A

NORTH STAFFORDSHIRE GROUP OF THE GEOLOGISTS' ASSOCIATION OF LONDON

EXCURSION THURSDAY 6TH JUNE 1996 TO THE AREA OF THE APEDALE-ASTBURY LOWER CARBONIFEROUS VOLCANOES AND THE SOUTHEAST MARGINS OF THE PERMO-TRIASSIC CHESHIRE BASIN AT GROTTO WOOD, MERELAKE HILL AND KENT HILL (AUDLEY)

LEADERS: David Thompson (Keele); John Rees (British Geological Survey).

Meet at Limekiln Farm, Astbury (NGR SJ 860 593) at 17.30 hrs through the courtesy of Mr Eric Potts (telephone 01260-273514).

1. Backgound: the geological and geophysical context of the Market Drayton-Apedale-Audley-Astbury area. The area (Fig.1) has been mapped many times by BGS, the general context being depicted in Figs 1, 10, 11 & 12. The latest extract from the 1:10000 map of the Astbury area is given in Fig.7. Earlier maps and sections are given in Figs 2-9. The area covers large parts of the Western Anticline of the Potteries Coalfield and the eastern margin of the Cheshire Basin. The Astbury area maps out as a pericline (Fig.2). Large and extensive positive magnetic anomalies over the wider area (Figs 13 & 14) are interpreted (Figs 11 & 12) in terms of an 8-10 km intermediate-depth Uriconian magnetic basement and a higher-level, 1-2 km depth, Apedale basic volcanic mass (c.25 km3), one of several possible centres developed along the Wem-Red Rock Fault lineament (see Rees et al. 1996; Rees and Wilson in press).

2. The sedimentary and volcanic rocks around the fishing pond at Limekiln Farm, Astbury. The party will walk around the fisherman's pathway on the east side of the pond (the site of the former quarry: Fig. 2), pausing to rummage upstream in the gully adjacent to the fisherman's pitch No. 24 to locate calcareous shales, limestones, tuffaceous beds and fossils from the Astbury Limestone-Shales of late Asbian/early Brigantian (P1a) age in the Dinantian (Lower Carboniferous) succession (see Evans et al. 1968 pp. 9-14 for details; here reproduced as page 2 and Figs 8 & 9).

The party will continue northwards along the path to between pitches 15 and 19 and scramble for 30m on a steep incline up and across the slope through the trees to gain access to a now modestly exposed outcrop (SJ 8626 5931) c.6-7m thick (Gibson and Hind 1899; Hind 1904; Evans et al. 1968). The succession (Figs 8 & 9) consists of 3 roughly graded beds of green-brown or dark red-brown tuff breccias and lapilli tuffs, interbedded with limestones and calcareous shales. The breccias contain angular blocks of basic lava which in this section show hyalo- and holo-crystalline olivine basalt (olivine, plagioclase, augite, at times vesicular and chlorite-calcite filled; phenocrysts flow-aligned) (Rees et al. 1996).

Fossils recovered from the "Astbury" succession overall (Evans et al. 1968, p. 10; see sheet 2) include very many species of corals, brachiopods and molluscs, showing that some of the limestones are of reef phase without fully reefal conditions ever developing hereabouts. Although the shell debris and interbedded limestones indicate accumulation in a shallow marine environment, the larger lava blocks suggest a source close to a volcanic orifice which was involved in 3 pulses of Strombolian-type pyroclastic eruption (Rees et al. 1996) which may have elsewhere built up sub-aerially. There may have been several volcanic centres, with the Astbury rocks representing either the northern extension of the Apedale volcanic field or part of a separate field (ibid. and see Fig. 11).

The trace element geochemistry of the Astbury volcanic rocks is compositionally similar to that of the Apedale tuffs and plots of Zr/TiO2 and levels of Niobium (Fig. 17a) indicate a mantle source typical of an oceanic island basalt (OIB). A plot of Nb-Zr-Y from the Apedale and Astbury rocks (see Fig. 17b) falls in the within-plate basalt field (WPA) whereas data from the tuffs of the Gun Hill borehole to the NE in Derbyshire suggests a plume-influenced mid-oceanic ridge basalt (P-type MORB) adjacent to the within-plate continental tholeiite basalt field (WPT) (ibid.). The data (ibid.) and the settings (Figs 16 & 18) are taken from Rees et al. 1996. The analysis of the immobile elements Ba, La, Nb, Rb, Ta and Th suggest the presence of mantle-derived OIB and a common asthenospheric source for the Astbury-Apedale magmas.

3. Time may permit the searching for Carboniferous Limestone fossils in the old quarries and debris slopes to the north of the farmhouse on the west side of the pericline.

4. Travel from Limekiln Farm to the lane leading southeastwards from Wood Farm into Grotto Wood (SJ 853 587) (see Fig. 7). Park tidily in very limited space. Rehearse the geophysical context (Figs 19, 20, 21) and the conventional stratigraphy and disposition of the Permo-Jurassic basin fill of the Cheshire Basin (Warrington et al. 1980; Evans et al. 1993; see Figs 22 & 24) against which to judge the puzzling occurrences of New Red Sandstone rock units and facies in the Grotto Wood, Merelake Hill and Audley areas. Locate the following rock types, facies and formations:

(a) Red-brown to yellow even-grained, medium-coarse, occasionally pebbly, cross-bedded sandstone dipping 20-280 and outcropping in a former large quarry to the east of Wood Farm. These rocks were formerly assigned to the Lower Keuper Sandstone (LKS; see Fig. 24) (Hull & Green 1866; Evans et al. 1968). In 1995 they were mapped as fluvial Helsby Sandstone Formation (HSF). They are now regarded as Anisian, lowest Middle Triassic: Warrington in Fraser and Sues 1994). The rock hefts heavily in the hand due to the presence of much barite cement. Evidence of thick, multiple barite veining is apparent in loose specimens and is due to post-Triassic mineralisation (? of early Tertiary age). Bands of green flaggy sandstone were once seen in the quarry. The rock was formerly used as building stone (dimension stone in today's parlance!), in particular in relation to the building of the LNWR line nearby.

(b) Foxy-red, mottled, argillaceous, fine-grained sandstones in the southern side of the lane cutting (SJ 853 586). These beds were once mapped as part of the LKS/Waterstones (see Fig. 24) (Hull & Green 1866, but see Pocock et al. 1906 p. 60 who interpret these beds and those in (c) next as of "Bunter" type). They are now assigned to the base of the fluvial Wilmslow Sandstone Formation (WSF) (Scythian-lower Triassic) (Evans et al. 1968; BGS 1995). This facies is usually interpreted as part of a persistent waning braided stream system which, in the upper parts of the formation elsewhere e.g. at Alderley Edge, becomes increasingly aeolian. Alternatively these beds could be regarded as a brief but quieter episode of fluvial deposition within the Chester Pebble Beds Formation (CPBF).

(c) Modestly hard, red-brown, medium-grained, pebbly cross-bedded sandstone exposed under the vegetation cover on both sides of the lane cutting some 20m southeast of the last locality. This outcrop was originally mapped as LKS (Hull & Green 1866). It was reinterpreted by Pocock et al., as just explained, and is now regarded as the top of the Chester Pebble Beds Formation (Scythian, Lower Triassic) (Evans et al. 1968) (Fig. 7). Pocock et al. 1906 p.60 claimed to see oft-pitted pebbles, implying deep burial and pressure solution of silica at points of contact between adjacent clasts - a key observation if it can be substantiated.

(d) Grey-black shales/mudstones, much broken down and weathered (with fish debris in the fragments), lie on both sides of the lane within 10m southeast of locality (c), interbedded with harder fine-grained yellow sandstones further up the track to the northeast. These beds are mapped as the very top of the Millstone Grits (Namurian zone G) or the lowest part of the Lower Coal Measures (Westphalian A) (see Fig. 7).

The junction between beds (c) and (d) should be located and interpreted critically, both in the lane cutting and in the adjacent, parallel gulley 5m to the south. The latter is a location which has been repeatedly dug out and conserved since the 1870s by the NSFNC and the NSGGA. Significant amounts of a black powdery material (manganese hydroxide?) have been developed at the junction.

This "junction" has been interpreted in many different ways with several different time connotations:

(i) Post-Triassic faulting of (a) Jurassic? (b) Cretaceous? (c) Tertiary? age, or (d) any combination of these ages - part of the fracture complex known as the Red Rock Fault Zone.

(ii) A steep scarp face (a fault-line scarp or a fault scarp or not necessarily related to a fault zone?) cut in Carboniferous rocks with Triassic rocks banked against the palaeolandform, but certainly associated with an unconformity of Trias on Carboniferous developed on rugged relief (see C. B. Wedd in Pocock et al. 1906 p. 56 as well as the most persistent views offered by Challinor 1965, 1970 , 1973, 1978).

(iii) Episodic faulting during the Permian, the Triassic and the Lower Jurassic as the region develops into a Mackenzie-type extensional basin, giving rise to the syndepositional growth of thicker units of the same sedimentary formations in the basin and thinner units of the same age on its flanks (Gale et al. 1984, Whitaker et al. 1985, Evans et al. 1993). The scenario (see Fig. 31) can accomodate many further episodes of post-Lower Jurassic faultinf as in (a) above. Fig. 31 presents the view of Evans et al. 1993.

(iv) Any combinations of the above.

The steep gravity and magnetic gradients across this junction and the "Red Rock Fault Zone" in general do not rule out hypotheses (i) and (iii) but they, and the evidence collected repeatedly on the ground since the 1850s, militate against hypothesis (ii).

The horizon at the base of the Helsby Sandstone Formation , bed (a) above, is now regarded as that which, on seismic evidence collected elsewhere in central Cheshire (Figs 1 & 32), presents an angular unconformity beneath which up to 0.75km of beds, including all the BHSF and the WSF, are cut out (Evans et al. 1993; see Fig. 31). Is the evidence seen by the group supportive, unsupportive or neutral with regard to these ideas?

5. Travel via the A34 to Hollins, Butt Lane; cross the traffic lights and climb Talke Hill for 0.6 km before turning right into Merelake Road. Continue for 1 km over Lower Coal Measures before the Red Rock Fault Zone is once again crossed at a slight bend left in the lane (Fig. 23). Continue past the old Knotty Railway Line, now a pathway Merelake Way, whose embankments used to reveal excellent exposures of New Red Sandstone rocks. Now only the northern end of the cutting shows yellow cross-bedded ?aeolian sandstones cut by many veins bearing barite mineralisation. These rocks are assigned (dubiously?) to the Helsby Sandstone Formation on the new BGS 1:50000 map for the Stoke area. Climb the southeast side of Merelake Hill and park on the left of the lane just beyond Sunny Hill Farm (SJ 811 538).

6. Merelake Hill. Walk the length of the road cutting to the northwest, once idyllic (see Fig. 24b, from Hull 1869) but now

greatly despoiled by road repairers and the dumping of household waste. Try to define and identify distinct rock types (lithofacies) assignable to particular processes (aeolian, fluvial or otherwise) characteristic of particular hypothetical palaeoenvironmental origins. Try to assign the facies to rock formations by reference first to observable data and/or then to hypothetical classification schemes proposed by Hull (1854, 1860, 1869), Gibson (1905, 1925) Poole & Whiteman (1966), Thompson (1970), Warrington et al. (1980), Evans et al. (1993), Warrington in Fraser & Sues (1944), British Geological Survey (1995) and Rees and Wilson (in press). Bear in mind that a major angular unconformity has been proposed on seismic evidence under central Cheshire (Evans et al. 1993; see Fig. 32) and by outcrop mapping in the Mid-Cheshire Ridge at the base of the Helsby Sandstone Formation (Poole & Whiteman 1966). The aim of your investigation is to have yourself appreciate the nature of the many problems relating to the understanding of these facies and formations rather than to propose or impose solutions.

For what it is worth, Hull (1869; see Fig. 24b) thought that the base of the succession was assignable to the Lower Mottled Sandstone (then Permian in age, now named the Kinnerton Sandstone Formation and of ?Permian ?Triassic age and interpreted as aeolian; see Fig. 25) and was succeeded by the Bunter Pebble Beds, now the Chester Pebble Beds Formation (CPBF) (Fig. 27). BGS mapping assigns all the lower beds to the CPBF (fluvial), none to the Wilmslow Sandstone Formation and only the uppermost beds to the Helsby Sandstone Formation (fluvial). Presumably this accords with the idea of an angular unconformity beneath the HSF (Figs 22, 31), though that relationship does not necessarily map out that way.

Look for signs of mineralisation; Wedd (1899) and Gibson (1905) have reported many barite ($BaSO_4$) veins and baryto-celestite (BaSr) $(SO_4)_2$ veins hereabouts. Whence the source of the S? the Ba? the Sr? Under what conditions, processes and at what time(s) did such deposits arise? What is the post-Lower Jurassic history of the basin? Is hydrocarbon genesis implicated in the mineralsiation? Are earthquakes and seismic pumping involved in the emplacement of the mineral veins (Sibson 1975) - recall the writer's address as chairman of the group (1989) and the signs of mineralisation suggested by Naylor et al. (1989).

Note the late Devensian 24000-13000 old glacial till which covers parts of the local area adjacent to the hillock and which was once exposed in the lane cutting to the northwest.

Regain the cars, drive northwestwards down Merelake Road towards Alsager (Fig. 23), reaching a T junction at Oak Farm. Turn left into the Audley Road and drive directly to Audley. Turn right at the T junction in Audley, travel westwards for a quarter of a kilometer and seek to park in front of the Audley Waterworks buildings near Audley Cricket Club.

6. Kent Hill Sand and Gravel Mines (SJ 789 509; see Fig. 26). Walk northwestwards up the hill realising that the gentle slope at the start of the walk may be underlain by the Kinnerton Sandstone Formation (KnSF) (aeolian? Permian? Triassic? Fig. 25) which was observed to be present at the base of the Pero-Triassic succession 4 km away at Heighley Castle Farm (SJ 773 466). The KnSF lies unconformably on the Keele Sandstone Formation (Westphalian D) hereabouts (Fig. 26).

Enter the still-fenced compound of Kent Hill Quarry & Mines, now owned and maintained by Severn Trent Water Plc. Permission to enter the quarry is by courtesy of Ian Blenkinsop (telephone 01782-577777).

The quarry walls and the tunnels and galleries provide unique and relatively good exposures of conglomerate, pebbly sandstone and sandstone dipping gently to the northwest. Members will wish to test whether the lithofacies and palaeocurrents hereabouts, which had been poorly seen earlier at Grotto Wood and Merelake Hill, compare with those superbly exposed at the Play Canyon, Park Hall Country Park (Western Coyney) (Steel and Thompson 1983) or in the Cheshire Basin generally (Thompson 1984) viz:

(a) Red horizontally bedded conglomerate with varying degrees of imbrication, which reveals a palaeocurrent comparable with those seen elsewhere (Fig.27) The deposits represent mostly mid-stream sheet bars developed at high flood discharge in a braided stream environment. Imbricated pebbles dip upstream.

(b) Red cross-bedded conglomerate bearing a palaeocurrent which is compatible with that of (a) above and the regional picture (see Fig. 27). These deposits represent braided river channels infilled by bars made up of sub-aqueous dunes or the avalanche ends of sheet bars.

(c) Red pebbly cross-bedded medium to coarse-grained sandstones, often with basal lag deposits but with comparable palaeocurrents to (a) and (b) above. These deposits are braided river channel-fill bars of similar type but lower energy than in facies (b) above.

(d) Red fine- to medium-grained argillaceous cross-bedded sandstones. These deposits are of similar origin but of much lower energy to those in (b) and (c) above, the finer clay minerals representing episodic settling from suspension onto and into the underwater dune sands.

(e) Red silty micaceous mudstones, present as thin, laterally impersistent units which represent periods of low discharge in the braided river environment when the suspended fines of the very muddy watres settled out into countless abandoned channels and ponds at a variety of levels on the braidplain. Strangely, few of these deposits have ever been seen to be mudcracked - evidently any hot dry seasons did not result in complete cessation of riverflow, so in this respect the rocks of the CPBF are very different to those of the KnSF below or the HSF above. At Park Hall the top of one such unit bears interference wave ripple marks caused by the blowing of strong persistent winds in two directions at right angles at different times. Angular and rounded clasts of mudstone of this facies may be found in each of facies (a) to (d) above as a result of such temporary deposits being torn up, rolled and rounded to vaying degrees by the onset of each fresh flood.

Investigation of the nature and origin of the extraformational pebbles above 16mm in size is always instructive. A useful procedure is to collect 50 pebbles randomly and sort them into kinds so as to ascertain rapidly the overall percentage of the main rock compositions which are present. Then go on to collect and count as diligently as possible the pebbles of granites, porphyries, rhyolites, tuffs, agates, previous quartzitic conglomerates (looking out especially for those which are tourmalinised). Likewise assemble and count different kinds of sandstones, siltstones, cherts (with corals, crinoids, bryozoa of Carboniferous age), orthoquartzites (with brachiopods e.g. Orthids, or trilobites of Palaeozoic age; see Cocks' 1993 studies of the derived fossils of the Budleigh Salterton Pebble Beds). Lastly collect and count the rare schists, mylonites and vein rocks which are not just composed of quartz. No records of derived fossils have yet been reported from the pebbles in the rocks at the localities visited this evening.

In the distant past, before cross-bedding was routinely used as a means of checking sourcing directions (i.e. the late 1930s) or K-Ar, Rb-Sr age dating became commonplace and indicative of provenance, many eminent geologists argued vehemently for an origin of the extraformational pebbles from the northwest e.g. the Northwest Highlands (Bonney) or the southwest e.g. the Southwest Peninsula (Shrubsole). Palaeocurrent data for the whole region is now available (Thompson 1984) (see Figs. 25 & 27-30) and can be tested against K-Ar dating, 280-290my, of the micas in the sandstones (Fitch et al. 1966) (c. 300my when suitably adjusted for the most recent decay constants).

The palaeocurrent data for Kent Hill, as yet uncollected, is likely to fit the regional pattern very well. A source of the pebbles of the CPBF in the Southwest Peninsula, the English Channel and Northern France seems to be well justified. (Suitable micaceous horizons for age-dating have not been tested at Park Hall or hereabouts so we have to rely on data for the Macclesfield area in order to make comparisons and tests).

The palaeogeography of Chester Pebble Beds times is depicted in Fig. 34 (from Warrington & Ivimey-Cook 1992). The source horizons and regions of plate tectonic origin of the derived fossils in the Pebble Beds at Budleigh Salterton (and by implication those in the equivalent pebble beds of the Midland Counties including the Cheshire Basin) are shown in Fig. 35. The brachiopods, trilobites and trace fossils in the pebbles came from four horizons deposited on a terrane known as Armorica. Two horizons originated in the Ordovician (one of Arenig age identified to the present Grès Armoricain of Brittany-Normandy-Sarthe-Mt Noire; the other of Llandeilian age relating to the Grès de May of the Caen area of Normandy but also comparable with material caught up in tectonic events at Gorran Haven, Cornwall) and two in the Devonian (the lower Lochkovian-Pragian fauna matching those of the Landévennec and Gahard Formations, formerly the Grès à Orthis monnieri, of Brittany; the upper Frasnian one possibly comparable with parts of the Grès de Goasquellou in the Traonliors Formation, 20 km east of Brest). All these deposits are of low-diversity, shallow marine, very mature siliclastic, ?passive margin type, rather like the Stiperstones Quartzites of Arenig age in Shropshire. Their positions in the terrane known as Armorica at various junctures, starting deep in the southern hemisphere in Arenig times c.490 mya, wandering the southern oceans and moving to dock with the southern part of the British Isles (known today as Eastern Avalonia) in early to mid-Devonian times c.385 mya (so as to be available, in what is now the English Channel and Northern France, to be eroded and transported northwards in lower Triassic times some 246 mya), is a most astonishing story (see Cocks 1993 and others).

The history of the mine. This has been researched by Terry Middleton (1986). There is little evidence of mineral extraction on Yates' map of 1775, Teasdale's map of 1832 or the first OS map (1:63360) of 1840. The pioneer 6-inch OS map of 1889 shows a the presence of a magazine (belonging to Riley's, the local gunsmiths). The 1900 and 1925 maps may contain evidence of small-scale sand and gravel operations. In 1929 Charles Edwards of Firs Farm, close by to the northwest, decided to opencast sand and gravel from a pit which grew to be 20m deep. This led to him following the best gravel beds underground to the southeast using hand drilling and blasting. Skilled labourers from local coal mines utilised bobbin powder (gunpowder stuffed into bobbins) and later compressed air drills in order to mine the gravel, so that silicosis soon became a problem amongst the workers. Gravel was transported in and from the mine by waggons which were hauled out of the quarry using a motor car engine. Washing and crushing took place on site and the product was sold to the Potteries Water Board for the construction of manholes. Ownership passed on to Messrs Farrington and Ellerton whilst Charles Edwards retained the right to be paid a royalty of 6d per ton. All working ceased in 1945 and the land was sold to the Potteries Water Board for £200 at a time when the Cooper's Green reservoir, still standing adjacent to the southwest, was constructed c.1950. The mine buildings and plant were eventually destroyed by 'Blaster' Bates and the original quarry, lying to the northwest in the farmer's field, was infilled so that now its position can hardly be identified.

Middleton (1986) has also surveyed and mapped the existing mine tunnels and galleries. This was very necessary because, until recently, the latter have been used as an emergency overflow facility for the waterworks reservoir in the event of pumping valve failure - hence the need for a steel security fence and locked gate around the former quarry in view of the remote possibility that a member of the public might be exploring the deepest and furthest galleries of the mines at a time when the the safety valves of the pumps failed and the mines were suddenly flooded.

Safety matters. The mine has large, strong, supporting pillars and its galleries are constructed along the strike and are therefore horizontal and easy to walk. Only the entrance passages are inclined but they are not steep. They are cut on the tops of sandstone beds of facies (d) mentioned above. Although the roofs of the levels are in good condition and there are few areas of collapse, members are asked not to enter any entrance passages or levels whilst they are taking part in the present excursion.

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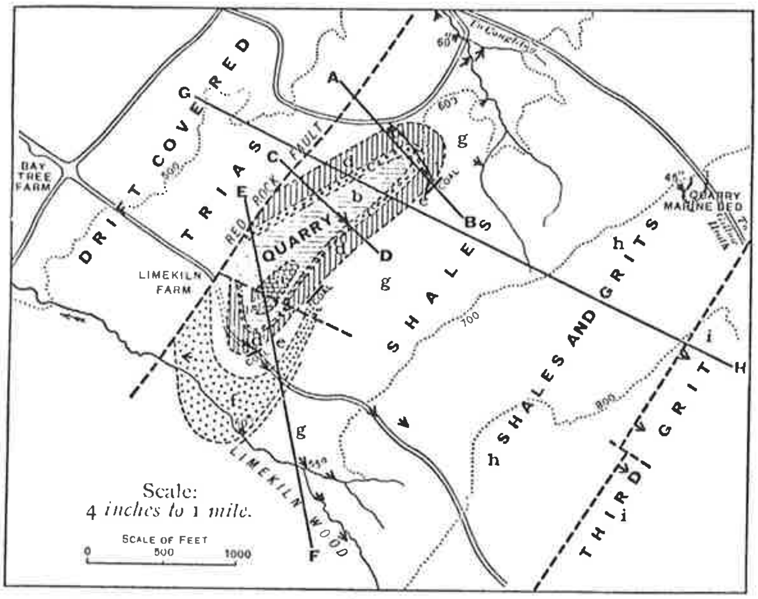
THE GEOLOGY OF THE ASTBURY ANTICLINE (GIBSON & HIND 1899 Q.J.G.S)

Fig. 2.—*Sketch-map of a portion of Congleton Edge.*



a = Limestone.
b = Shales and thin limestones.
c = Agglomerate and tuff.
d = Shales, limestones, and tuffs.
e = Shales with coal.
f = Grit.
g = Shales and thin earthy limestones.
h = Shales and grit.
i = Third Grit.

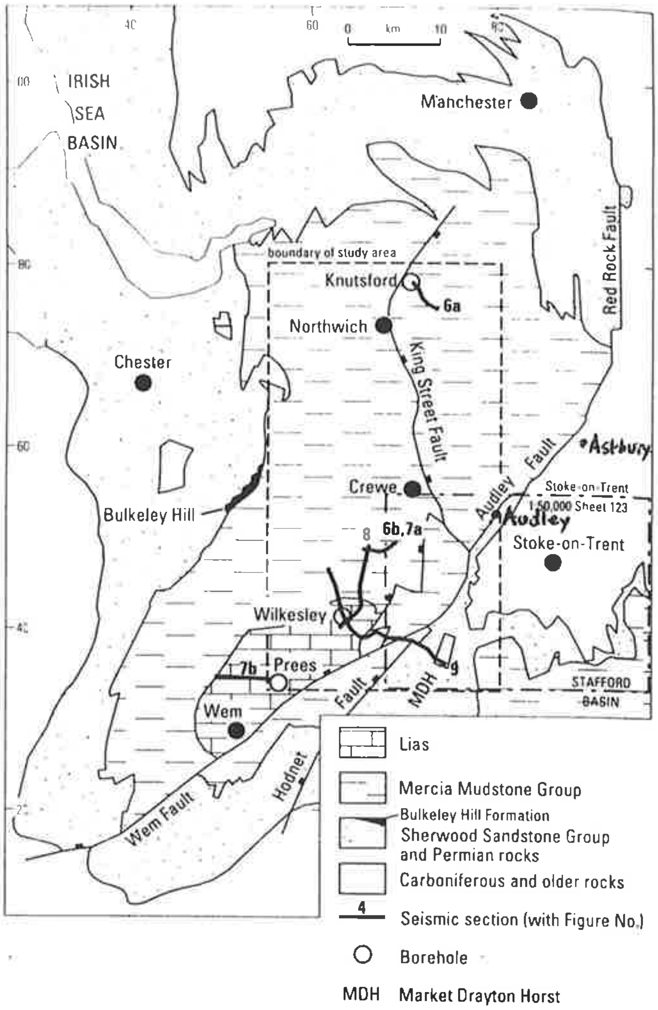
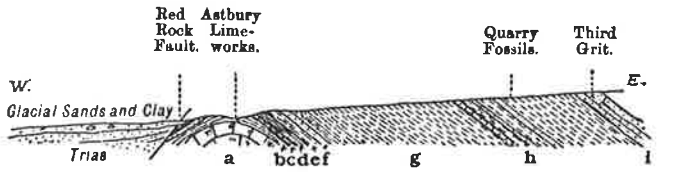


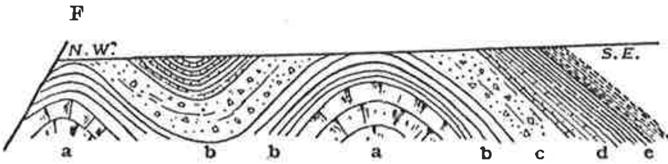
Fig. 1. Geological location map of the Cheshire Basin with approximate locations of seismic reflection lines (from Evans, D.J et al. 1993)

Fig. 3 —*Section along GH (see map, fig. 1, p. 548) on the scale of 4 inches to the mile.*



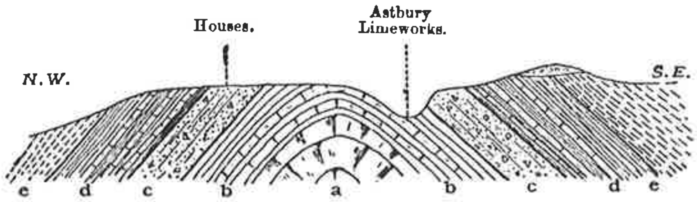
a = Limestone.
b–f = Shales, limestones, agglomerates, tuffs, and grit.
g = Shales and thin earthy limestones.
h = Shales and grit.
i = Third Grit.

Fig. 4.—*Section along line AB (see map, fig. 1, p. 548) on the scale of 25 inches to the mile.*



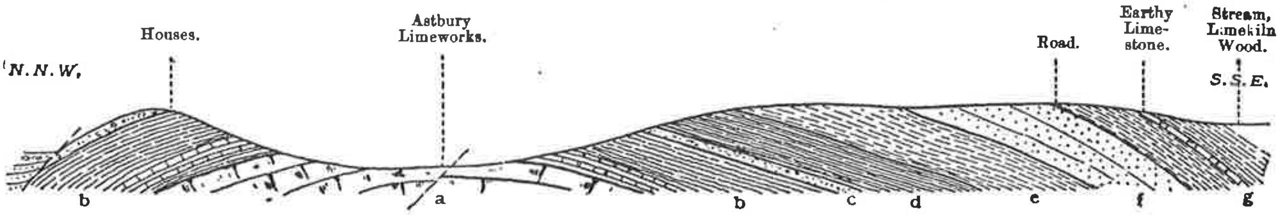
a = Limestone.
b = Shales and thin limestones.
c = Agglomerate and tuff.
d = Shales, limestones, and tuffs.
e = Shales with coal.
F = Red Rock Fault.

Fig. 5.—*Section along CD (see map, fig. 1, p. 548) on the scale of 25 inches to the mile.*



a = Limestone.
b = Shales and thin limestones.
c = Agglomerate and tuff.
d = Shales, limestones, and tuffs.
e = Shales with coal.

Fig. 6.—*Section along line EF (see map, fig. 1, p. 548) on the scale of 20 inches to the mile.*



a = Limestone.
b = Shales and thin limestones.
c = Tuff.
d = Shales.
e = Shales with coal.
f = Grit.
g = Shales and thin earthy limestones.

Fig. 7


LKM
Several hundred feet not exposed due to faulting
KS
PB
Not exposed due to faulting and unconformity
ROWHURST 6 (in two leaves)
BURNWOOD 2
Presumed horizon of Gin Mine Marine Band
MOSS 4
Moss Cannel Marine Band on MOSS CANNEL 2
Sandstone YARD 2½
RAGMAN (Ra) 3
ROUGH SEVEN-FEET (R7-FT) 3
HAMS (H) 6-6½
COAL Thin
BELLRINGER (Be) 6-7
Sandstone
TEN-FEET (10-FT) 6
Sandstone
BOWLING ALLEY (BA) 4½
HOLLY LANE (HL) 4½
HARD MINE (Hd) 4-6
NEW MOSS (NM) 2
FLATTS 2
Sandstone
BANBURY (Ba) 3-6½
COAL Thin
COCKSHEAD (Co) 7-8½
Sandstone
BULLHURST (Bu) 4-6
Sandstone
WINPENNY (Wi) 2½-3¼
Sandstone
Sandstone
DIAMOND 2-3
SILVER 2¼
BRIGHTS 2¼-3
Sandstone
KING (K) 2½-3
Sandstone
Whetstone
CONJECTURAL
RED ROCK FAULT
MOW COP FAULT
HUMMOCKY TOPOGRAPHY
CHESHIRE
Lime Kiln Wood
Gillow Heath
86
88
85
60
59

ASTBURY LIMESTONE

There are now no remaining exposures of the Astbury Limestone, but extensive collections have been made in the past. A brief list of fossils obtained from the Carboniferous Limestone at Astbury is given by Hind (1910, p. 574), and the fossils from Astbury in the Geological Survey and Museum Collection and in another at Keele University, mostly made by Mr. J. T. Wattison, have been examined. Details of the horizons represented are generally missing or inadequate, but probably all the following come from the main body of the limestone: the corals have been named by Mr. M. Mitchell; the other forms by Dr. W. H. C. Ramsbottom.

Corals. **Auloclisia mutata* Lewis, *Caninia juddi* (Thomson), **Caninophyllum archiaci* (Milne Edwards and Haime) *?monense* Lewis, *Chaetetes depressus* (Fleming), *Clisiophyllum ingletonense* Vaughan, *C. keyserlingi* M^c^Coy, **Dibunophyllum sp. ?bourtonense* Garwood and Goodyear, *Fasciculophyllum densum?* (Carruthers), *Heterophyllia sp.*, **Koninckophyllum scarlettense* Lewis, **K.* cf. θ Vaughan, *Lithostrotion martini* Milne Edwards and Haime, *L. sp.* (*arachnoideum* M^c^Coy sp. group), *Michelinia tenuisepta* (Phillips), *Syringopora sp.*, *Zaphrentites enniskilleni* (Milne Edwards and Haime), *Z. ashfellensis* (Lewis) towards *derbiensis* (Lewis). In addition, Smith and Gullick (1925) figured *Emmonsia parasitica* (Phillips) from Astbury.

Brachiopods. *Antiquatonia* cf. *hindi* (Muir-Wood), *Buxtonia sp. nov.* [very large form], '*Camarotoechia*' *sp.*, *Echinoconchus punctatus* (J. Sowerby), *Eomarginifera sp.*, *Gigantoproductus sp.* [thin-shelled], *Girtyella? sacculus* (J. de C. Sowerby), *Linoproductus sp.* [tumid, incurved, lacks rugae on ears], *Plicochonetes sp.*, *Pugnax acuminatus* (J. Sowerby), *P.* cf. *reniformis* (J. de C. Sowerby), *Pustula magnituberculata* Thomas, *P. pustulosa* (Phillips), *Schizophoria resupinata* (Martin), *Schuchertella* aff. *fascifera* (Tornquist), *Spirifer striatus* (Martin), *S. trigonalis* (Martin). Hind (1910) recorded *Megachonetes siblyi* (Thomas) [as *Chonetes compressa* Sibly], but there are no specimens in the collections examined.

Molluscs. *Bellerophon* cf. *sowerbyi* d'Orbigny, *Bucanopsis* cf. *exilis* (de Koninck), *Naticopsis sp.*, *Straparollus sp.*, *Parallelodon bistriatus* (Portlock); orthocone nautiloid indet. In addition Hind (1920) recorded *Koninckioceras ingens* (Fleming) from Astbury.

The corals, particularly those marked above with an asterisk, indicate a D_1 age. The brachiopods support this conclusion, and it is notable that most of the species are common in the D_1 reef-beds of Derbyshire, and seem to indicate that at least some of the limestone is of reef phase. The extensive coral fauna suggests that full reef conditions were not developed, or were only briefly maintained. W.H.C.R.

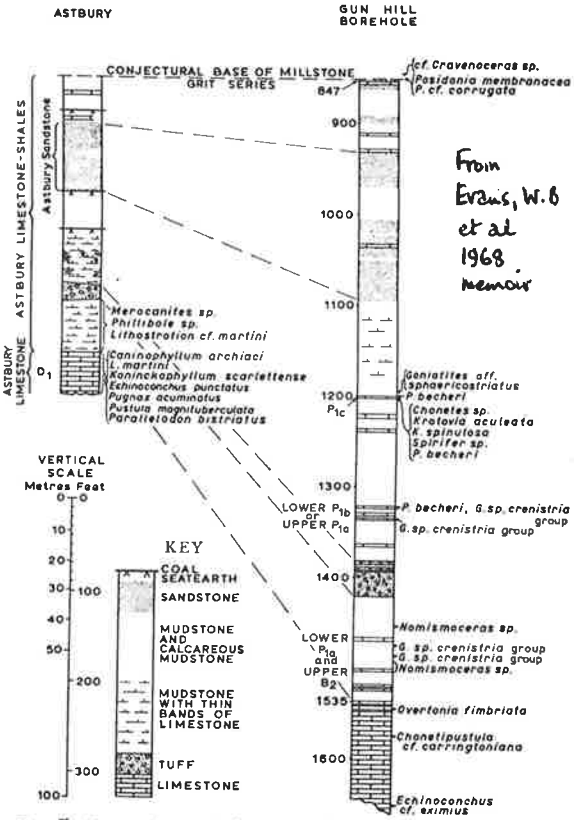


FIG. 8 *Comparative vertical sections of the Carboniferous Limestone Series at the Astbury Inlier and in the Gun Hill Borehole. Figures on the left of the Gun Hill section denote depths in feet below surface. The names of fossils from the Gun Hill Borehole are quoted from Hudson* (in Hudson and Cotton 1945, *pp. 321-5*)

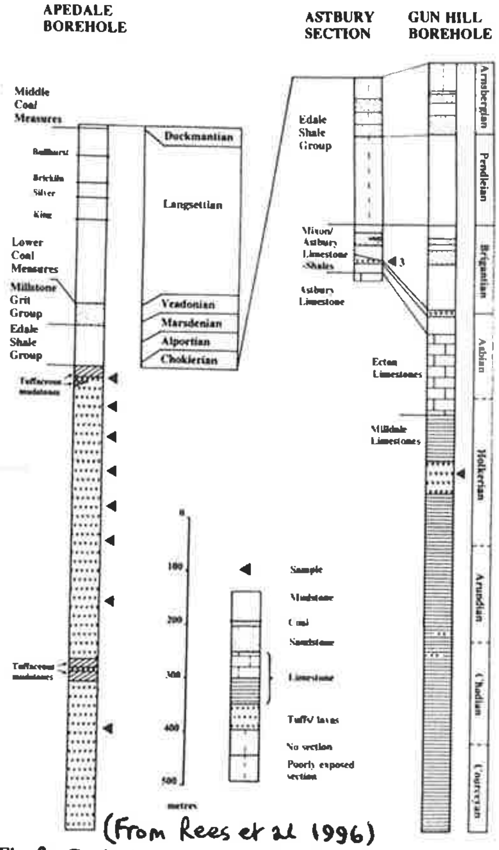
(From Evans et al 1968 p. 8)

ASTBURY LIMESTONE-SHALES

The shales and thin limestone beds above the main limestone at Astbury Quarry have provided an interesting fauna, including the following, which are again consistent with a D_1 horizon: *Pleurocrinus grandis* Wright [F. W. Cope coll., now in Manchester Museum, No. L. 12249], *Orbiculoidea nitida* (Phillips), *Merocanites sp.* [figured by Hind 1902, Pl. 2 fig. 11, and 1907, pl. 14, fig. 11, as *prolecanites compressus*, but the specimen, British Museum (Natural History) C. 28495, shows that the suture was inaccurately figured], *Phillibole sp.* [specimens B.M. (N.H.) In. 22855–7], *Acanthodes sp.*, *Cladodus sp.* and *Orodus elongatus* Davis [these three fish were recorded by Wellburn (1902, 1903) as from Astbury Quarry, but Hind (1904, p. 178) indicated that they were associated with the *Merocanites* in the shales above the limestone]. Hind (1910, p. 574) also recorded Cyathaxoniid corals from these beds, but specimens have not been re-examined.

W.H.C.R.

The best section visible at the time of resurvey was in a gully cut into the south-eastern face of the quarry [8619 5921] where beds lying apparently near the base of the tuffaceous group were exposed. The following detailed section was measured by Mr. D. Thomas:



(From Rees et al 1996)

Fig. 9. Geological logs of the Apedale Borehole (by A. A. Wilson), and the Dinantian and early Namurian sequences exposed at Astbury and recorded in the Gun Hill Borehole (see Fig. 10 for locations).

	ft	in.
Mudstone, grey .. .. about	6	0
Mudstone, brown .. .. about	2	0
Limestone, reddish grey		6
Not exposed, probably limestone ..	2	0
Limestone, dark grey and shaly; thin partings of shaly limestone ..	2	4
Mudstone, calcareous, grey; several bands of yellow-brown tuff ..	2	7
Mudstone, tuffaceous, yellow-brown	2	6
Limestone, grey, crinoidal; partings of tuffaceous mudstone	1	0
Tuff, yellow		1
Mudstone, grey, shaly		2
Limestone, grey, crinoidal ..		6
Mudstone, tuffaceous, yellow ..		4
Limestone, black		6
Mudstone, tuffaceous, yellow, with a little red staining, thin partings of gypsum		7
Limestone, dark grey		4
Tuff, calcareous, yellow-brown; poorly preserved crinoid debris; *Lithostrotion* cf. *martini;* gastropods; trilobite pygidium	3	0
Tuff, agglomeratic	1	3
Limestone, tuffaceous, dark grey ..		8
Mudstone, calcareous, grey, reddish purple in bottom 1½ ft	3	9½
Limestone, grey		4½
Mudstone, grey, silty, calcareous ..	3	3
	33	9

In a stream [8642 5956], 250 yd N. of the quarry, a few feet of alternations of pale grey tuffaceous limestone and yellow-brown tuff are visible, lying in the same general part of the sequence. The exposure yielded *Lithostrotion* cf. *martini*, *Antiquatonia sp.*, '*Camarotoechia*' *sp.*, *Eomarginifera sp.*, *Reticularia sp.*, costate Productid fragments, Orthotetid fragments, smooth Spiriferid fragments, *Hypergonia sp.*, gastropods indet., cf. *Parallelodon bistriatus*, lamellibranch juv. and *Liroceras?* W.B.E.

The Apedale tuffs, North Staffordshire: probable remnants of a late Asbian/Brigantian (P1a) volcanic centre

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From STROGEN, P., SOMERVILLE, I. D. & JONES, G. LL. (eds), 1996, *Recent Advances in Lower Carboniferous Geology*, Geological Society Special Publication No. 107, pp. 345–357.

Astract: A borehole sunk in 1920–21 at Apedale, North Staffordshire, unexpectedly proved a tuff-dominated sequence, at least 840 m thick, below a thin cover of Silesian sedimentary rocks. The tuffs were initially interpreted as Dinantian in age. However, there are similarities of form and lineament between an aeromagnetic anomaly centred upon Apedale and anomalies in the Welsh Marches associated with Neoproterozoic (Uriconian) rocks, suggesting that Neoproterozoic rocks occur at Apedale and that the tuffs in Apedale Borehole might also be of this age. Recent modelling of geophysical data shows that Apedale is underlain by two (magnetic) volcanic bodies – a deeper ridge of probable Uriconian rock, and a shallower, broadly stratiform body which includes the tuffs in the Apedale Borehole. Comparison of the tuffs at Apedale with others in the region suggests that they are of P1a (late Asbian to early Brigantian) age. Although our knowledge of the extent of the Apedale tuffs is poor, their thickness shows that they erupted from one of the largest centres of Dinantian volcanism in central England. The trace element geochemistry is very similar to that of Dinantian volcanic rocks in southwest England.

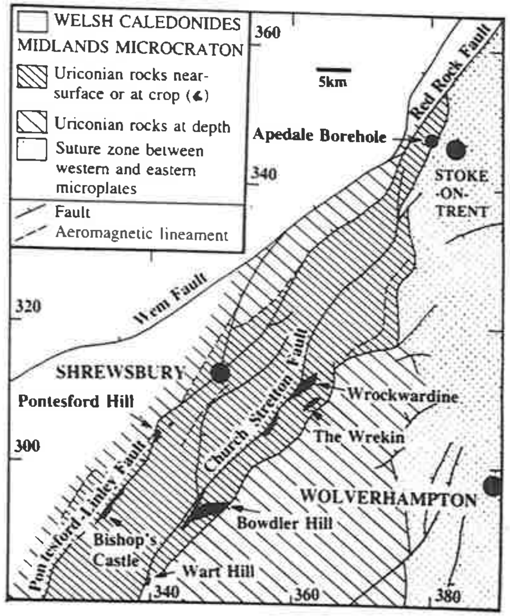


Fig.12. Map of the same region as that of Fig. 4, showing the main geological features of the western microplate of the Midlands Microcraton. Location of the figure and the outline of the microcraton are shown in Fig. 1.

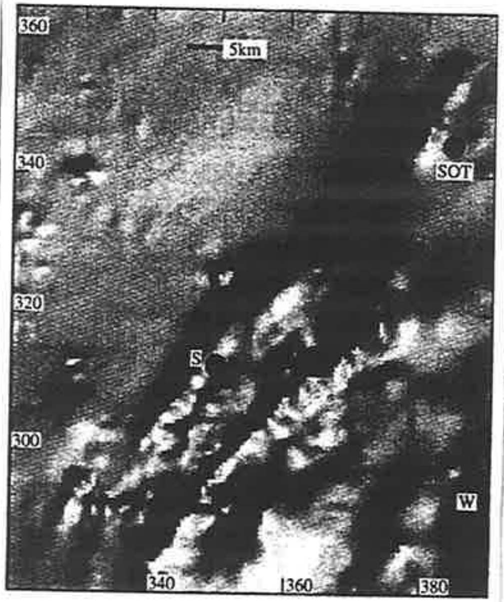


Fig.13. Shaded relief plot of the aeromagnetic data for the region between Apedale and the Welsh Marches. In this shaded relief plot the magnetic anomalies appear as a pseudotopography which have been illuminated from the southeast to enhance lineaments. The position of the Apedale Borehole is shown in Fig. 5. SOT, Stoke-on-Trent; S, Stafford; W, Wolverhampton.

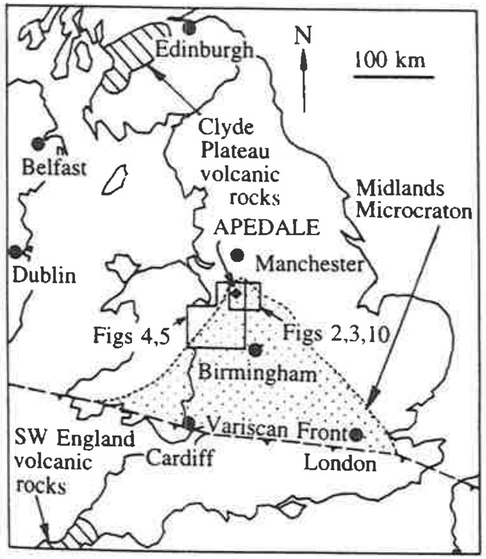


Fig.10. Map showing the location of Apedale, and other figs and sites referred to in the text. The extent of the Midlands Microcraton is shown as a stippled area.

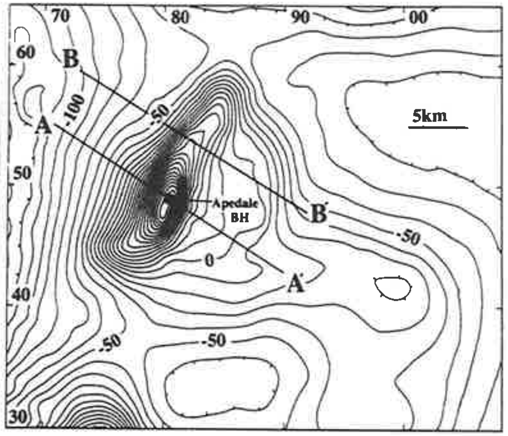


Fig.14. Detailed aeromagnetic map of the area around Apedale (map covers the same area as Fig. 2). The lines show the positions of aeromagnetic profiles in Fig. 6. The aeromagnetic data were obtained by surveys flown in 1955 at 305 m mean terrain clearance, with E–W flight lines at a spacing of 1.61 km and N–S tie lines with a spacing of 9.66 km. Ticks towards magnetic lows.

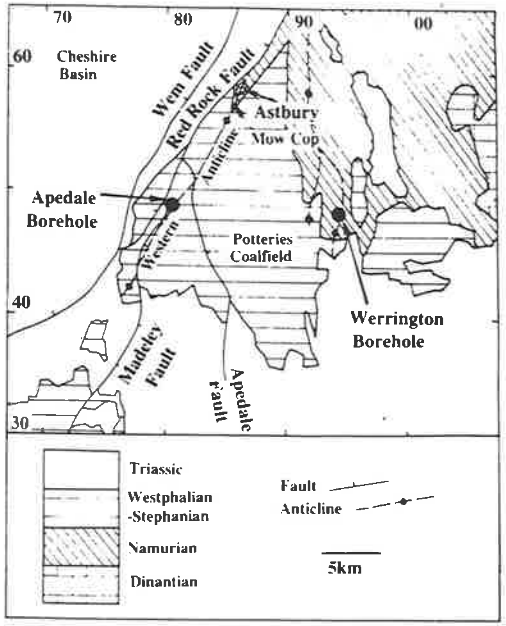


Fig.11. Geological map of the area around Apedale.

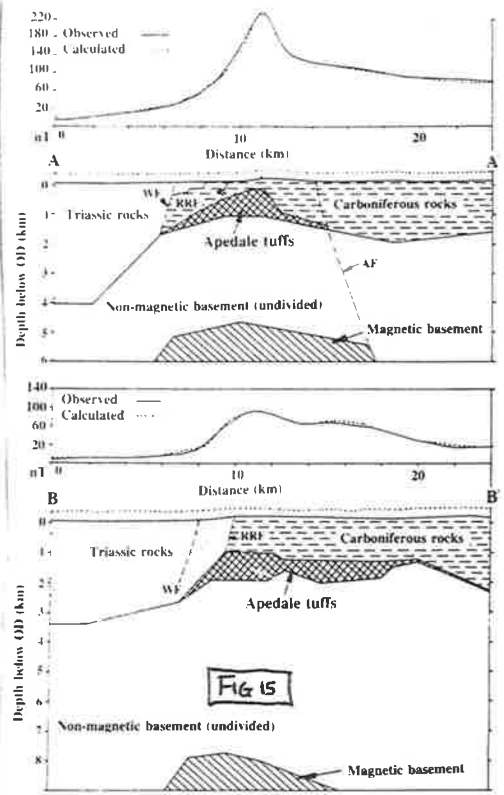


Fig.15 Observed aeromagnetic profiles and models based on interpretations assuming finite strike extents. Locations of profiles A–A′ and B–B′ are shown in Fig. 3. Susceptibilities: Apedale tuffs 0.02 SI, magnetic basement (Uriconian) 0.025 SI; remainder 0.00 SI. The thickness of Triassic and Carboniferous rocks is based on geological evidence. The Carboniferous rocks shown are mostly Silesian; the base of the Dinantian sequence is uncertain. BH, Apedale Borehole, WF, Wem Fault, RRF, Red Rock Fault, AF, Apedale Fault.

3.

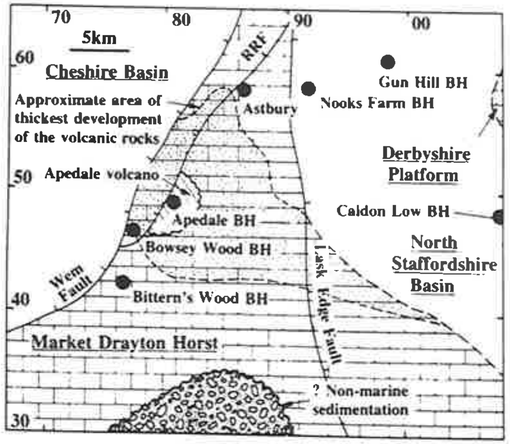


Fig. 16. Map showing the Dinantian and early Namurian setting of the Apedale area (area is the same as that shown in Figs 2 and 3). BH, Borehole; RRF, Red Rock Fault. Brick ornament represents area of the structural block. Shaded area is the postulated extent of thick volcanic rocks. Tick marks indicate the downthrown side of faults.

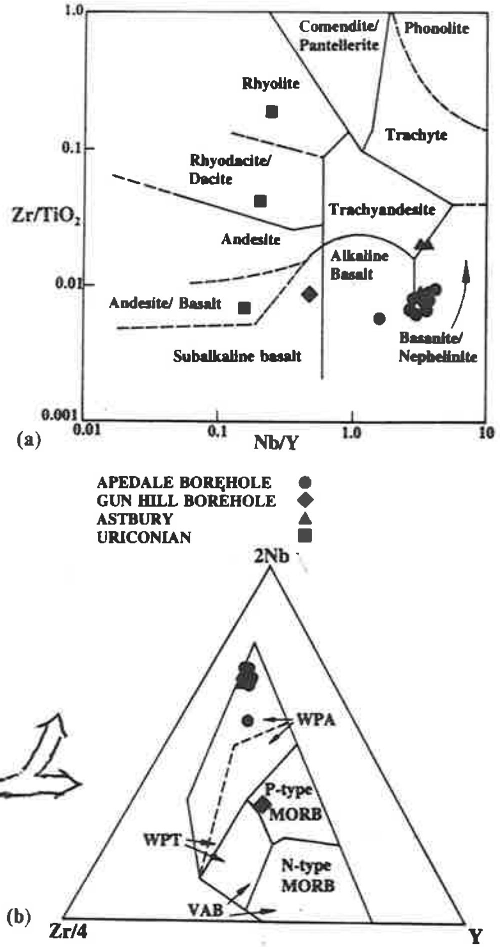


Fig. 17. Element discrimination diagrams. (a) Trace element data plotted on the Zr/TiO$_2$ v. Nb/Y diagram of Winchester & Floyd (1977). Uriconian data from Pharaoh *et al.* (1987*b*). (b) Trace element data plotted on the Nb-Y-Zr diagram of Merchede (1986). WPA, within-plate alkaline basalt; WPT, within-plate tholeiite; P-MORB, Plume-modified mid-ocean ridge basalt; N-MORB, normal mid-ocean ridge basalt; VAB, volcanic arc basalt.

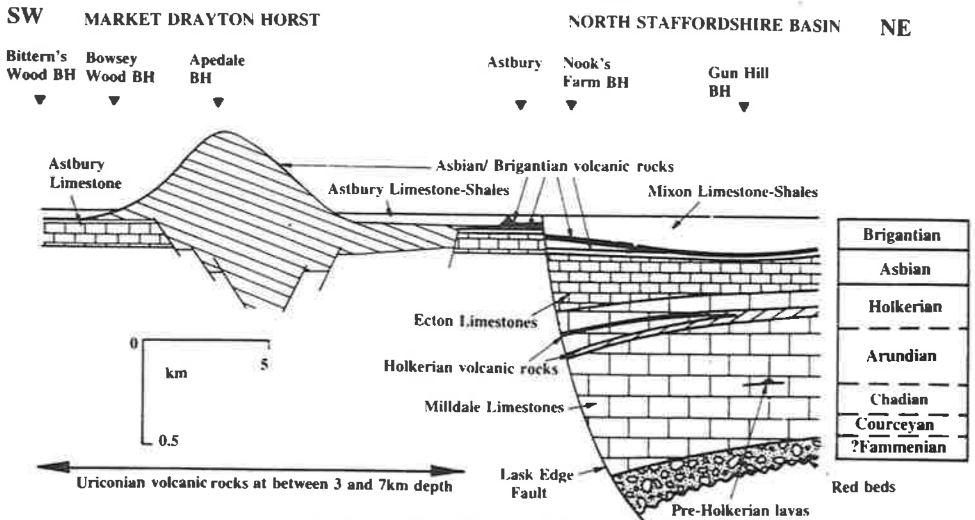


Fig. 18. Model showing the proposed relationship of the Apedale Tuffs with volcanic rocks in the North Staffordshire Basin. Note: the model represents the setting late in the Dinantian; the Astbury Limestone Shales were eroded in the area of Bowsey Wood and Bitterns Wood boreholes prior to Namurian sedimentation.

Figure 19 Bouguer gravity anomaly map of the Cheshire Basin (calculated against IGF 1930, relative to Pendulum House, Cambridge)

From Thompson (1984 p.29)

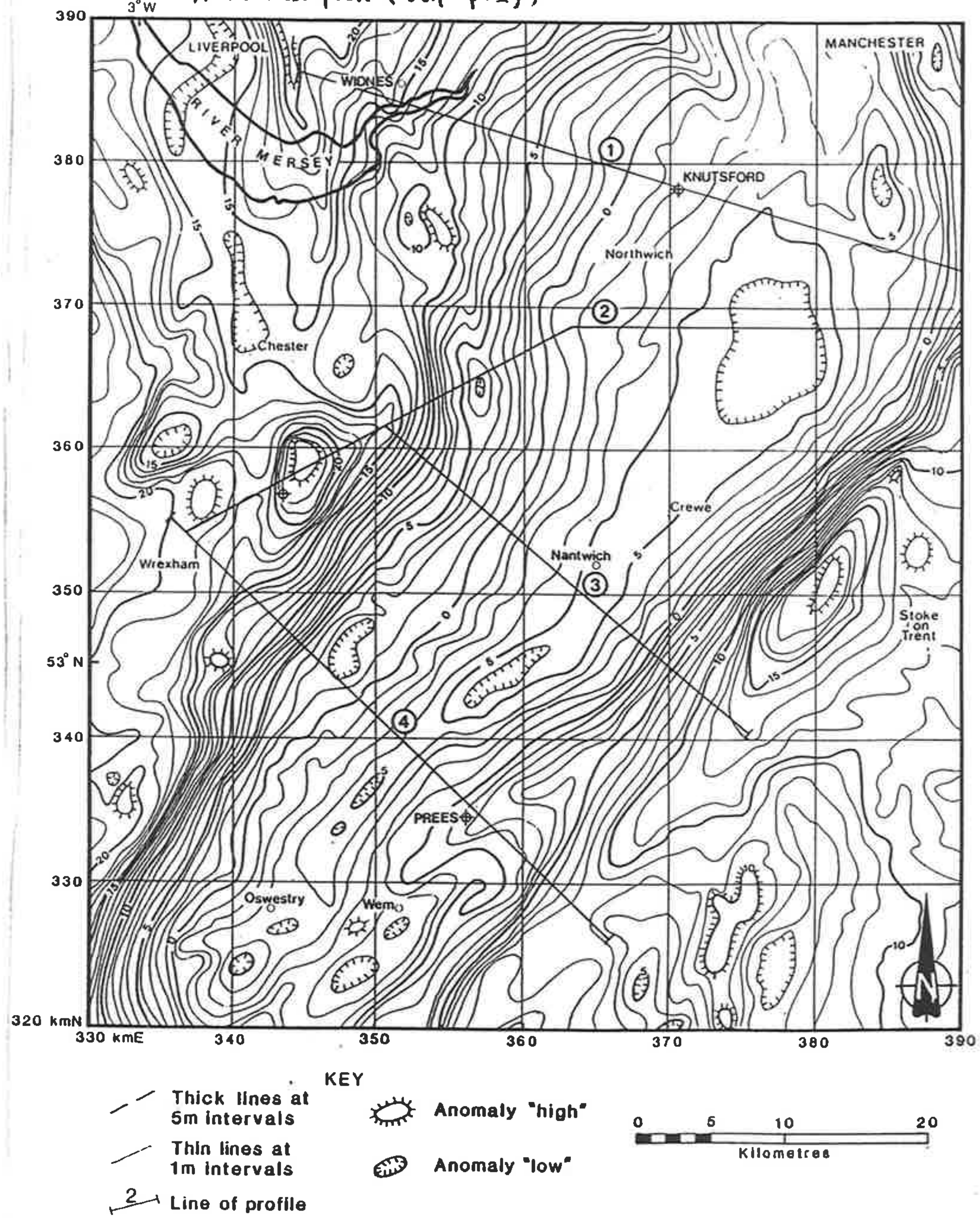


Figure 20 Structure contour map of the base of the Permo-Triassic in the Cheshire Basin
From Thompson D.B. (1984 p. 31) (After Gale et al. 1984)

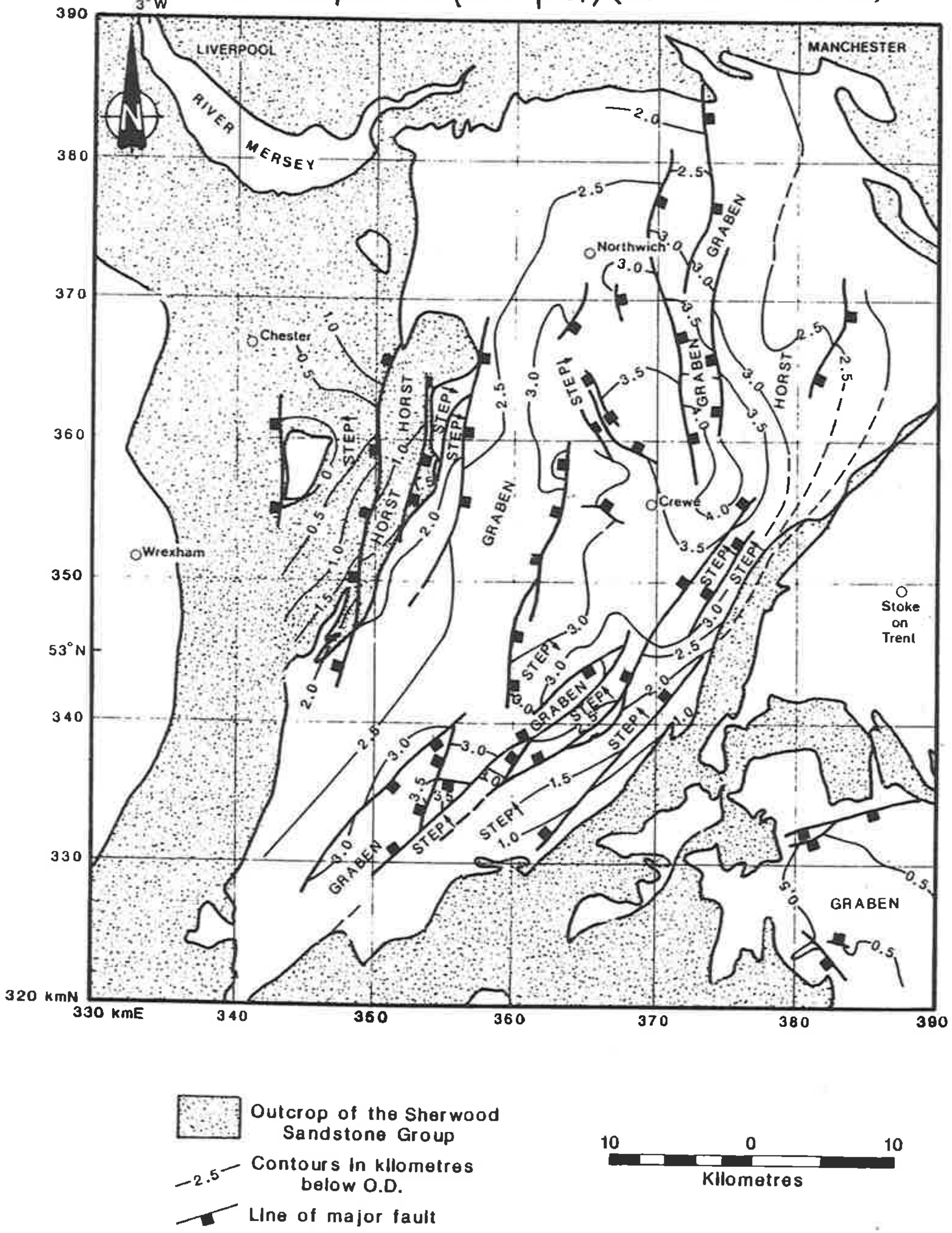
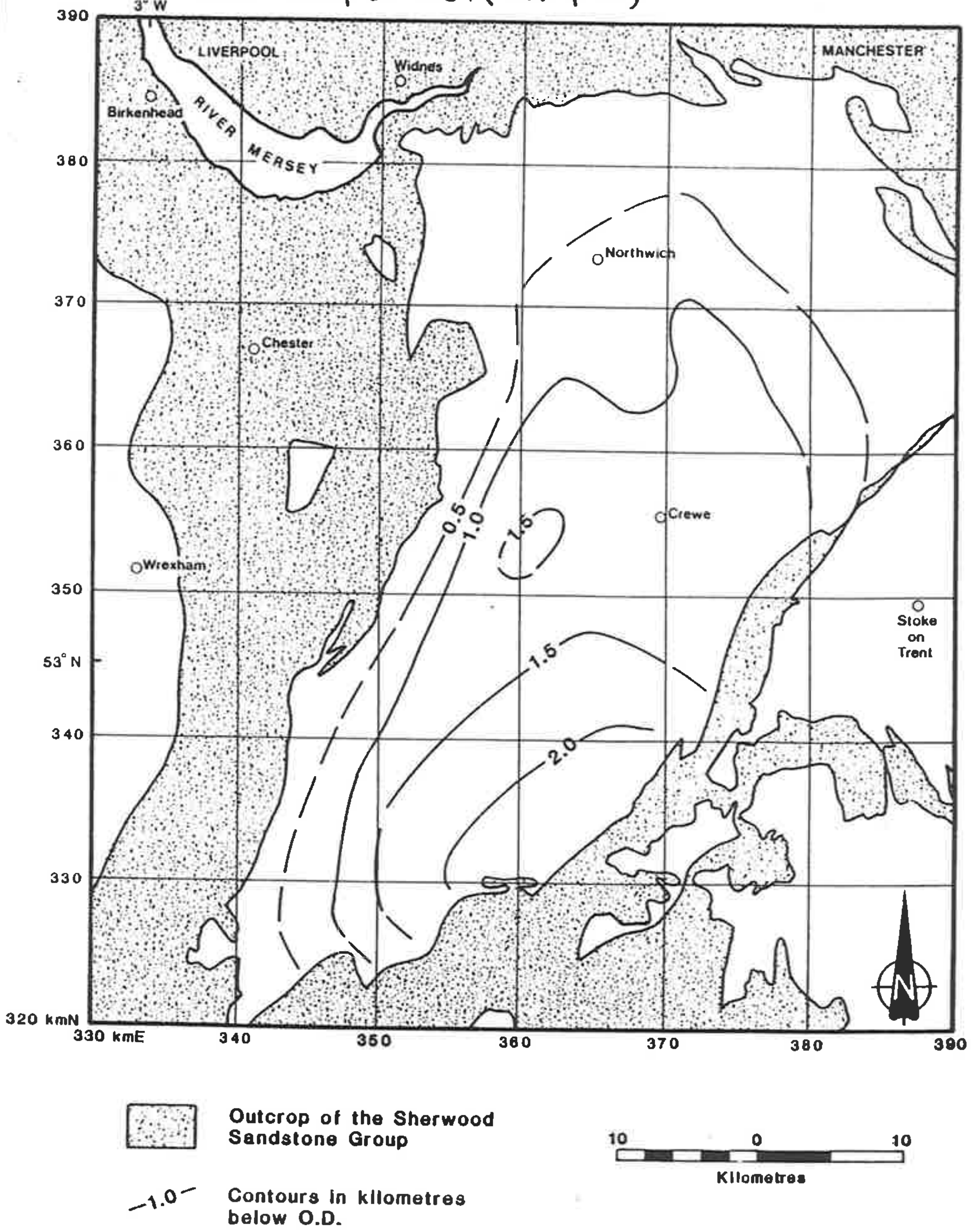
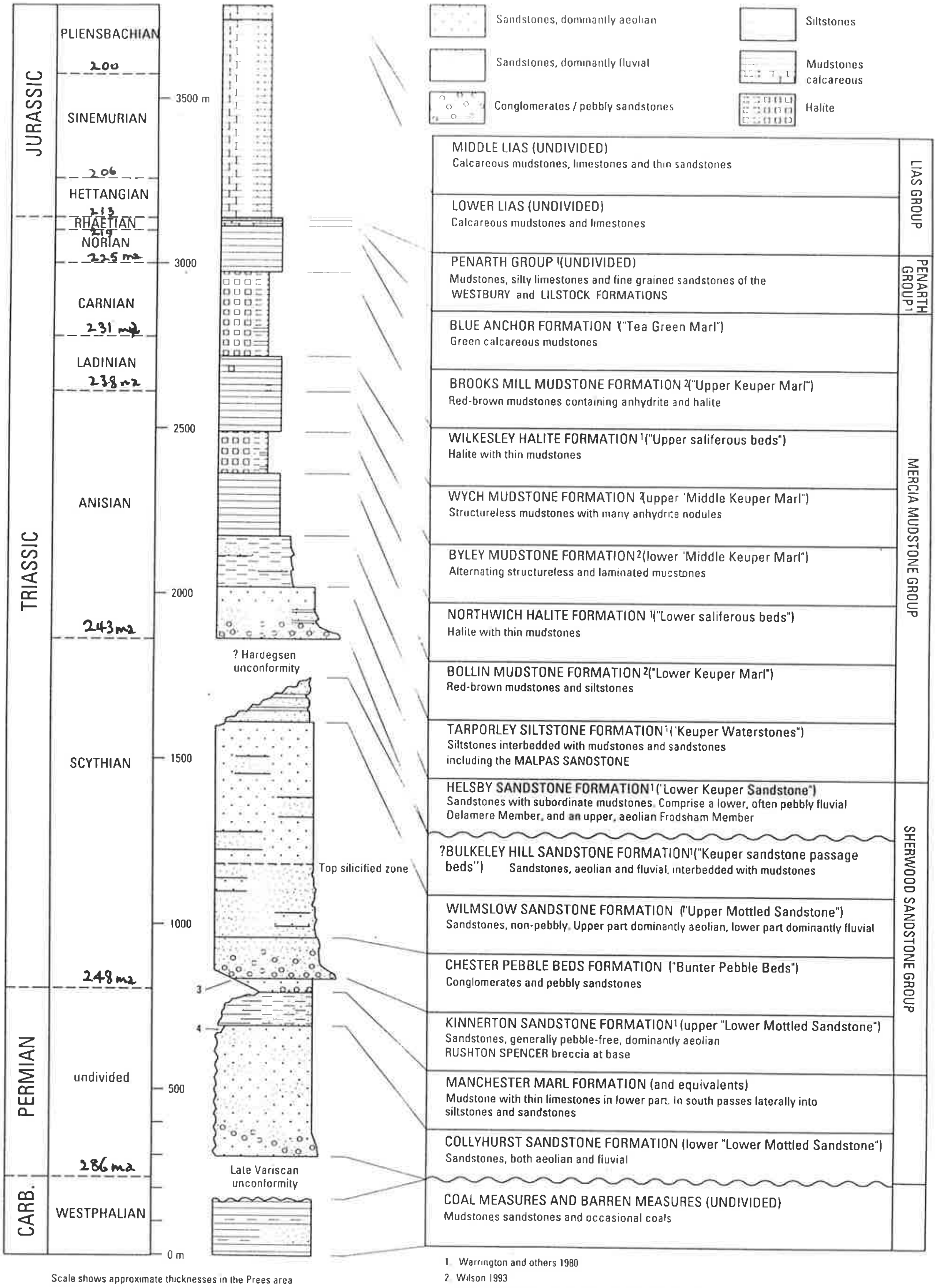


Figure 21 Structure contour map of the top of the Tarporley Siltstone in the Cheshire Basin
From Thompson D.B. (1984 p. 33)



6

From Evans D.J et al. (1993)



1 Warrington and others 1980
2 Wilson 1993
3 Local unconformity on footwall blocks of the Wem-Red Rock Fault System
4 Local unconformity, North Cheshire Basin

Fig. 12. Generalized vertical section and litho-stratigraphy of the study area (details of the ages for the Helsby Siltstone, Tarporley Siltstone, Bollin Mudstone and Northwich Halite formations and the Wych and Byley Mudstone formations, from Wilson (in press) and Benton *et al.* (in press)).

map being redrafted

Figure 24 Generalised stratigraphic succession and environments of deposition. A. Possible environments. B. Lithology. C. Stratigraphic divisions. (old terminology in brackets)

(From Thompson. D B 1984 p. 13 with additions)

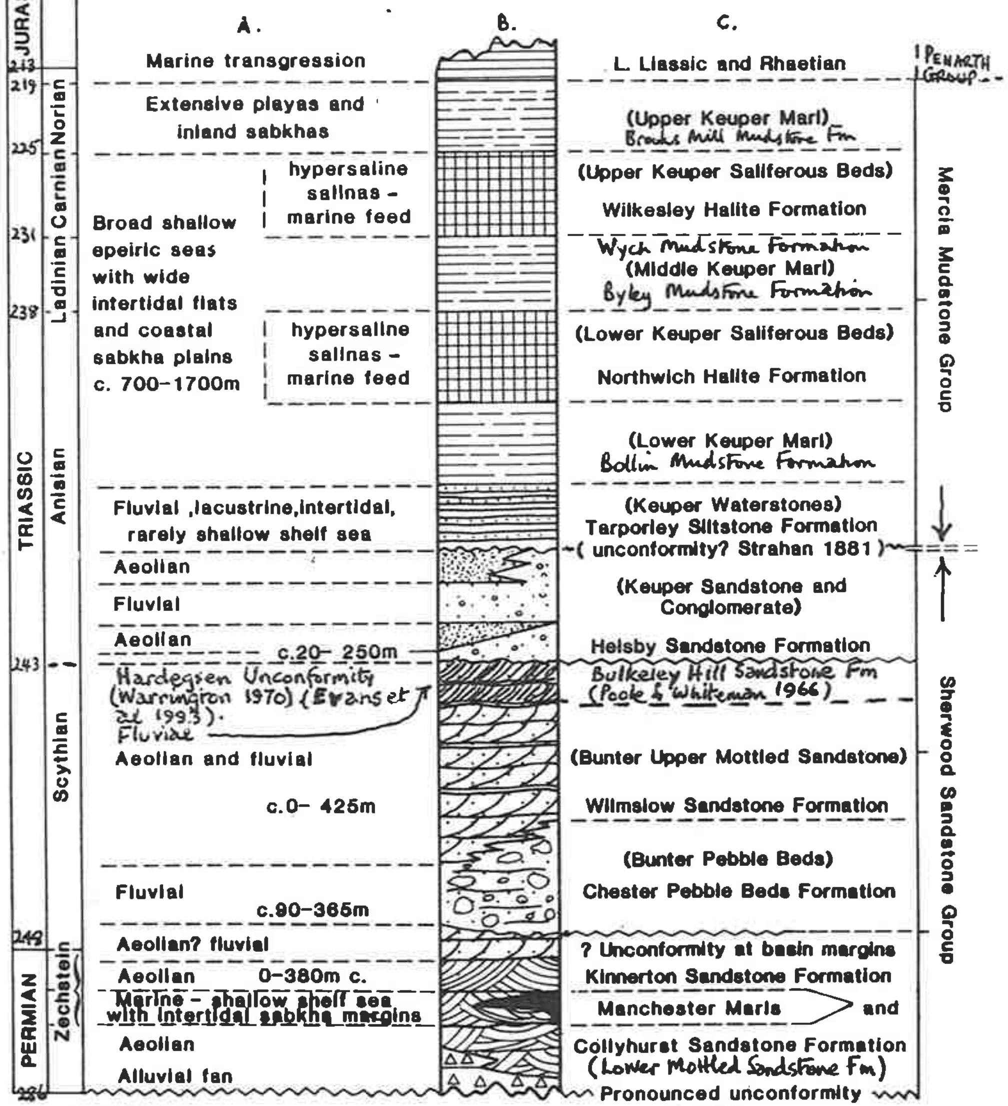


Fig 24B SECTION THROUGH MERELAKE HILL, STAFFORDSHIRE.

From HULL, E. (1869) p. 42 Fig. 20

Lower Mottled Sandstone. Conglomerate beds.

Figure 25. Palaeocurrents: Collyhurst, Kinnerton and Bridgenorth Sandstones.

From Thompson D.B. (1984 p. 42)

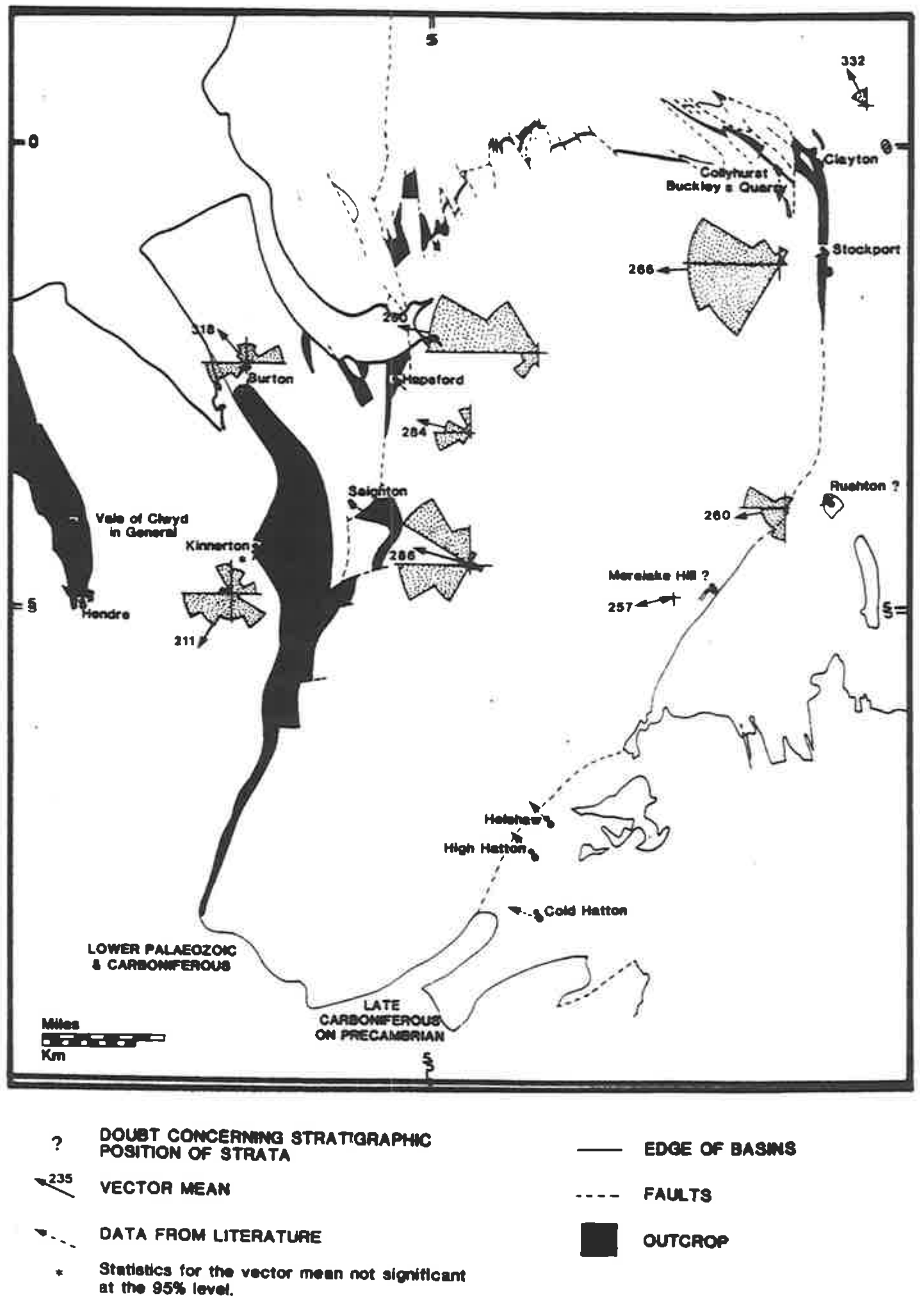
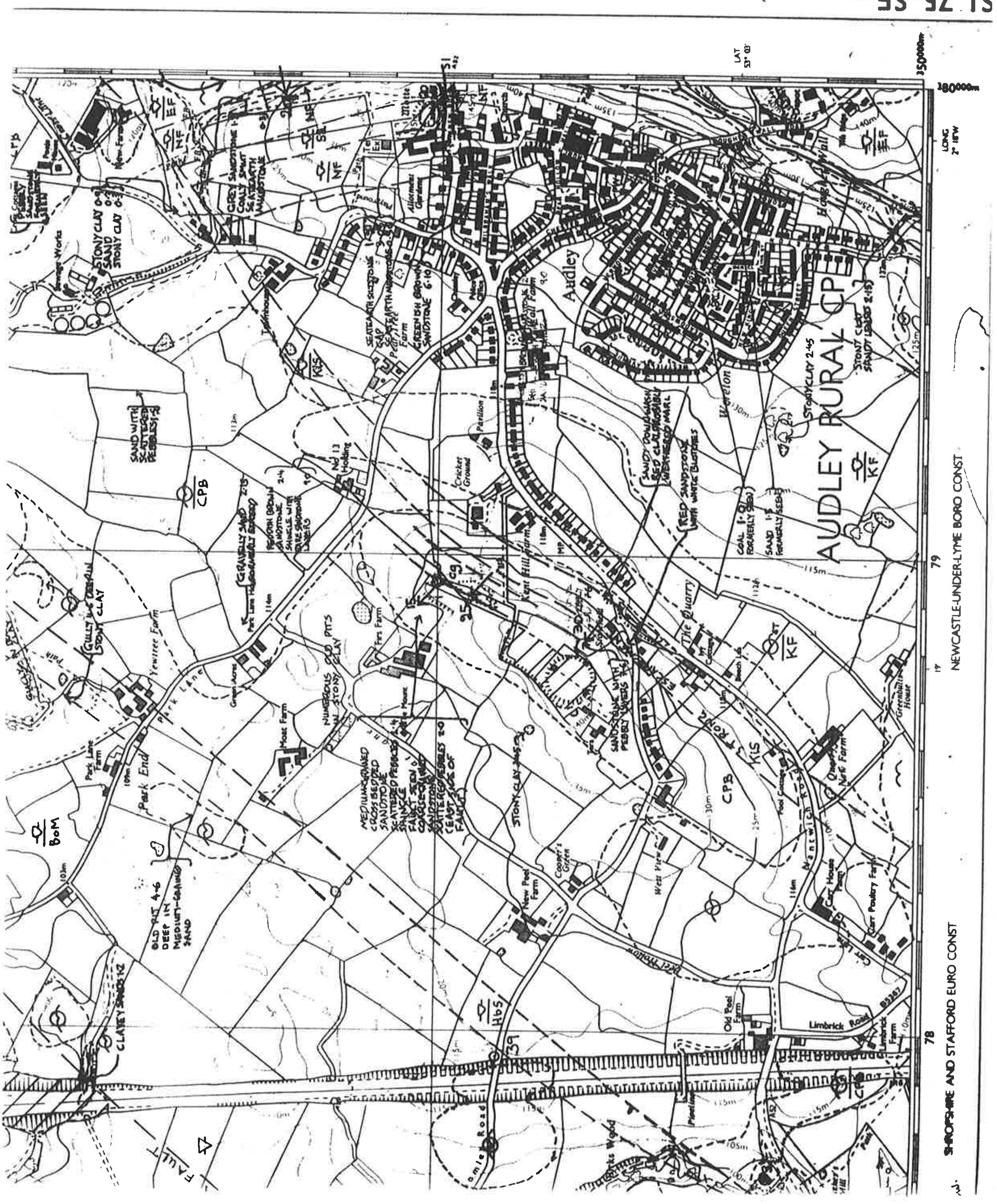


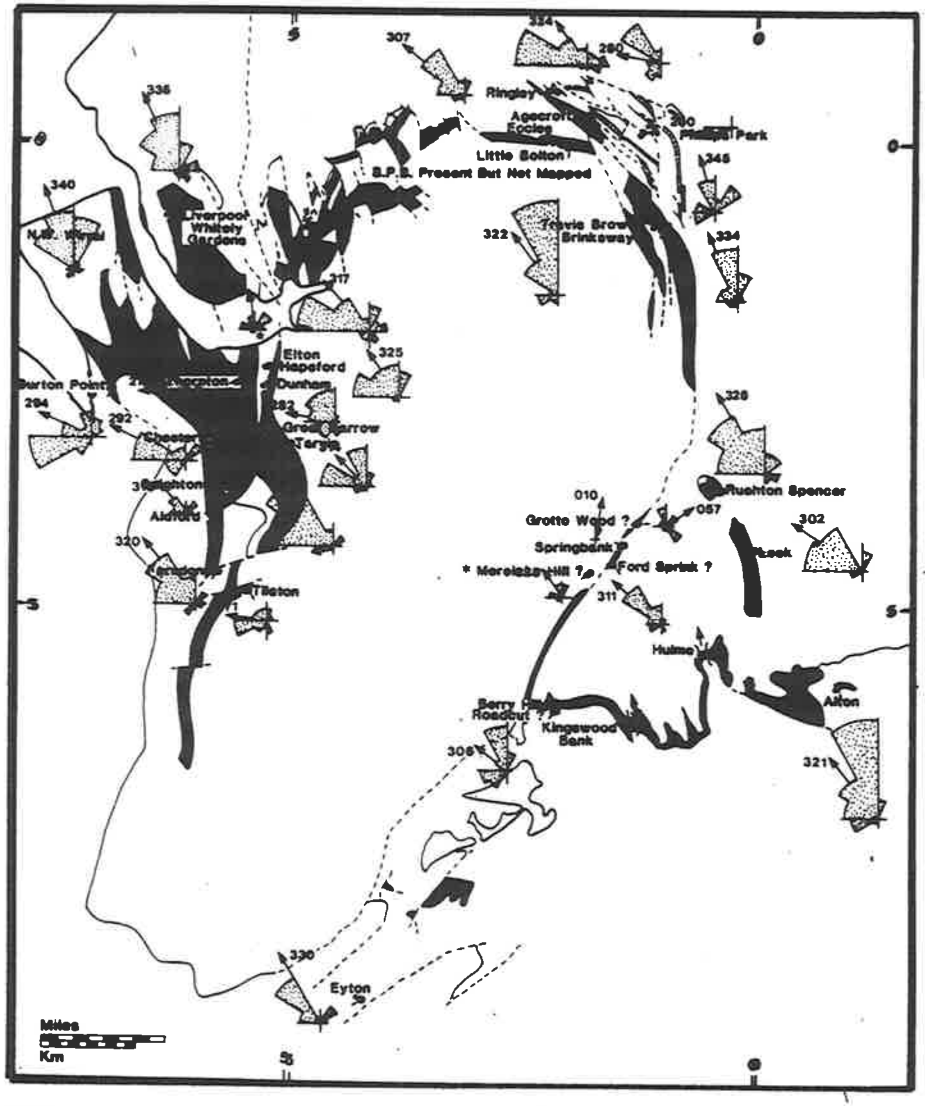
FIG. 26



AUDLEY RURAL CP
Audley
NEWCASTLE-UNDER-LYME BORO CONST
SHROPSHIRE AND STAFFORD EURO CONST
Park End
Park Lane
Nantwich Road
Limbrick Road
Cricket Ground
The Quarry
Moat Farm
New Peel Farm
Old Peel Farm

Figure 27. Palaeocurrents: Chester Pebble Beds Formation.

From Thompson (1984, p. 43)



MANCHESTER MARL OUTCROP

CPB OUTCROP, PARTIAL IN S.E.

FOSSIL VALLEY

DIRECTION OF CHANNEL EDGE & FILL FLUTES

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

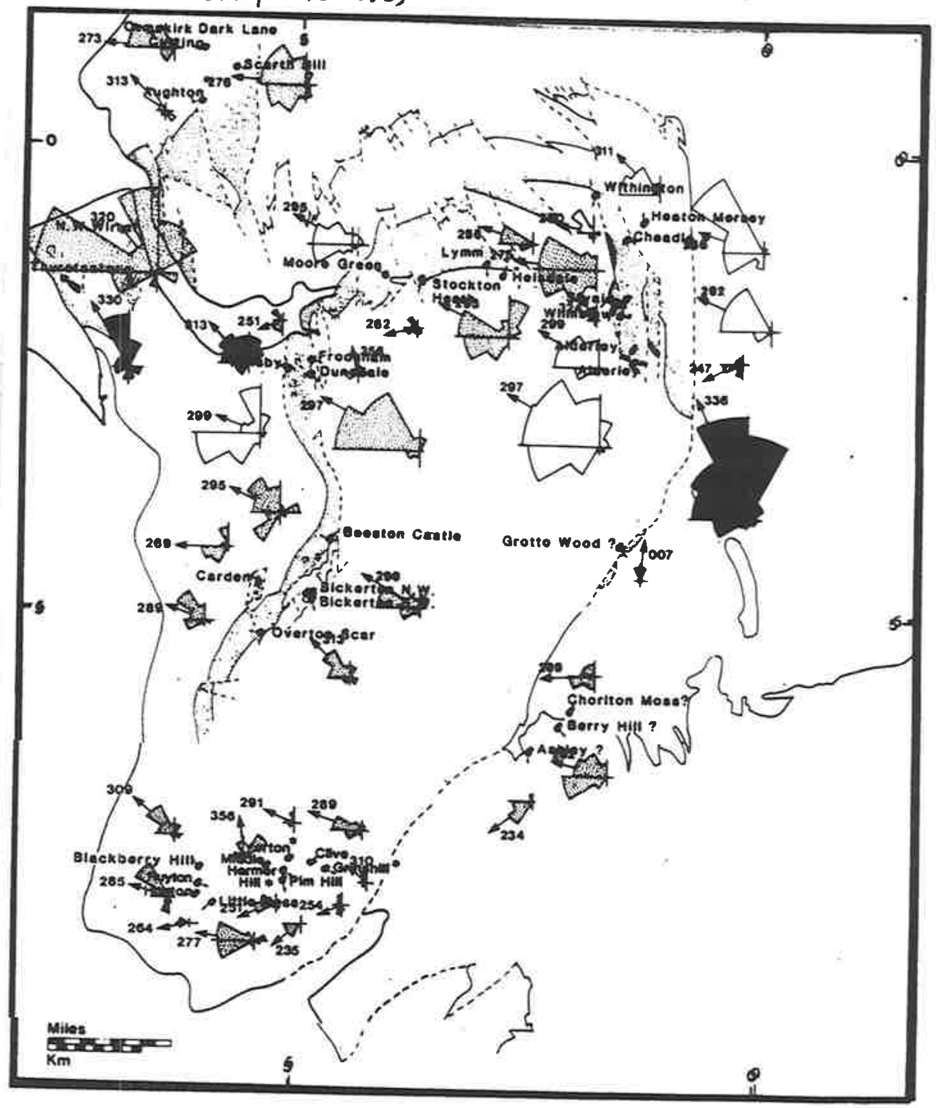
VECTOR MEAN

EDGE OF BASINS

FAULTS

Figure 28. Palaeocurrents: Wilmslow Sandstone Formation and Helsby Formation (Alderley Conglomerate Member)

(From Thompson 1984 p. 44 with additions for North Shropshire 1996)



OUTCROP & DATA OF ALDERLEY CONGLOMERATE MEMBER (LKS)

OUTCROP OF THURSTASTON MEMBER (UMS & LKS)

PALAEOCURRENT DATA OF MAIN WILMSLOW SANDSTONE (UMS)

(UMS) UPPER MOTTLED SANDSTONE (BUNTER)

(LKS) LOWER KEUPER SANDSTONE

VECTOR MEAN

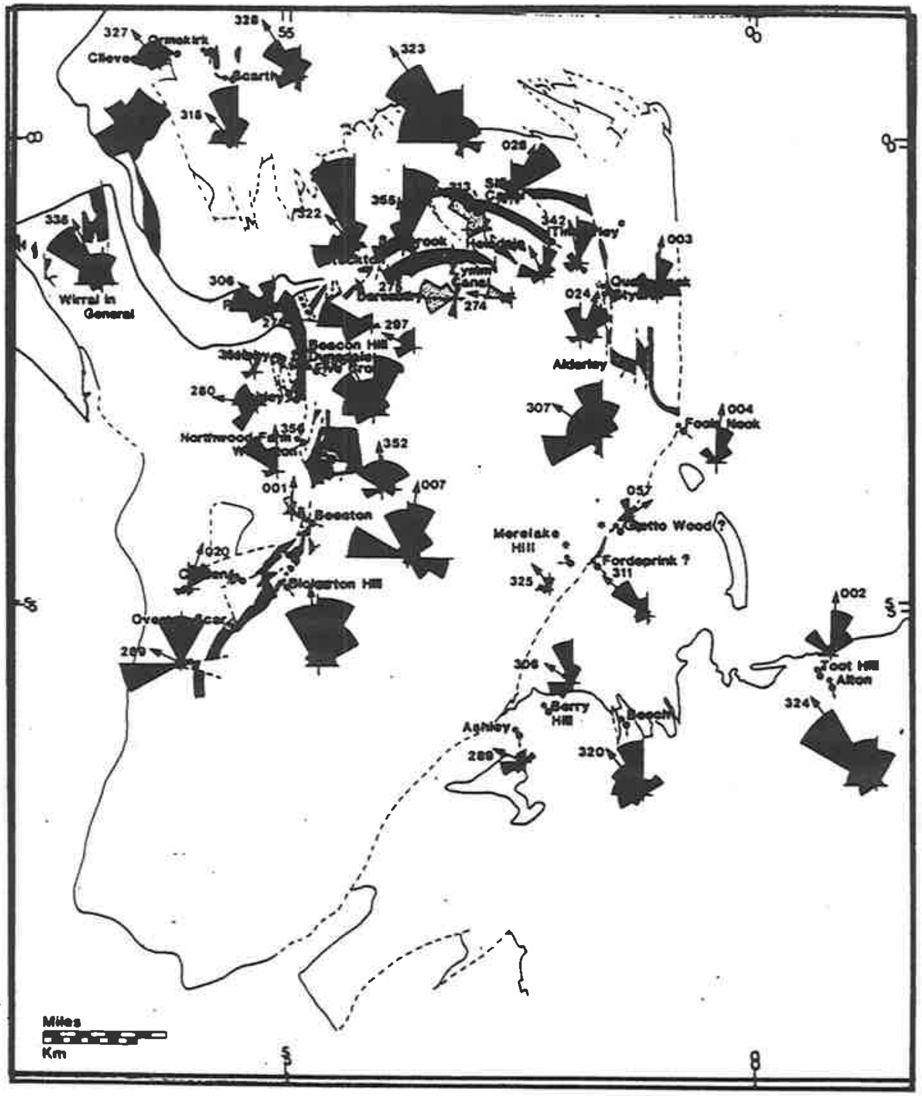
EDGE OF BASINS

FAULTS

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

Figure 29. Palaeocurrents: Helsby Sandstone Formation.

From Thompson D.B (1984 p 45)



OUTCROP OF DELAMERE PEBBLY SANDSTONE MEMBER AND PALAEOCURRENT DATA

PALAEOCURRENT DATA FOR INTERBEDDED SOFT SANDSTONE

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

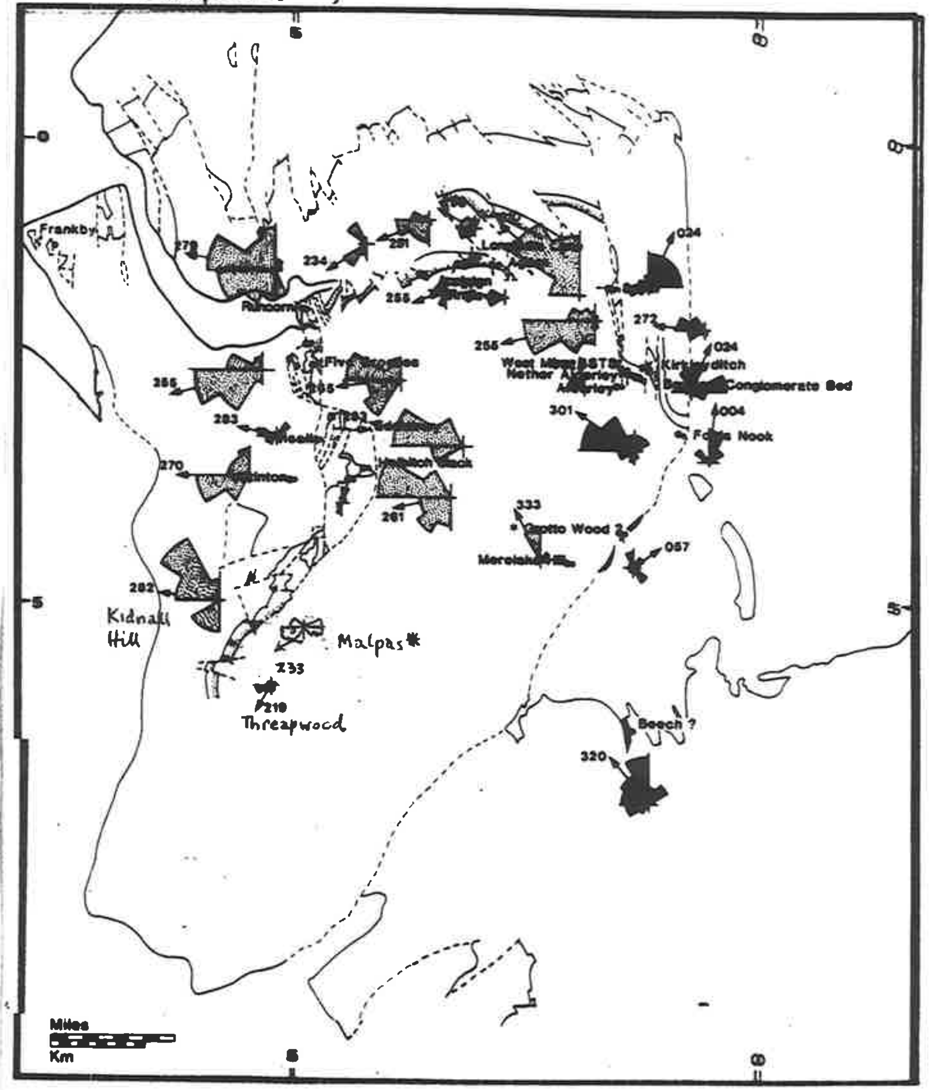
234 VECTOR MEAN

EDGE OF BASINS

---- FAULTS

Figure 30. Palaeocurrents: Upper Part of Helsby Sandstone Formation and Tarporley Siltstone Formation.

From Thompson, D.B. (1984 p. 46) with corrections additions for North Shropshire (1996)



OUTCROP & DATA FOR FRODSHAM SOFT SANDSTONE MEMBER (LKS)

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

DATA FOR MALPAS SOFT SANDSTONE (KW)

(LKS) LOWER KEUPER SANDSTONE (KW) KEUPER WATERSTONES

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

234 VECTOR MEAN.

EDGE OF BASINS

---- FAULTS

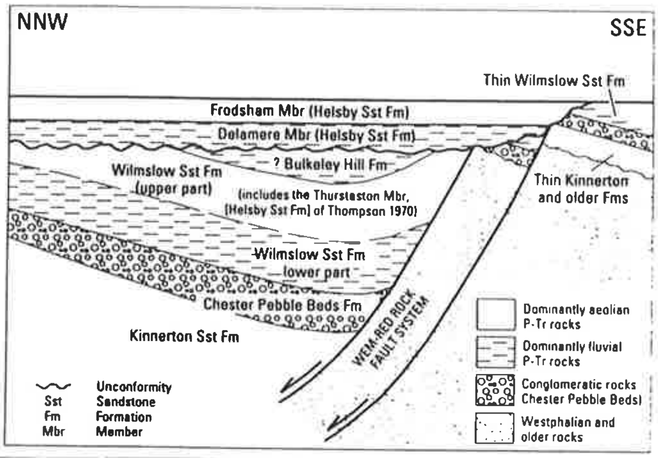


Fig 31 . Interpretive sketch section illustrating the relationship of strata to the intra-Triassic unconformity recognized in the seismic reflection data.

From Evans et al 1993

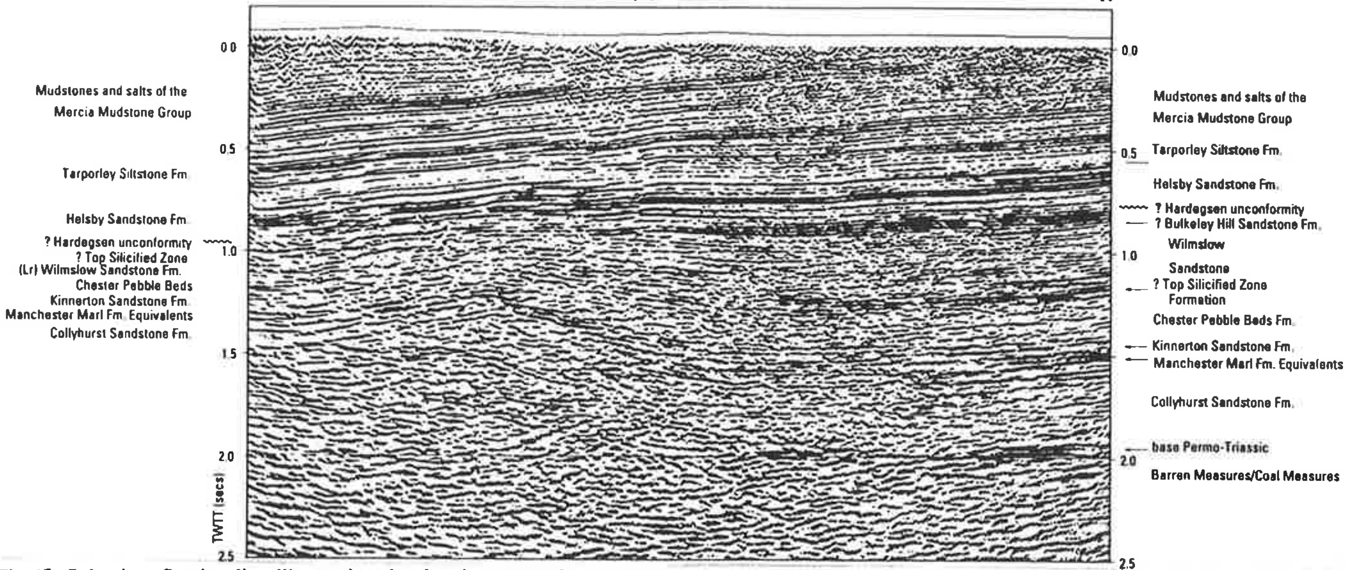


Fig. 32 Seismic reflection line illustrating the development of a sequence boundary showing truncation of underlying reflections. The sequence boundary is interpreted as the Hardegsen Unconformity, present at the base of the Helsby Sandstone Formation. Folding of strata, which occurs within the hangingwall of the fault, is attributed to the regional uplift of the basin during extension.

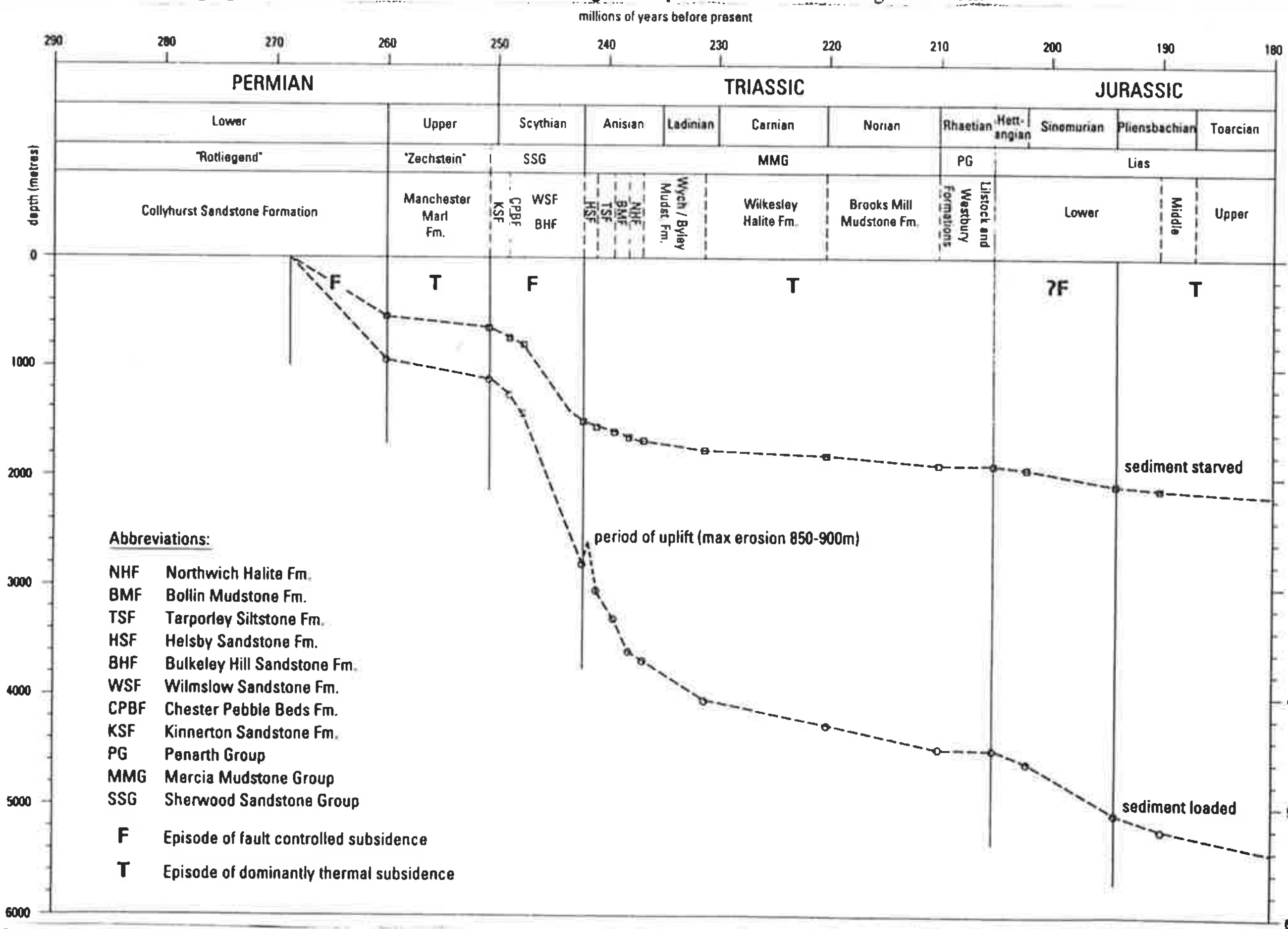
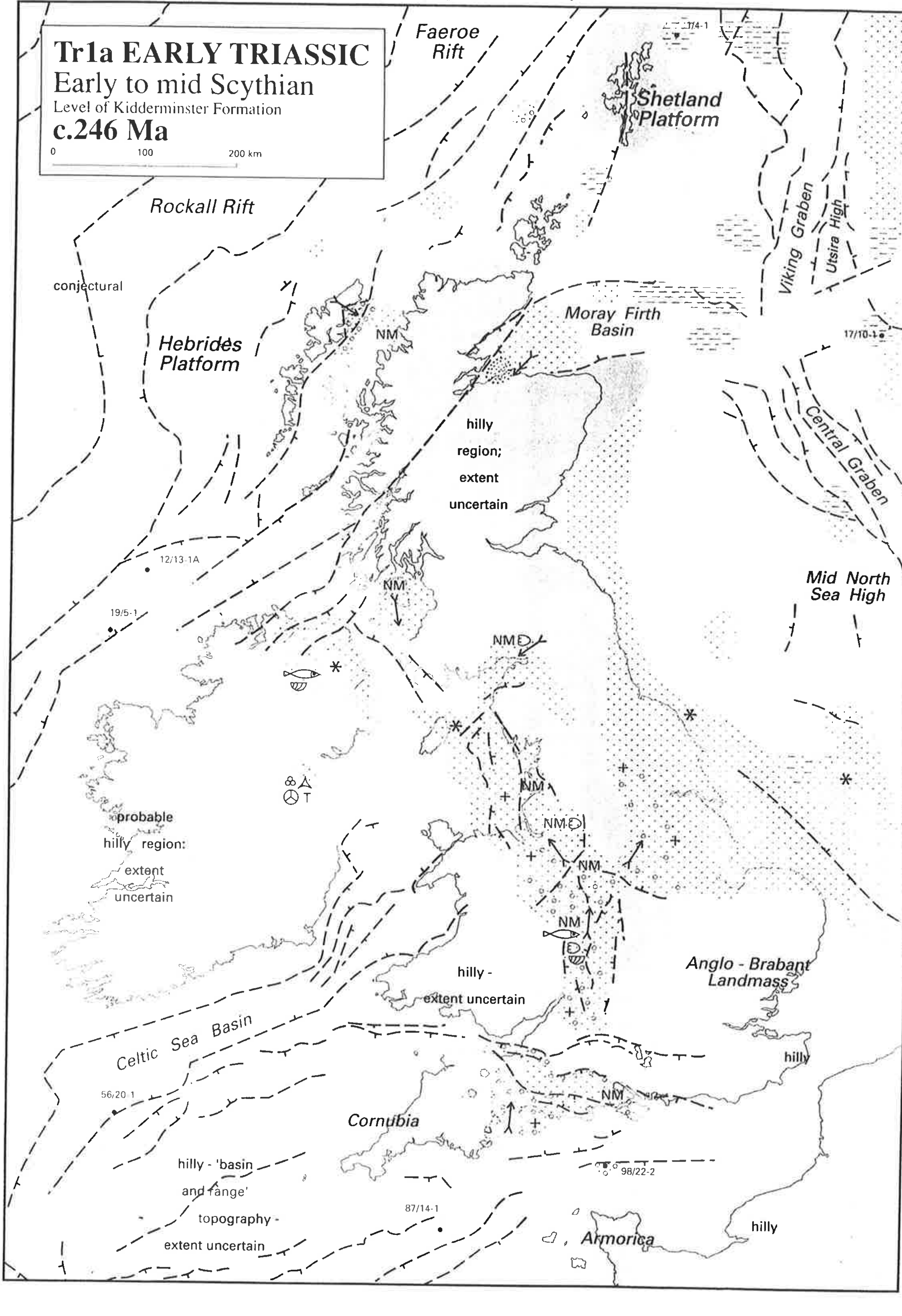


Fig. 33 Burial history (subsidence) curves for the Permo-Jurassic strata in the central Cheshire Basin. Examples for sediment loaded and sediment starved (water filled) basins are shown.

FROM : WARRINGTON, G. in COPE, J.C.W et al. (Eds) 1992 Fig. 34



 1993 Jl. Geol. Soc. Lond. 150 (2), 219-226.

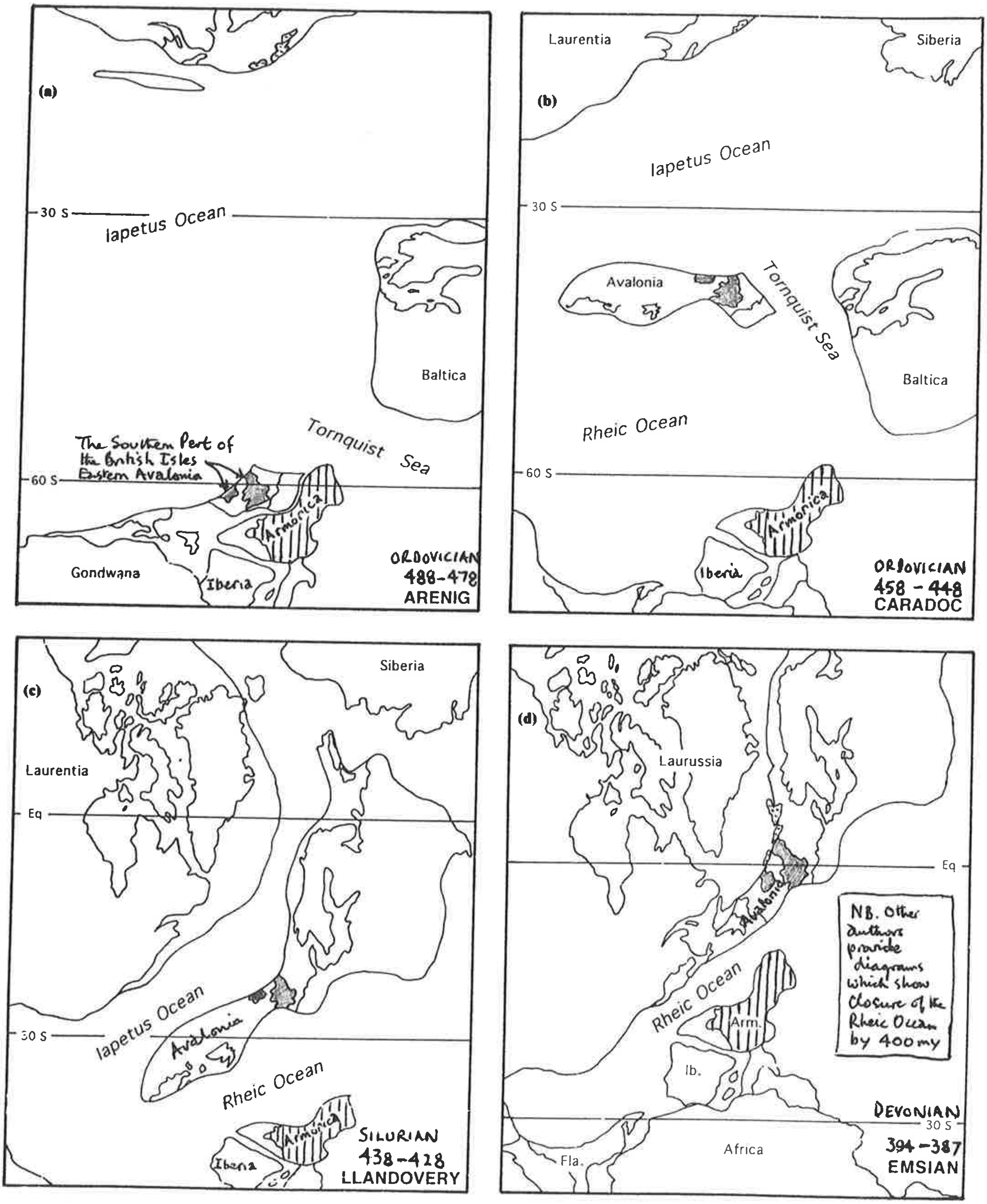


Fig. 6. The palaeogeography of northwest Europe, (**a**) in Mid-Arenig times, with southern Britain attached to Gondwana, (**b**) in early Caradoc times, with Avalonia, including the London–Brabant massif, detached from Gondwana, (**c**) in late Llandovery times, showing the Avalonian fusion with Baltica and the narrowing Iapetus Ocean and (**d**), in mid-Devonian times, after the closure of Iapetus. Arm., Armorica; Ib., Iberia; Fla., Florida.

The terrane upon which the orthoquartzitic shallow marine deposits and faunas developed which have given rise to the pebbles and derived fossils in the "Bunter" Pebble Beds of the British Isles (eg the Budleigh Salterton Pebble Beds; the Kidderminster Pebble Beds and the Chester Pebble Beds).