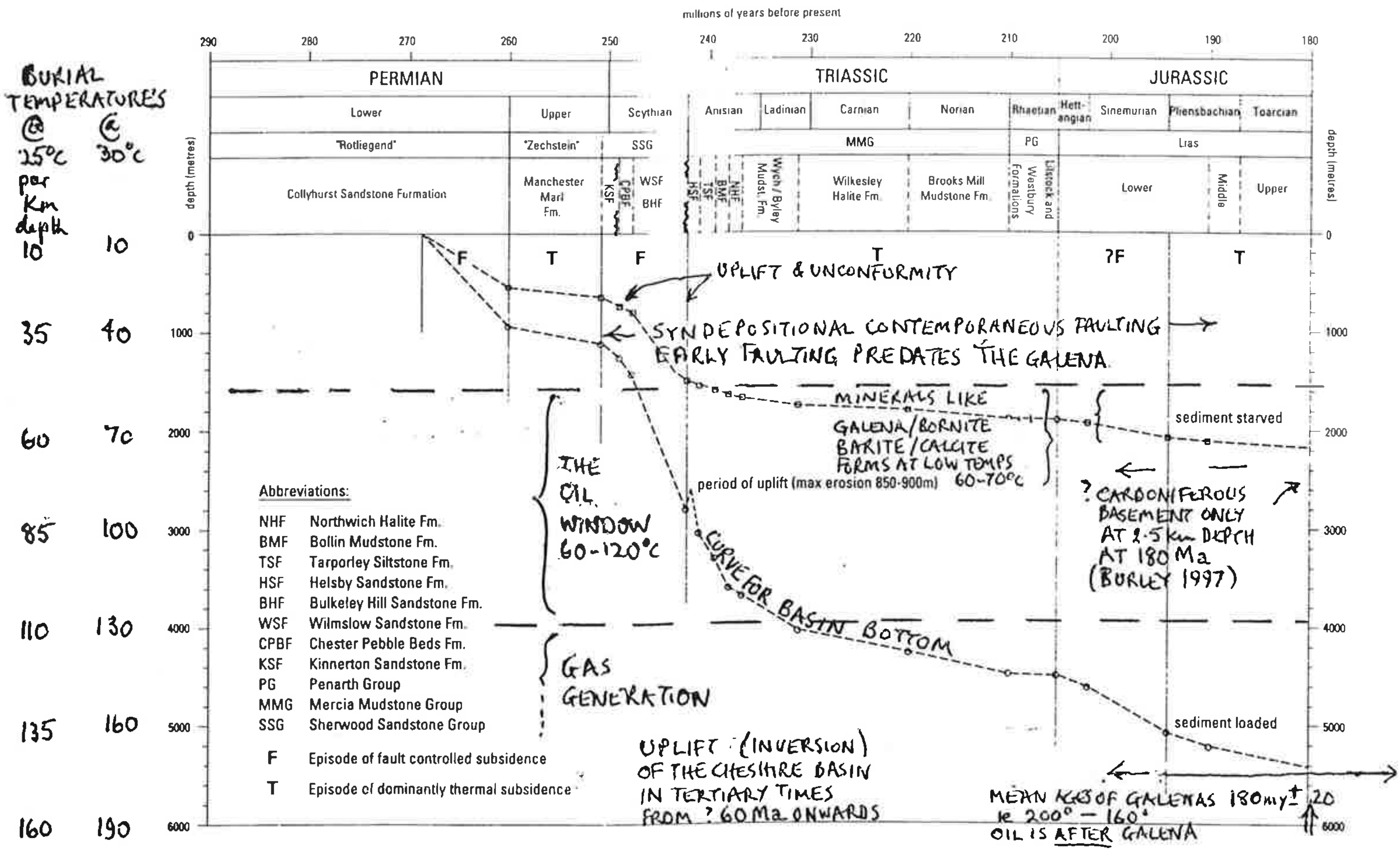
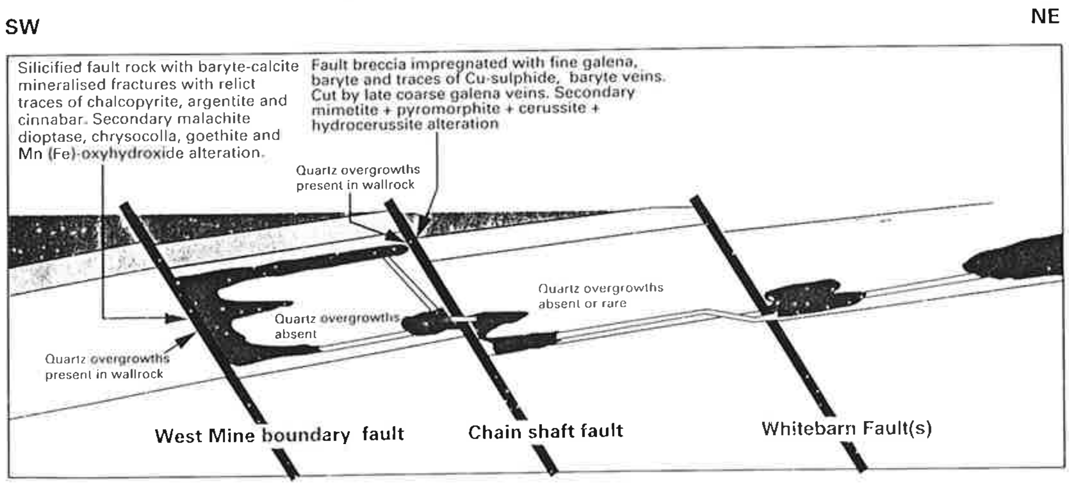


Fig. 11. Burial history (subsidence) curves for the Permo-Jurassic strata in the central Cheshire Basin. Examples for sediment loaded and sediment starved (water filled) basins are shown. (After Evans et al 1993 p.866).

FROM A BRITISH GEOLOGICAL SURVEY PUBLICATION / PROMOTION SHEET
ANON (BGS) 1999 COPPER. Keyworth Notts, BGS (folding leaflet)

Red beds of Triassic age in the English Midlands contain copper-dominated polymetallic deposits of this type. The most productive mineralisation occurs in fluviatile sandstones and conglomerates of the Sherwood Sandstone Group in the *Alderley Edge* area of the Cheshire Basin. The ore comprises mixtures of copper carbonates with small amounts of arsenates, oxides and phosphates. In addition to copper, the ore contains small amounts of lead, cobalt, vanadium, zinc, manganese, nickel, arsenic and traces of gold. Baryte is widespread. The deposits show many of the characteristics of continental red-bed SCDs, and the location of the mineralisation is related to traps controlled by faulting and an overlying cover of the Mercia Mudstone Group. The estimated grade of the worked deposits is 2.1% Cu. Recent multidisciplinary research suggests a complex mechanism of formation involving the release of metals by the breakdown of primary minerals in the basin sediments, scavenging of metals from mudstones in the basin by density-driven brines, interaction with reducing fluids from the basement causing precipitation of ores, and alteration of the ore assemblage by meteoric groundwater following basin inversion. These studies indicate the presence of other prospective areas for mineralisation of this type in the Midlands.



Alderley Edge: diagrammatic illustration (not to scale) of the relationship between faults and mineralised sandstone bodies in West Mine. The mined extent of copper mineralisation is shown in dark grey.

TABLE 2. Detailed species by locality list of all minerals known or claimed from the ore deposits at Alderley Edge and Mottram St Andrew..

Mineral	AE	EV	WM	WD	MM	COMMENT
ANGLESITE	Yes	*	*	*		Widespread as minute inconspicuous crystals with oxidised galena (B, 1994).
ANTLERITE	Yes	*				A greenish crust (B, 1994), rare.
ASBOLANE	Yes	*	*	*	*	Common as black sooty patches. Figured by Sowerby (1811) as black oxide of cobalt.
AURICHALCITE	Yes			*		Very rare, as blue-green radiating blades with hemimorphite (B, 1994).
AZURITE	Yes	*	*	*	*	Very common as a blue encrustation and intergranular cement, also as small nodules.
BARITE	Yes	*	*	*	*	Abundant. As white to pinkish vein fillings and cementing sandstone.
BEAVERITE	Yes			*		Probably quite common as a yellowish encrustation (L, 1994).
BEUDANTITE	Unc					Identification of beudantite-type minerals by XRD alone is not reliable. See B, 1994.
BORNITE	Yes	*				An alteration product of chalcopyrite (IV, 1982).
BROCHANTITE	Yes	*		*		Widespread but not common. Bright green crystals from Doc Mine (B, 1994).
CALCITE	Yes	*				Uncommon. First recorded from a sandstone bed (H, 1864).
CALEDONITE	Dis					Erroneously reported based on specimens in MM (EB, 1959), discredited (B, 1994).
CERUSSITE	Yes	*	*	*	*	Common as small inconspicuous crystals, most often with galena (B, 1994).
CHALCOCITE	Yes	U		*		As black impregnations in sandstone (IV, 1982).
CHALCOPYRITE	Yes		*	*		Widespread, commonly altering to other sulphides.
CHRYSOCOLLA	Yes	*	*	*	*	A common component of bluish and greenish flowstone crusts (B, 1994).
COBALTITE	Unc					IV, 1982 report a mineral similar in composition to nickeliferous cobaltite.
CONNELLITE	Unc	U				Visually identified as minute royal blue radiating spherules (B, 1994)
COPPER	Yes	*				Uncommon, early reports refer to copper ore, not native copper (B, 1994).
COVELLINE	Yes	*				Common as a bluish metallic coating on sulphides (IV, 1982).
CUPRITE	Yes	*				Rare, as wine-red crystals with copper (B, 1994).
CYANOTRICHITE	Unc	U				A possible component of a bluish gel (B, 1994).
DESCLOIZITE	Dis					A specimen in the Kingsbury collection (NHM), is fraudulently labelled (GR).
DJURLEITE	Yes					The major black copper sulphide at AE (IV, 1982).
DUFTITE-α	Yes				*	As black botryoidal crusts, visually indistinguishable from mottramite (DG).
DUFTITE-β	Yes				*	Minute vanadium-rich lenticular crystals and sage-green crusts (DG).
ENARGITE	Dis					Suggested by Warrington (1965) but almost certainly an error (B, 1994).
ERYTHRITE	Yes	*		*		Widespread, but uncommon. First recorded as cobalt bloom of a crimson cast (S, 1811).
GALENA	Yes	*	*	*	*	Common, both as a vein filling and cementing sandstone.
GERSDORFFITE	Yes					As optically-zoned crystals containing Ni, Co, and Fe, enclosing pyrite (IV, 1982).
GOETHITE	Yes				*	Blackish botryoidal at MM (DG). Ubiquitous as limonite (B, 1994).
GYPSUM	Yes	*		*		As post-mining efflorescences and coatings (B, 1994).
HEMIMORPHITE	Yes	*		*		Very rare as radiating sheaves of colourless crystals (B, 1994).
HETEROGENITE	Dis					A specimen in the Kingsbury collection (NHM) is almost certainly not from AE.
IDAITE	Yes					Chalcopyrite alters to a brown anisotropic phase with properties close to idaite (IV, 1982).
JAROSITE	Yes	*				Probably widespread as a yellowish powdery coating, but inconspicuous.
LANGITE	Yes	*				Uncommon as blue pseudohexagonal crystals (B, 1994).
LAVENDULAN	Unc			U		A visual identification of microscopic blue needles (B, 1994).
LEADHILLITE	Yes	*				Very rare, as colourless to pale green blocky hexagonal crystals (B, 1994).
LIBETHENITE	Dis					A highly questionable interpretation of early assays of bulk ore (B, 1994).
LINARITE	Yes	*		*		Uncommon, but locally conspicuous, the blue impregnations are easily mistaken for azurite.
LIROCONITE	Dis					Not confirmed by modern analytical methods, almost certainly an error (B, 1994).
MALACHITE	Yes	*	*	*	*	Common as a green impregnation in sandstone, a major copper ore.
MARCASITE	Yes	*				Traces with other sulphides (IV, 1982).
MASSICOT	Dis	U				Not confirmed by modern methods and easily confused with other minerals (B, 1994).
MELANTERITE	Yes	*				As blue-green efflorescences (B, 1994).
MIMETITE	Yes	*			*	Common, but indistinguishable in hand specimen from pyromorphite (B, 1994).
MINIUM	Yes	*				Very rare, specimens are in the Russell collection at the NHM (B, 1994).
MOTTRAMITE	Yes				*	As a black botryoidal crust, and rarely, drusy crystals on sandstone (B, 1994) (DG).
OLIVENITE	Yes	U		*		Early reports are questionable. B, 1994 lists this species based on specimens in the NHM.
OSARIZAWAITE	Yes					As yellowish-green crusts and impregnations in sandstone (B, 1994).
PARARAMMELSBERGITE	Yes					As minute inclusions with other arsenides (IV, 1982).
PHARMACOSIDERITE	Yes	*				Very rare, as minute orange-brown cubes (B, 1994).
PLANCHEITE	Dis					The first British record, but based on a fraudulent Kingsbury collection (NHM) specimen (GR).
PLUMBOGUMMITE	Yes				*	A pale brown encrustation on mottramite (DG).
POSNJAKITE	Yes	*				Rare, as thin blue crusts, visually indistinguishable from langite (B, 1994).
PYRITE	Yes	*		*		Widespread but not common (M, 1964), also as the nickelian variety bravoite (IV, 1982).
PYROMORPHITE	Yes	*		*	*	Common as colourless, yellow and green crystalline crusts and impregnations in sandstone.
ROSCOELITE	Dis					All published records are based on a misunderstanding of R, 1876.
SCORODITE	Unc	U				Listed (in C, 1979), but requires confirmation (B, 1994).
SIDERITE	Unc	U				Listed (by T, 1970), but requires confirmation (B, 1994).
SILVER	Yes	*				Very rare, as minute dendrites (B, 1994).
SMITHSONITE	Yes					(IV, 1982), very rare.
SPHALERITE	Yes	*				Uncommon (IV, 1982).
SPIONKOPITE	Yes					Rare (IV, 1982).
SULPHUR	Yes	*				Probably widespread as small rounded crystals in galena, inconspicuous (B, 1994).
TETRAHEDRITE	Yes	*				Microscopic argentian and zincian inclusions in galena (IV, 1982).
TYROLITE	Yes	*	*	*		Rare, as thin green blades, often with chrysocolla (B, 1994).
VANADINITE	Dis					Listed by a number of authors (see B, 1994), but considered doubtful, no known specimens.
WITHERITE	Dis					Recorded (G, 1919) on the basis of a trace of carbonate in an analysis of a barite-rich stratum(!).
WULFENITE	Yes	*	*	*		Rare, but widespread, in tiny inconspicuous yellow and orange tabular and pyramidal crystals.