MANCHESTER GEOLOGICAL ASSOCIATION

Field excursion: An Introduction to the Geology of the Area around Stoke-on-Trent Sunday 12th September 1993

Excursion leader: David B Thompson (Keele University but former President of MGA 1968-70)

The purpose of this field excursion is to introduce members to a sample of key localities which illustrate the geological history and economic geology of the area in both past and present times. A start will be made in the Upper Carboniferous Succession at Madeley Heath Brick and Tile Works. The localities at Maer, Hanchurch and Butterton which follow will enable members to savour the delights of the area where Charles Darwin visited his cousins the Wedgwoods and where, as a budding geologist of the first rank, he is alleged to have been the first to discover the dolerite dykes of the area. The fact that he had been prompted to do this as a result of Roderick Impey Murchison being keen for him and others to apply a then-new but woefully inadequate predictive theory, illustrates aspects of the history of science which are often neglected. The results of recent geochemical work and fission-track dating on the Late Cretaceous/Palaeocene dykes of North Shropshire and North Staffordshire will be introduced and discussed against the overall picture of the evolution of the British Tertiary Igneous Province. The route of this part of the excursion is depicted on Fig.1; the general geology on Figs. 2, 3 and 4.

The excursion will continue with a journey through the "earthquake belt" of Trent Vale and end in the former sand and gravel quarries of the Park Hall Country Park at Weston Coyney near Longton (Figs. 15-18).

1. **Meet at the entrance to Madeley Health Brick and Tile Works SJ 786454** at 10.00 hrs. Permission to visit has been given by Martin Crosby of Redland Bricks Ltd. The brickpit displays a very fine succession in the Upper Carboniferous Westphalian C-D including the top of the Etruria Mudstone Formation (well drained alluvial plain with river channel deposits, riverplain mudstones and ferricrete palaeosol horizons: source material for the brick and tile industry) and the succeeding Newcastle Sandstone Formation (alluvial plain with channels, lakes and delta swamps, non-marine lamellebranchs *Anthraconauta phillipsii* and *A. tenuis*, ostracods, fish scales, drifted plant debris, *in situ* tree trunks) (Figs.2,3). These are followed by Quaternary deposits (?sub-glacial lodgement tills) which lie unconformally above at the southern side of the pit. Pre Quaternary, ?mineralised faults cut the quarry and restrict its development.

2. Travel eastwards to Keele Village, turning south down the length of Three Mile Lane to Whitmore. Turning right, follow the A53 through Baldwin's Gate, cross the **Grand Junction Railway** and **"Whitmore" Station** of 1837 (**Loc.3**) from which Charles Darwin and his wife Emma took the train to London in order to honeymoon in late January 1839. Continue through Baldwin's Gate before turning left down Sandy Lane to meet the A51 (the former Chester-Nantwich-Stone-London coach road). Turn right before taking the road left to **Maer Village, Maer Church and Maer Hall (Loc.4)**, the home of Josiah Wedgwood II, a distinguished but reluctant potter of few words (see photo A) (Fig.6).

It was here between 1817 and 1842 that Charles Darwin (see photo A) and his sisters frequently visited, particularly after the death of their mother in 1817, in order to socialise and hunt, shoot and fish. The background to Charles Darwin's interest and accomplishments in geology, and igneous geology particularly, will be discussed in relation to: old Mr Cotton of Shrewsbury; his two years at Edinburgh University as a medical student es Hall); his three years at Cambridge as a theology student (Rev. John Henslow, Rev. Adam Sedgwick); his tour of North Wales in 1831 on horseback with the last mentioned; the third choice offer of a trip on HMS surveying ship Beagle (1831-6) as the second naturalist and gentleman companion to Capt. Robert Fitzroy. Dr Robert Wareing Darwin FRS at first refused permission to take the appointment but had his mind changed by letters from Uncle Josiah Wedgwood II whom Charles was visiting in order to plead his case (the exchange of letters is in the University Library: Wedgwood archives). It was at Maer Hall and at Shrewsbury that the first pencil sketch of Darwin's Species theory was written (35pp.) in 1842.

The story will be told of how in 1834 at Acton Reynald Hall, North Shropshire, Roderick Impey Murchison was introduced to a dark rock (greenstone porphyry - now tholeiitic dolerite) cutting pebbly red sandstones (now the Chester Pebble Beds Formation, Lowest Triassic in age). Having recently worked in the Breidden Hills where igneous rocks, lavas and dykes were common, Murchison was keen to link the origins of these rocks with the new dykes at Acton Reynald and the topography of the perceived double line of hill masses extending to the ENE: Moel-y-Golfa - Rodney's Pillar; Clive Hill - Grinshill, Hawkstone-Bury Walls; the hills around Ashley and Loggerheads ...(Fig.7). To do this he was keen to be the first to use the newest theory - "The Theory of Elevation" of the frenchman Elie de Beaumont (1829-1830) - in the British Isles. In so doing, and using a theory which did not have great credence even in its own time, he predicted the presence of dykes in the hilly areas of North Staffordshire (Fig.7).

Thus he came to write to Robert Garner, physician of the North Staffs Infirmary at Etruria and personal doctor to Josiah Wedgwood II of the Etruria pottery, in order to ask him to look out for dykes. Garner did not find any dykes but Charles Darwin did. Kirkby (1894) writing c.50 years after the event notes that "the dyke was discovered some time afterwards by Darwin, who was on a visit to Josiah Wedgwood at Maer and told him of it. Mr Wedgwood told Mr Garner and the latter has it marked in (sic) the map illustrating his History of Staffordshire" (Garner 1844). The date of this discovery could be anywhere between 1836 and 1844 but circumstantial evidence will be used to tie down the date to 1842. The exact location of Darwin's discovery is not known but two places have been suggested, both of which will be visited later. The dyke(s) in Hanchurch Woods were discovered independently by James Kirkby, a true amateur, in the early 1840s (Kirkby 1894).

The point made here is that an important new discovery in science was made by a person not engaged in this particular scientific research programme. It was made by a gifted individual who had probably been briefed by Murchison himself, for Darwin was at that time in the swim of things whilst acting as secretary to the Geological Society between 1838 and 1841. He had been briefed on the basis of an inadequate theory which had been badly applied to the geological evidence of the area. Being the first person in the British Isles to use the theory appeared to be the driving force for Murchison, for he was ever aware of the need to polish his emergent reputation, even after the publication of The Silurian System (1839). Notice that the amateur's discovery is largely unknown.

3. **Drive along the likely route of one of Charles Darwin's long walks from Maer to the Hanchurch Hills**, i.e. *via* Hill Chorlton, Chapel Chorlton (**Loc.5**) (the former the building stone quarry for Maer Church - in the Bromsgrove Sandstone Formation - formerly the Lower Keuper Sandstone - on the east of the lane), *via* Stableford and Pennyleasow to where, in the Hanchurch Hills, a dark rock would have been seen in the early 1840s crossing the bright red pebbly sandstone exposed on the surface and flanks of the road from Hanchurch to Stableford (**Loc.6**). This rock is now the Kidderminster Conglomerate Formation (once the Bunter Pebble Beds) of Lower Triassic, ?Scythian age, c.245 million years ago (see Fig.8).

Conduct a "search and find" operation for two outcrops of the dyke rock hereabouts, one adjacent to the road, a second in an old quarry south of the road, where Molyneux (1861) once claimed to have seen copper mineralisation (malachite).

4. Drive northwards taking the A519 briefly before turning left and northwestwards through Hanchurch village in order to take the twisting lane past Butterton Hall to **Butterton Lodge Gates (Loc.7)**. It is near here that Walcot Gibson, the Geological Survey Officer who came from mapping South Wales in 1897 to start work mapping the geology of the North Staffs Coalfield, made field notes and sketches of a dyke crossing the lane. He stated, without documentary or circumstantial evidence, that Charles Darwin had been the first person to discover a dyke at this location (Gibson 1902, 1905) - the second "Darwinian" locality.

More recently the area has been mapped geologically by Cope (1947, 1966 and in Exley 1970) who depicted one dyke and Exley (1970) who contemplated two dykes. The area has been the object of a vertical field magnetic gradiometer survey by Sowerbutts (1988) whose data give good reason to recognise the presence of two dykes across the corner of the two lanes. This interpretation has been adopted in the new 1:50000 Stoke geological sheet. Members of the party are invited to search for loose fragments of dolerite in the lanesides hereabouts.

The trend of the dykes, 350° and parallel with the Apedale Fault 1.25 kms away to the east, is suggestive of an upper crustal Malvernoid structural influence which controls both the dykes and the fault. The trend is toward the dykes of the Bowland Fells (where six dyke localities are known) (Fortey 1992) but there they are aligned more north westerly (320°). A general prolongation towards Arran

and Mull is obvious. There is no hint of a connection with the dykes of North Shropshire, Anglesey and the Mourne Mountains-Antrim area of Northern Ireland.

5. Drive southwards before turning left (eastwards) and parking in front of Butterton Church (built probably of Lower Triassic Sandstones of the Bromsgrove Sandstone Formation, Scythian in age, possibly from Chapel Chorlton Quarry rather than the Hollington Quarries near Cheadle, Staffs.). Walk down Butterton Church Wood southwards for 400 m to the former roadstone quarry: **Butterton Church Wood Quarry (Loc.8)**. We visit by kind permission of Mr C J Matthews of Lymes Farm (Butterton)

The dykes were first noticed by Edward Binney FRS of Manchester and W Warington Smythe in 1851 (see Ward 1894), but they were not recognised or plotted on the first geological survey maps or sections of Hull (1857) and Hull and Green (1859). The quarry was most carefully described by Molyneux (1861) without igneous rock being mentioned! By 1890 the outcrop was well known enough for the GA of London to visit it (Hind 1890) (Photo B; Fig.9). Dyke rocks were described by Ward (1894) and Kirkby (1894) and specimens from here were sent by Sir Archibald Geikie (1897) for measurement in the early days of geomagnetic studies by Rūcker and White (1898). Two dyke rocks were described and diagramatised by Wilcot Gibson (1898 published 1905) (Fig.10) whose drawings (but not his text) suggest that multiple intrusions may be present. The outcrop was visited by the Geologists Association again in 1903. The petrography of alkali olivine dolerites/basalts was described by Flett (1905) who soon (1910) recognised the best nepheline bearing rocks in the British Isles. Later Alexander Scott (1920, 1925, 1926) deputy principal of Stoke-on-Trent Technical College (but formerly a lecturer in petrology at both Oxford and Glasgow Universities) took petrographic description of the rocks of this general area to new heights and produced a petrogenetic history of the area). In postwar years the dykes have been described by Cope (1966), Exley (1970) and Thompson (1975). Recently the presence of two dykes has been investigated by a vertical field magnetic gradiometer in the area immediately south of the quarry (Sowerbutts 1987) and the presence of minor offsets (?faulting) has been noted (Fig.11). The development of three dykes *en echelon*, with rising and falling tongue-shaped upper surfaces, is equally a possibility.

K-Ar age dating has been achieved by Miller (in Cope 1966) and Evans (1969) on the western freshest dyke, the date of c.52 my suggesting an Eocene Ypresian age. Subsequent zircon fission track dates suggest an age of 59-62 my (Palaeocene Danian) (Lewis et al. 1992) whilst apatite fission track dates suggest a cooling of the sandstones adjacent to the dykes below 90-110° at 54 my (ibid.). The oldest dates suggest correlation with the first phases of intrusion-extrusion associated with the opening of the North Atlantic (Dewey and Windley 1988) (Figs.12 and 13); the youngest dates with the late phase of intrusion-extrusion and /or the mineralisation of the dykes and adjacent sandstones.

Reverse magnetisation was reported by Dagley (1969) – a not uncommon feature of Tertiary times.

Recent geochemical trace element studies (Thompson and Winchester in preparation) show that these alkali olivine dolerites/basalts of Butterton-Hanchurch are of a quite distinct kind compared with their counterparts at Yarnfield-Norton Bridge (Fig.14). Both these suites are totally different from the two tholeiitic dolerite suites of North Shropshire, which in turn best relate to the dykes of Anglesey and Northern Ireland. Geochemically the Staffordshire dyke suites are quite close, however, to the rocks at Grindleton and Caton in the Bowland Fells.

6. Travel eastwards via the B5038 to Trentham turn right along the A34 briefly, then left along the A past **the lately defunct Trentham Colliery at Hem Heath.** This is the zone of the "Potteries Earthquakes" experienced from 1975 onwards.

Continue to Longton and take the B5039 to Adderley Green, turning right onto the B5040 for 0.5km before turning sharp left at the lane signposted "Hulme". Most of this journey is across once productive coal measures including the Blackband Formation on whose outcrop the six towns grew up.

7. **Parkhall Country Park SJ 9345**

(a) **Willfield Quarry SJ 926452.** The relationship of Carboniferous and overlying Triassic Rocks will be investigated (Fig.15).
The lithofacies of the earliest Triassic Rocks will be established and interpreted (Hawkesmoor Sandstone and Conglomerate Member) (Fig.16).
Walk eastwards for 0.4km.

(b) **The Play Canyon (= Hulme Central North) Quarry SJ 931450**
Sandstone and conglomerate lithofacies will be investigated in this huge former sand and gravel pit (Fig.17).
Structural features are of great interest.
Issues of exploitation v amenity will be aired against the background of the relatively recent restoration of c.400 acres and its use for leisure purposes (Fig.18).

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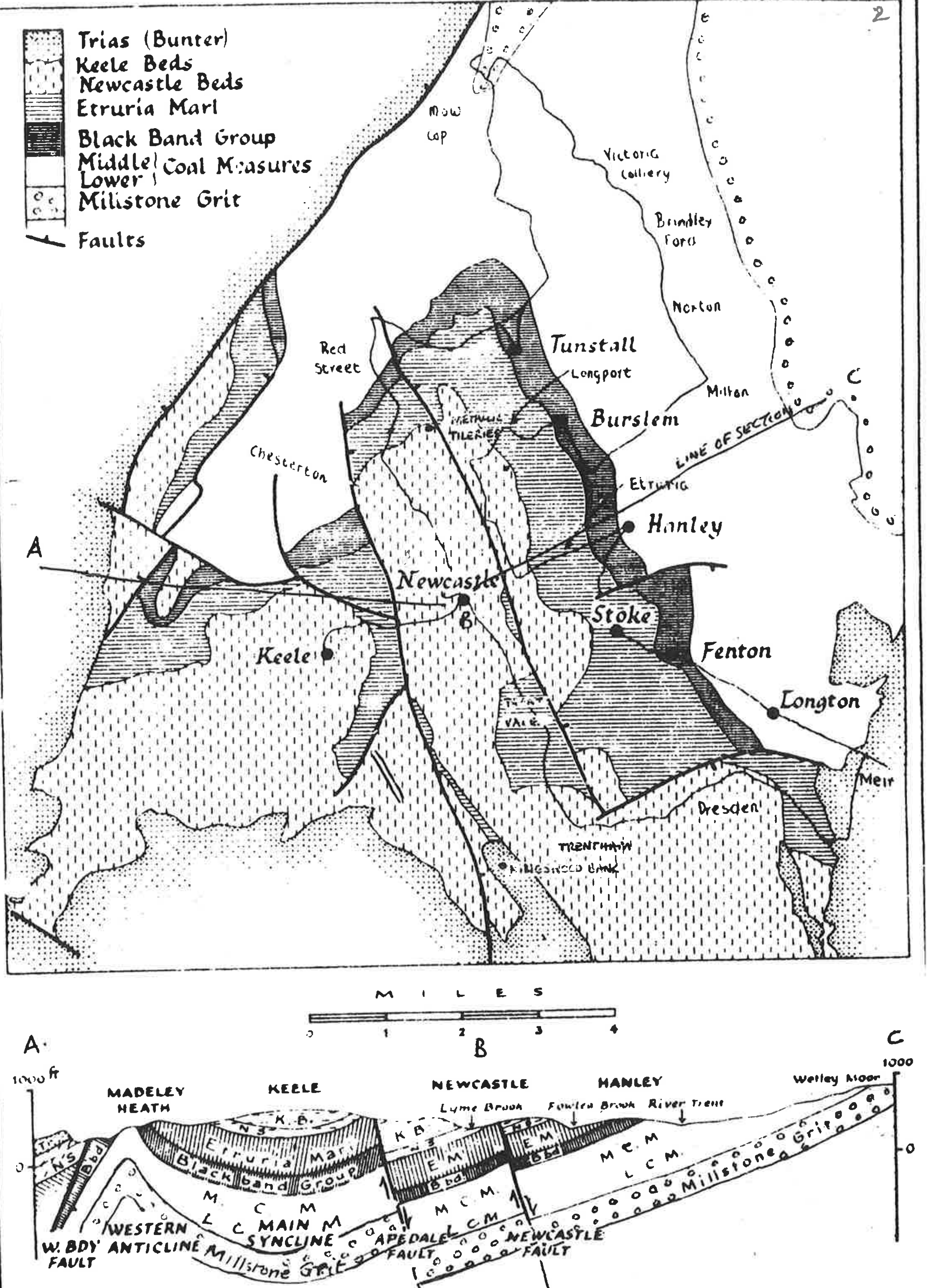


THE POTTERIES COALFIELD

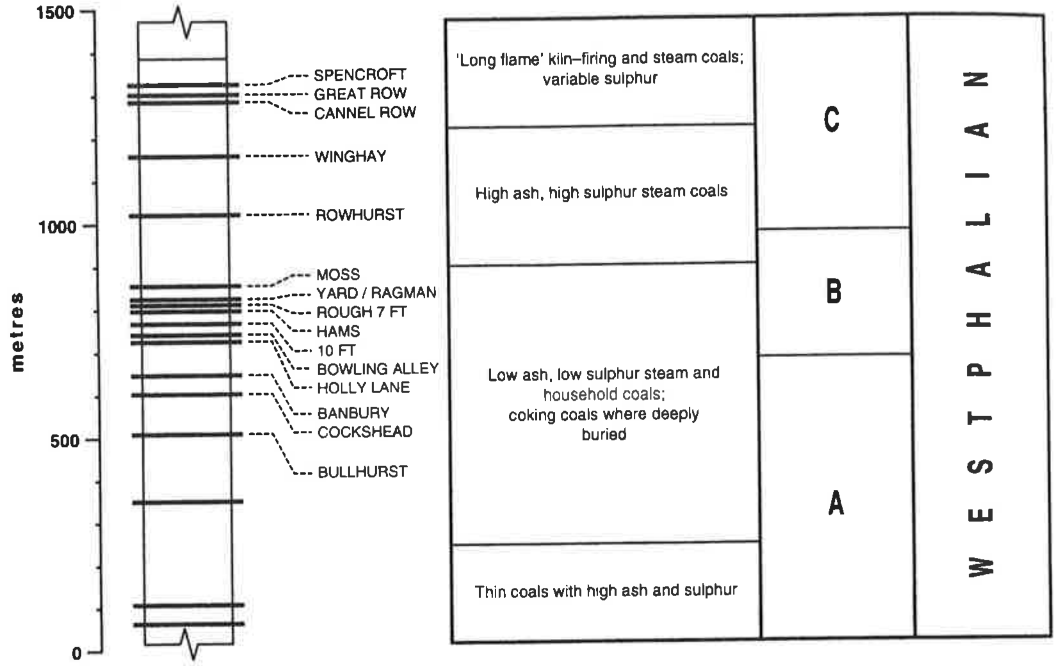


FIGURE 2.11 Stratigraphic occurrence of coal types in the north Staffordshire coalfield.

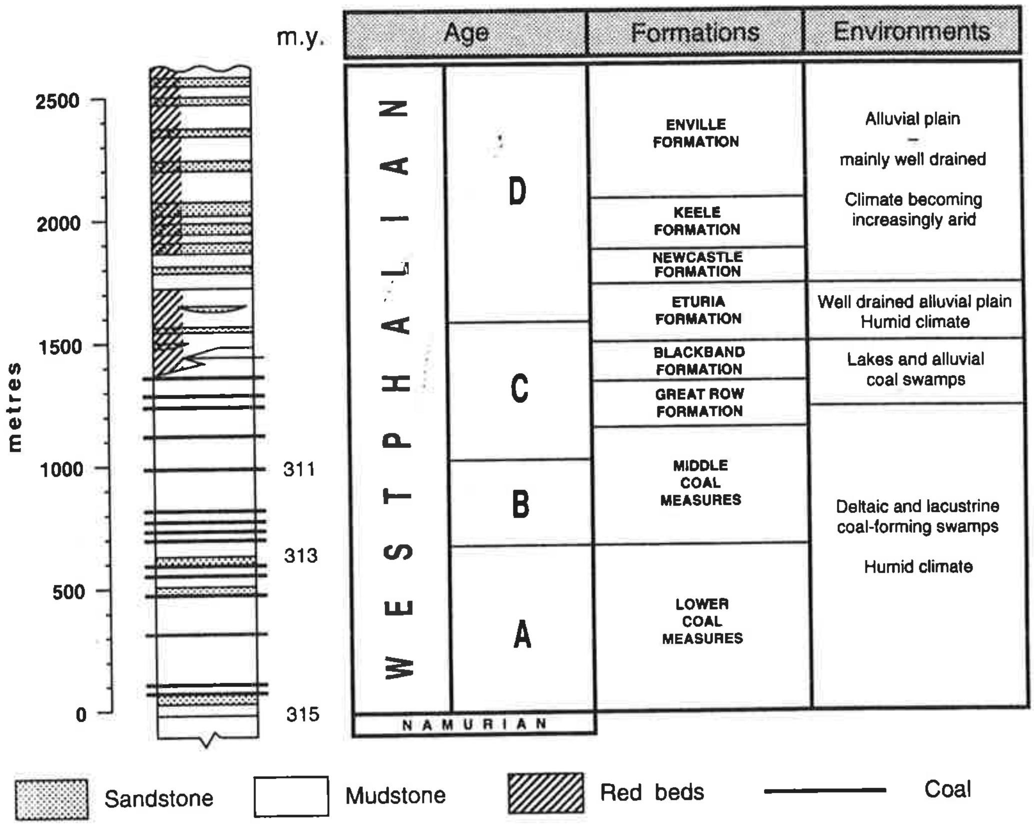
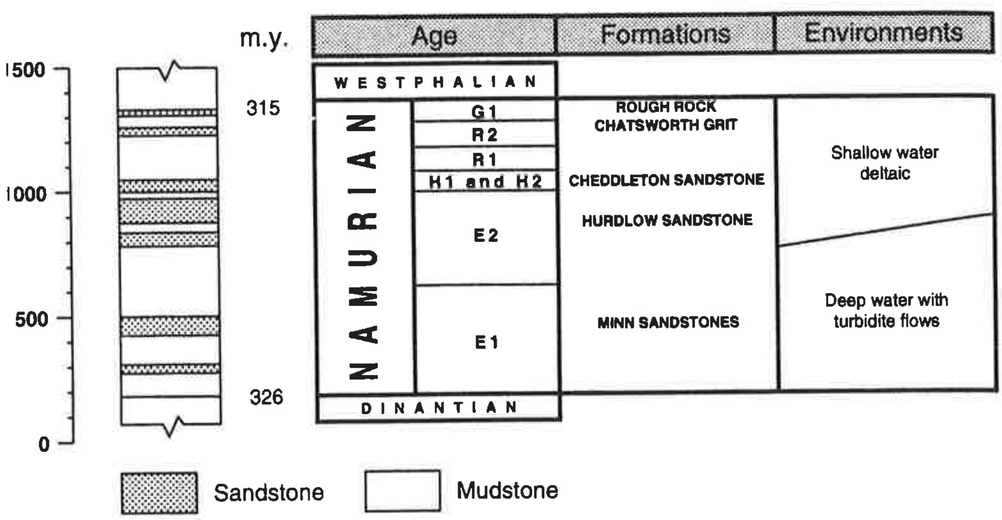


FIGURE 2.5 Generalized sequence of Westphalian rocks present in north Staffordshire.



JRE 2.4 Generalized sequence of Namurian rocks present in north Staffordshire.

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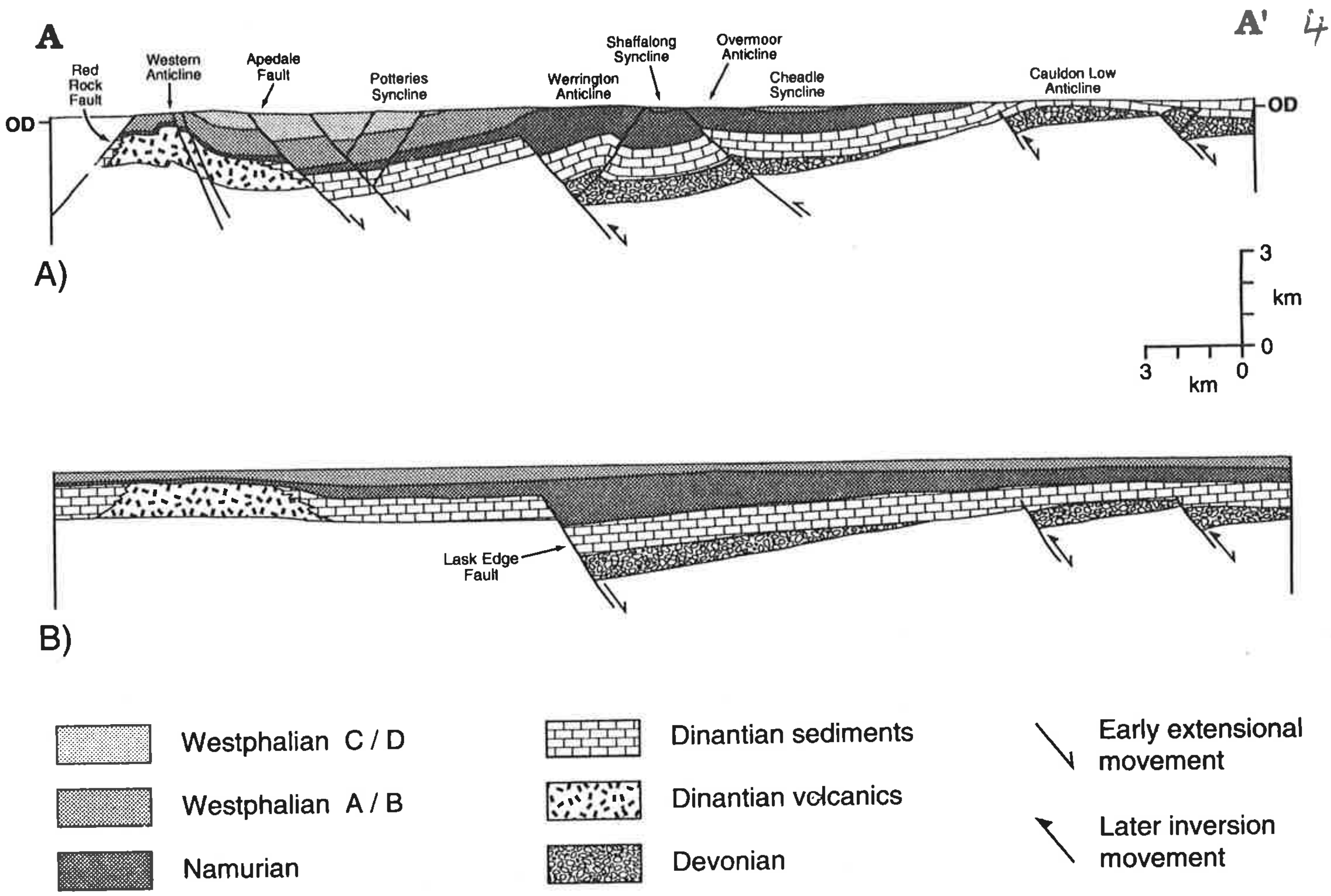


FIGURE 2.6 True-scale, structural cross-section through north Staffordshire: A) present situation; and B) situation at end of Westphalian B. Note the control on the size and position of Variscan fold structures exercised by the Dinantian Apedale volcanic pile and the Lask Edge Fault.

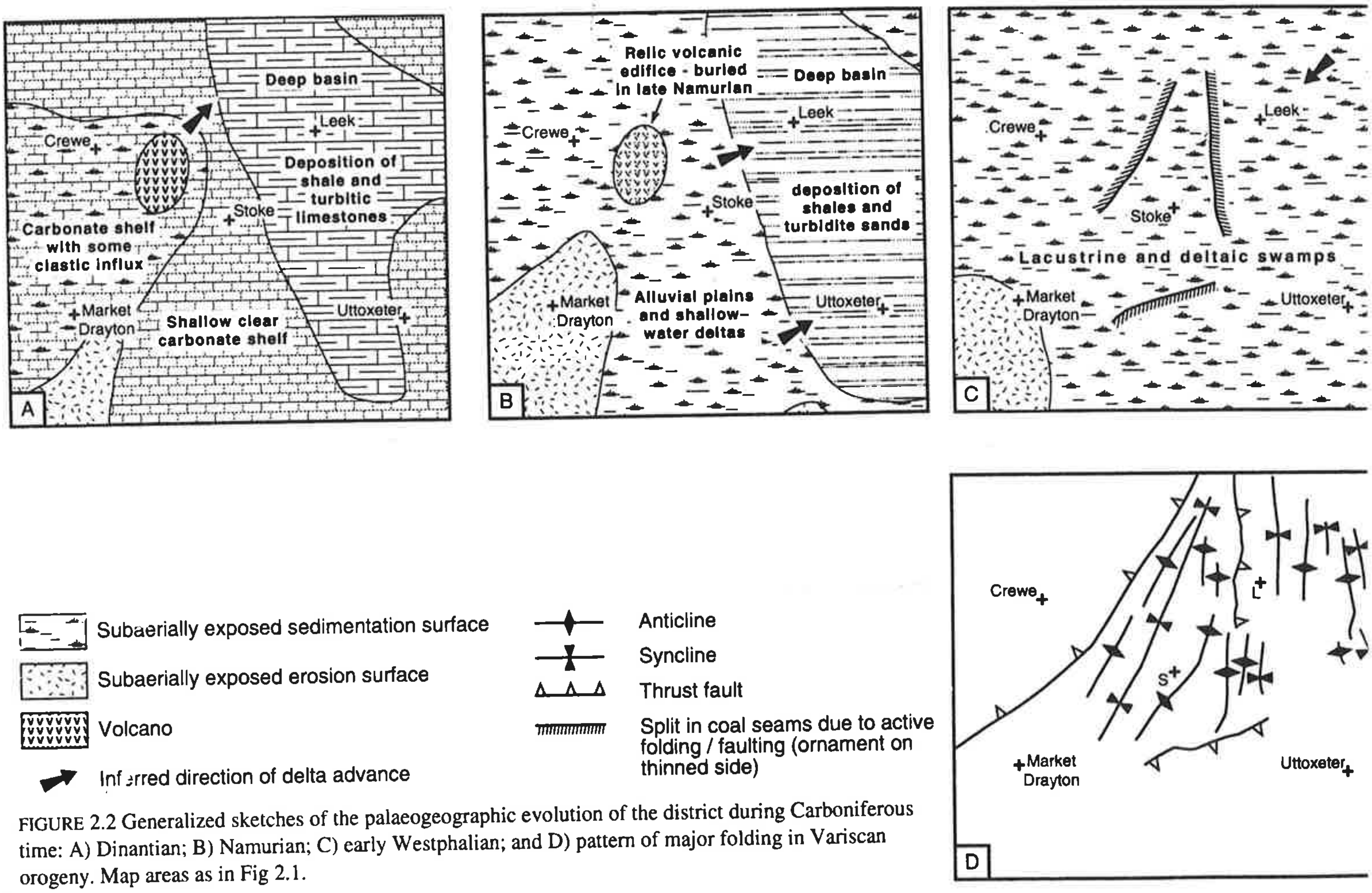
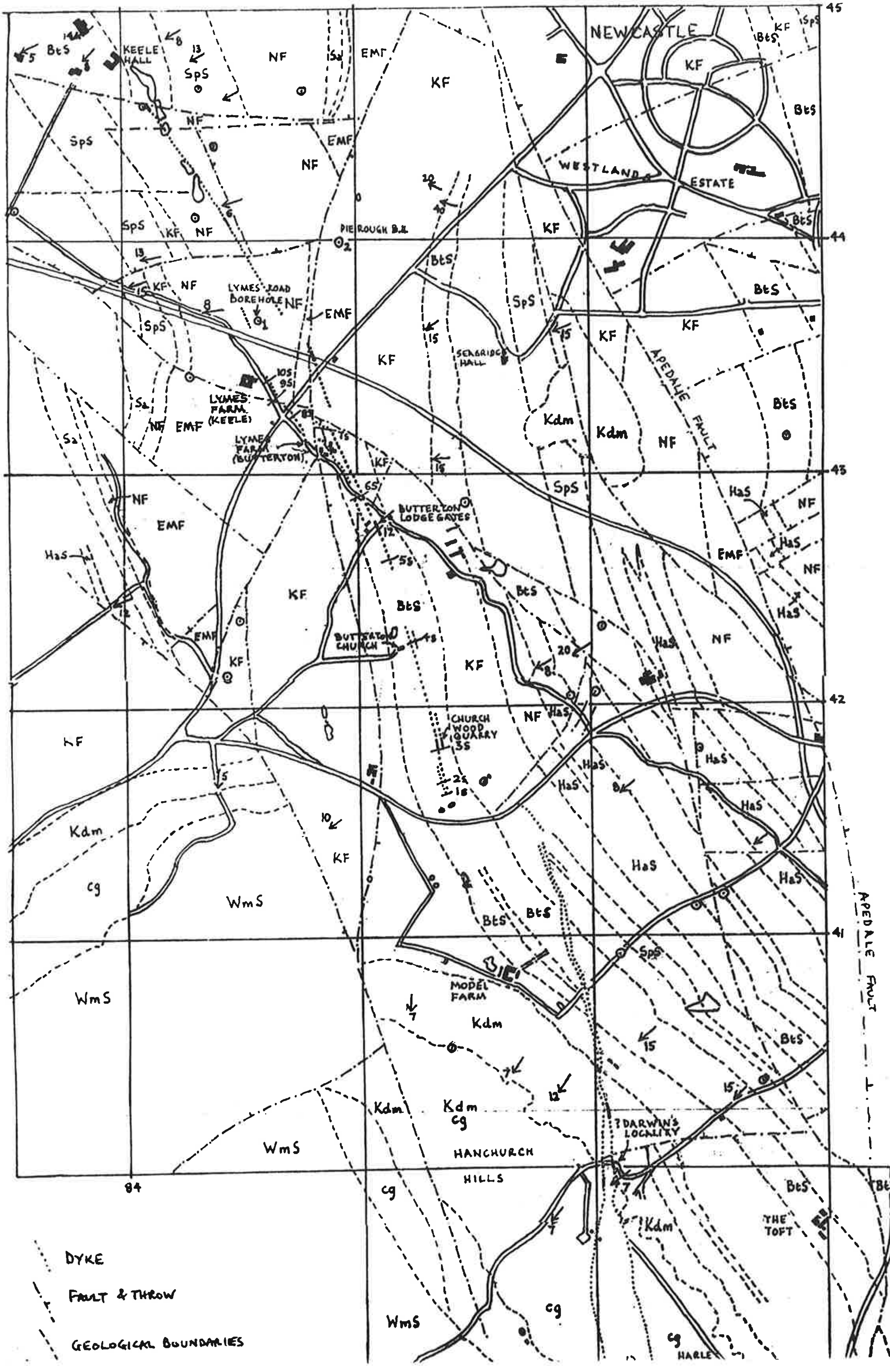


FIGURE 2.2 Generalized sketches of the palaeogeographic evolution of the district during Carboniferous time: A) Dinantian; B) Namurian; C) early Westphalian; and D) pattern of major folding in Variscan orogeny. Map areas as in Fig 2.1.



NEWCASTLE
WESTLAND ESTATE
KEELE HALL
PIE ROUGH B.H.
LYMES ROAD BOREHOLE
LYMES FARM (KEELE)
LYMES FARM (BUTTERTON)
BUTTERTON LODGE GATES
SEABRIDGE HALL
BUTTERTON CHURCH
CHURCH WOOD QUARRY
MODEL FARM
APEDALE FAULT
? DARWIN'S LOCALITY
HANCHURCH HILLS
THE TOFT
HARLE
BtS
SpS
NF
KF
EMF
Kdm
HaS
WmS
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45
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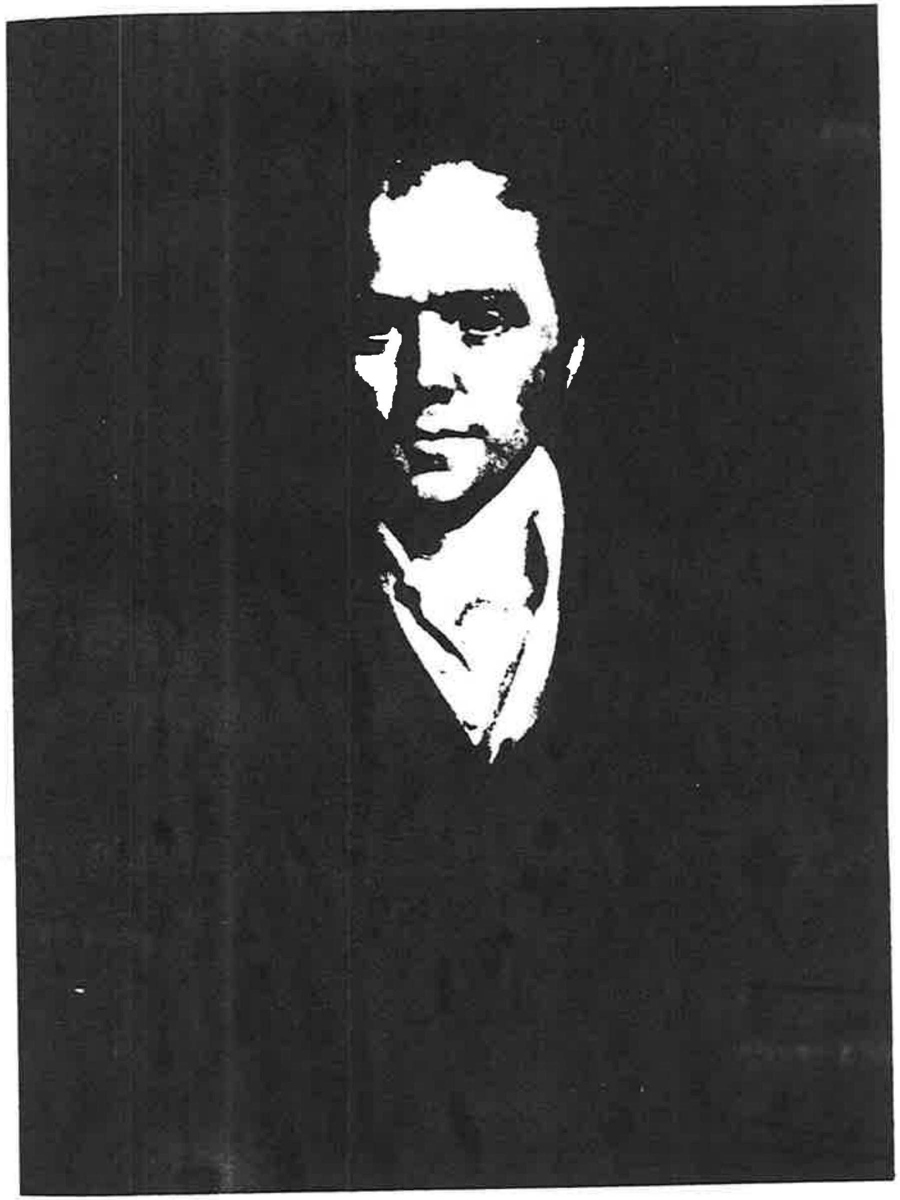
DYKE
FAULT & THROW
GEOLOGICAL BOUNDARIES

PHOTOS (A)

Charles Darwin, 1840.

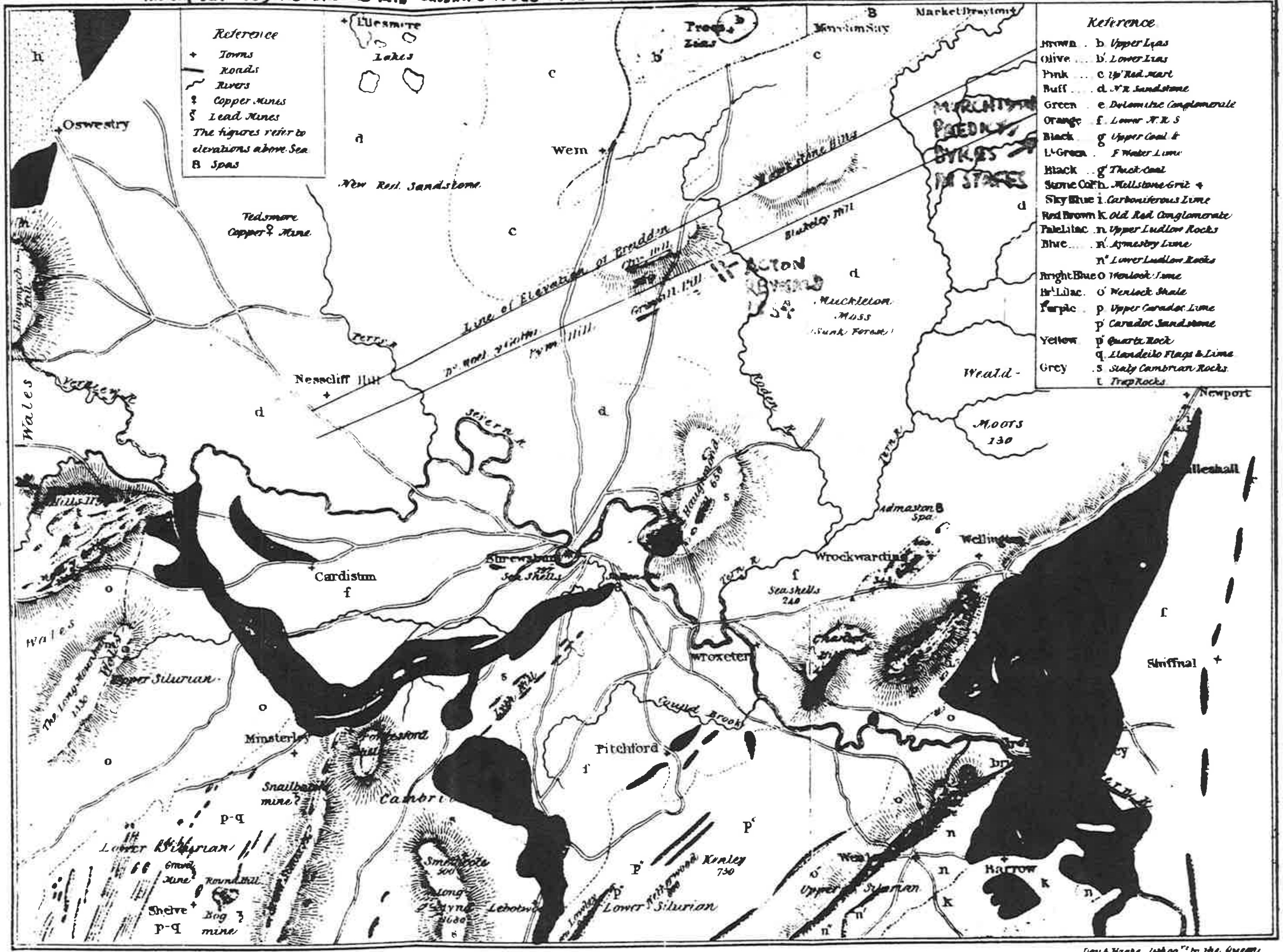


Josiah Wedgwood II. Portrait by William Owen.

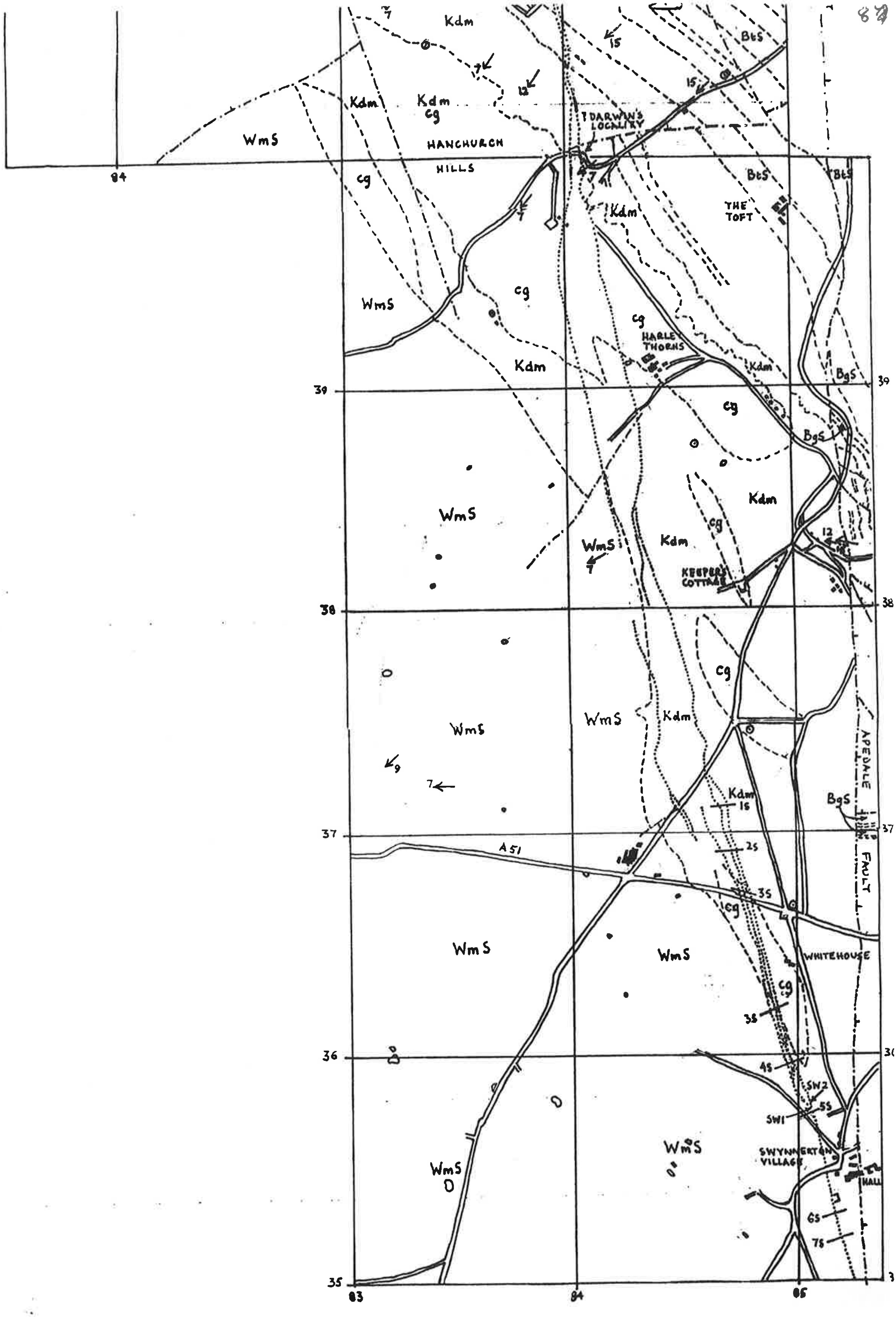
Courtesy of the Trustees of the Wedgwood Museum, Barlaston

6

MURCHISON 1839 REFERS TO MID-CHESHIRE RIDGE LINE IN ADDITION : KIRKBY (1894) REFERS TO A LINE EMANATING FROM THE WREKIN



BREIDDEN HILLS


Kdm
cg
WmS
HANCHURCH
HILLS
? DARWIN'S LOCALITY
BtS
THE TOFT
HARLE THORNS
BgS
KEEPERS COTTAGE
A51
WHITEHOUSE
SWYNNERTON VILLAGE
HALL
APEDALE FAULT
SW1
SW2
84
39
38
37
36
35
83
85

FIELD VISIT OF GEOLOGISTS ASS'N TO BUTTERTON HALL QUARRY

c. 1893? 9

PHOTO (B)

CAN YOU DATE THE EXCURSION ON THE STYLE OF THE LADY'S COSTUME?

CAN YOU IDENTIFY FURTHER NAMES OF PARTICIPANTS?

See Hind et al 1903 p. 181

'Butterton Hall Quarry' c. 1890?
with W. Whittaker (bearded?)
+ Walcott Gibson (2nd from right?)
Copy of original in the possession of Ted Watkin (NSGGA)
(information on back of original in ? John Ward's handwriting)

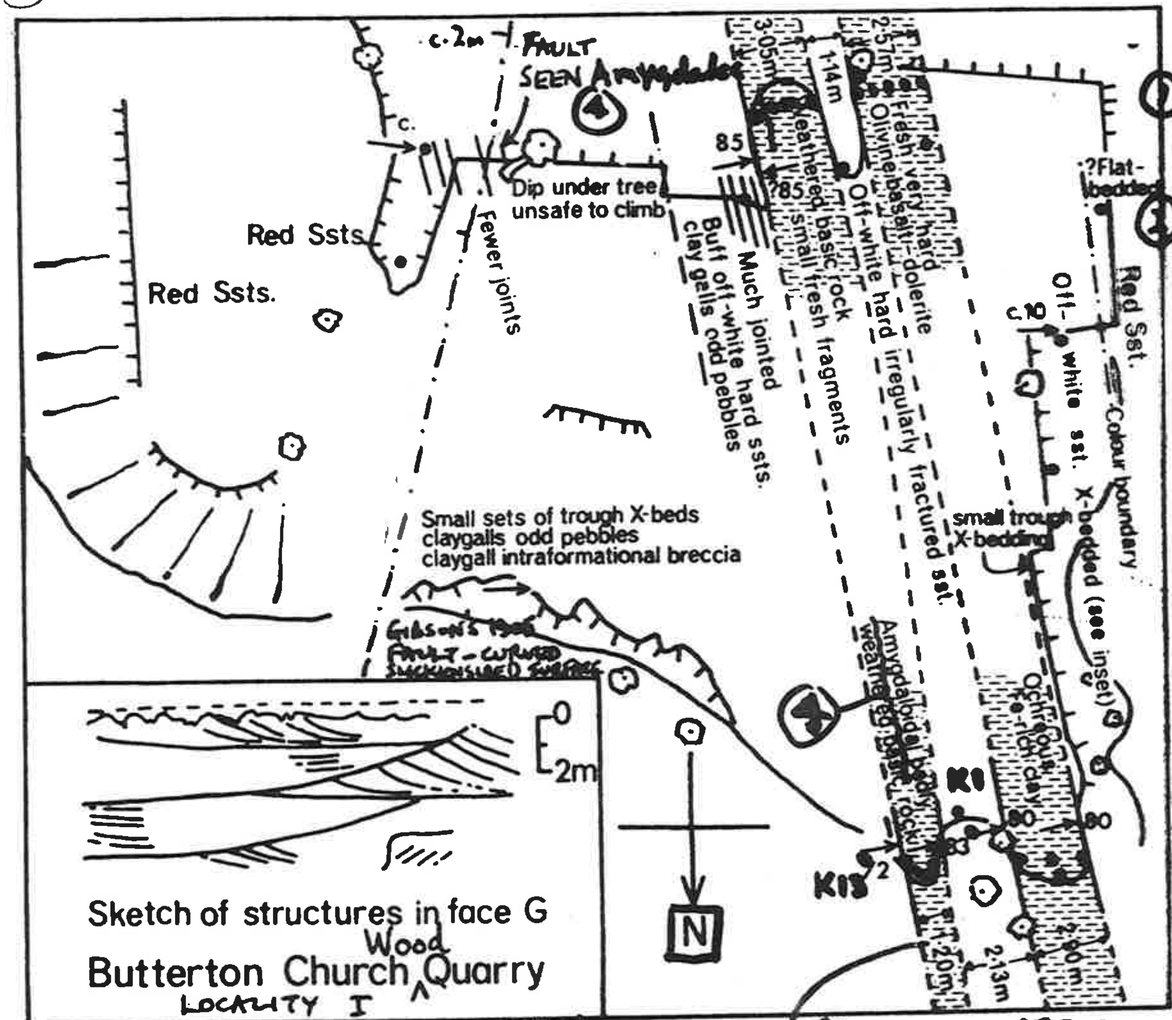


Fig. 3. Outline geological map of Butterton Church Wood Quarry. LOCALITY I. (Thompson 1970)

5 Mineralised?

EXTRA DESCRIPTION FROM GIBSON 1905 p 193

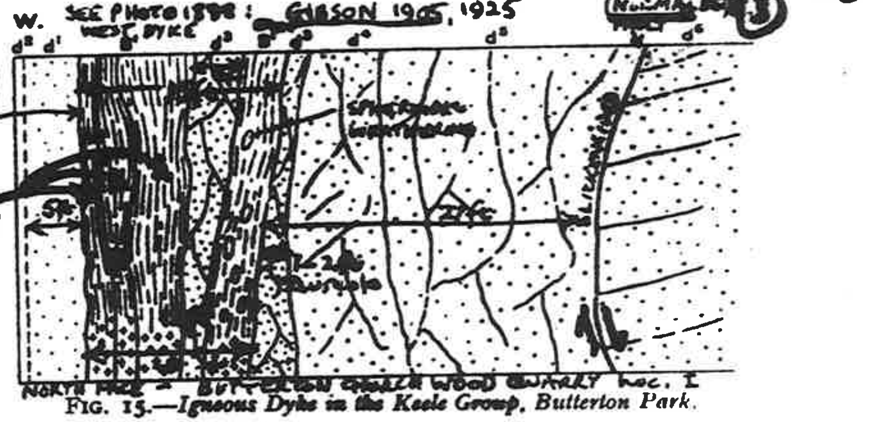


FIG. 15.—*Igneous Dyke in the Keele Group, Butterton Park.*

d² Unaltered sandstone.	d³ Altered grit, 3 to 4 ft. wide.
d¹ Altered do., 3 ft. wide.	d⁴ Soft white sandstone, 10 ft. wide.
B¹ Dyke, 8 ft. and 3 ft. wide.	d⁵ Olive coloured sandstone.
	d⁶ Red sandstone.

NORTH SIDE

F. WOLVERSON COPE 1966 p. 32

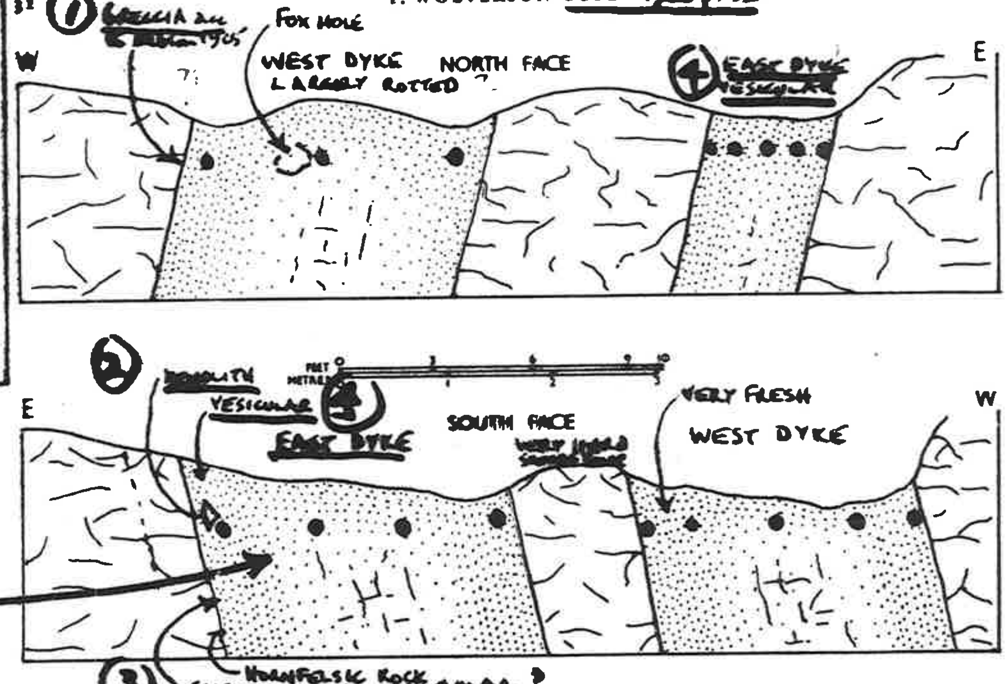
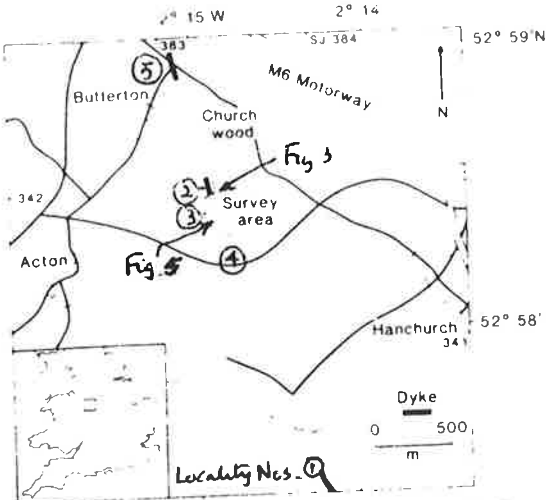
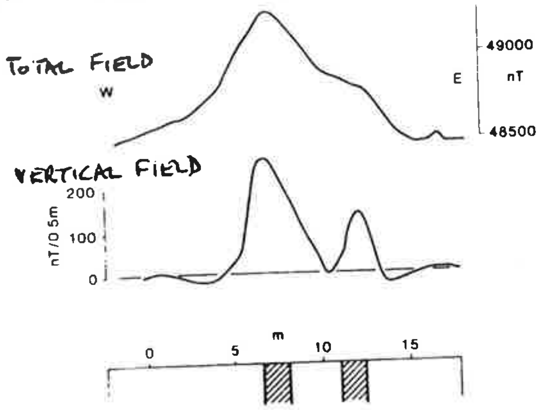


FIGURE 3 — Diagrammatic representations of the Butterton Dyke as exposed in the faces of the disused quarry at the south end of Church Wood, Butterton. Sandstone is indicated by unshaded areas with markings of strong irregular jointing. Decomposed dolerite is represented by the dotted areas; fresher dolerite appears as cores marked with sub-parallel joints.

MAGNETIC MAPPING OF THE BUTTERTON DYKE - W.C.C SOWERBUTTS (Jl. geol. Soc. Lond. 144 1987 pp29-33.)



g. 1. Location map showing known exposures of the Butterton yke and the area where the magnetic survey was made.



g. 3. Magnetic profiles obtained above the northern end of hurch Wood Quarry (Grid Ref. SJ84; 834420) and section showing e position of two dykes (hatched) observed in the quarry face. ie total magnetic field measurements show one broad anomaly hereas the profile of vertical magnetic gradient shows separate iomalies over each dyke.

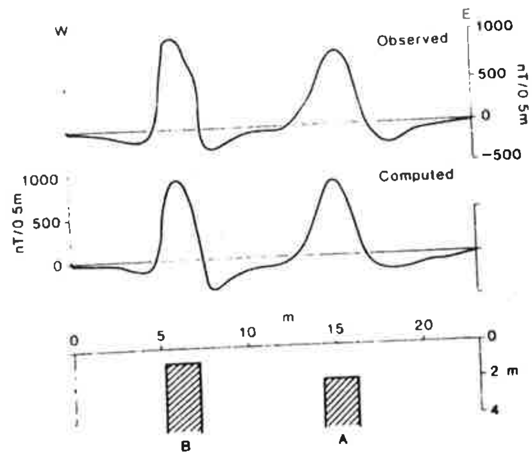
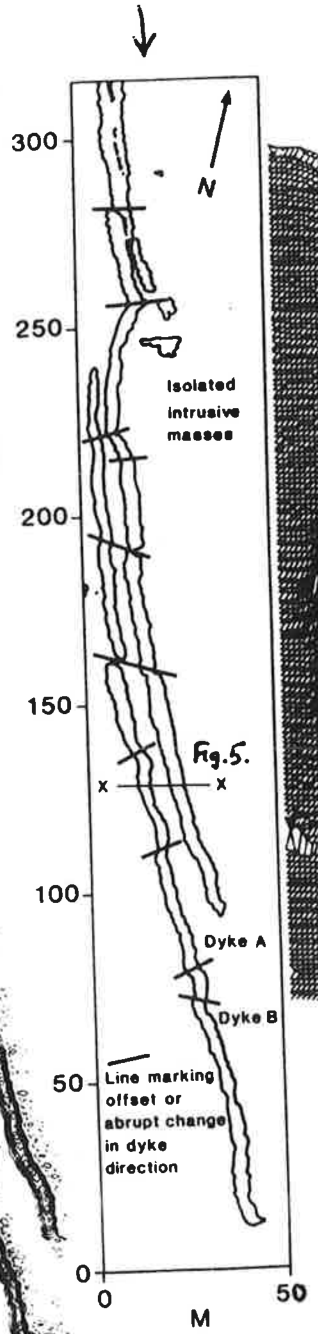
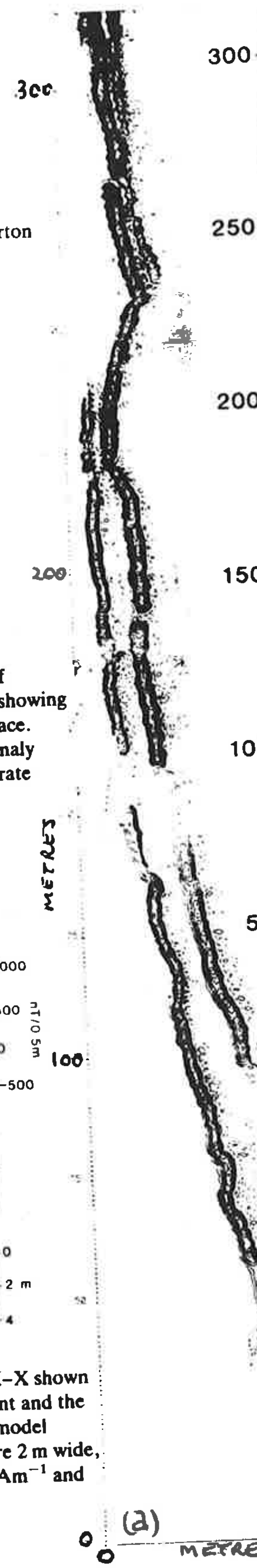


Fig. 5. Vertical magnetic gradient profiles for the line X–X shown in Fig. 4. The top profile is the measured vertical gradient and the bottom profile gives values computed for the two-dyke model shown in section below. In the model Dykes A and B are 2 m wide, 2 and 1 m below the surface, with magnetizations of 20 Am^{-1} and 8 Am^{-1} respectively.

Fig. 4. Map showing the +10 nT/0.5 m (+20 nT m^{-1}) magnetic contour to illustrate the detailed nature of the igneous intrusions. Places are marked where the orientation of the dykes appears to change. X–X marks the line of the magnetic profile shown in Fig. 5.





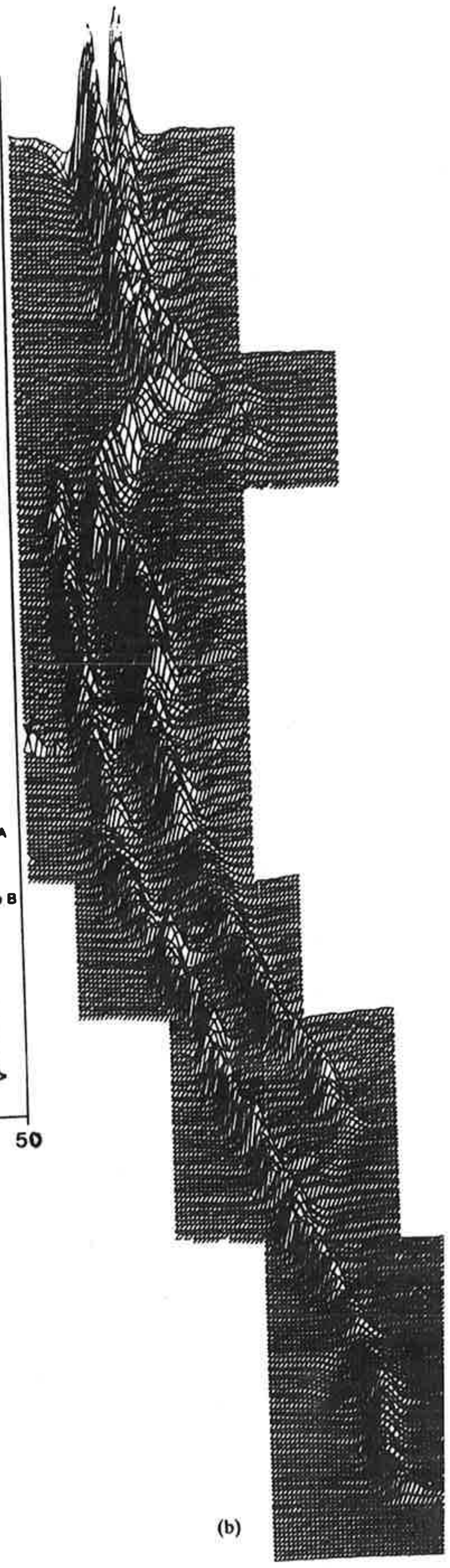
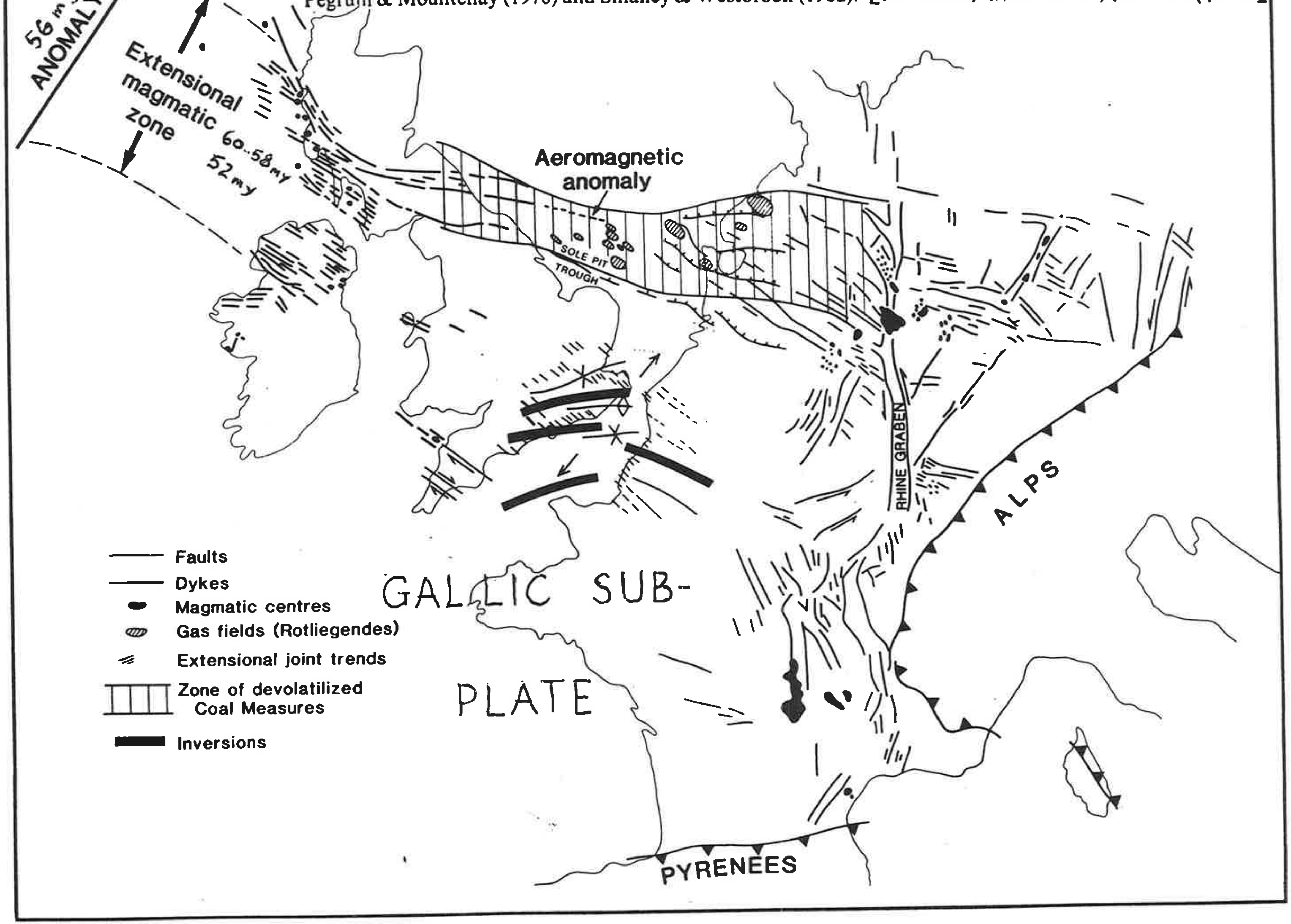


Fig. 2. Contour map and isometric plot showing the results of a vertical magnetic gradient survey made over p the Butterton Dyke. The contour interval used is 10 nT/0.5 m (20 nT m^{-1}), positive values are contoured as so lines and negative values as dashed lines.

FIG. 1. Map of NW Europe showing the main tectonic features developed in the Palaeocene to Oligocene. Sources variable and mostly referred to in text. Aeromagnetic anomaly after Kirton & Donato (1985) and NW trending mesofracture system in S England and N France after Bevan & Hancock (1986). Other data from Pegrum & Mountenay (1978) and Smalley & Westbrook (1982). [From Dewey J.F. and Windley, B.F 1988, p. 26.]



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From Dewey J.F. and Windley B 1988
p. 28

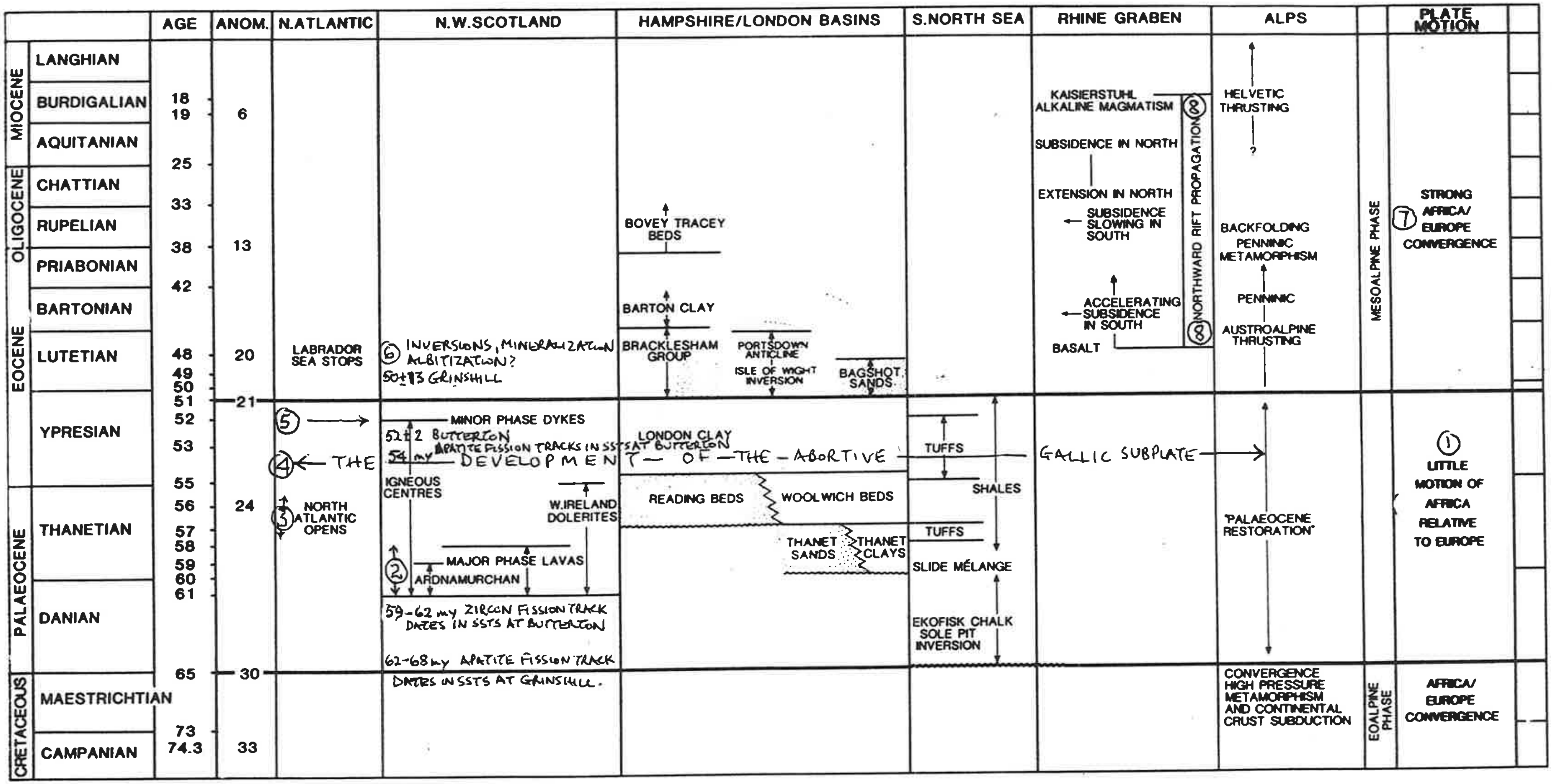

Fig. 2. Time chart of principal events in the evolution of NW Europe from the late Cretaceous to the Miocene. Data from Knox & Harland (1979), Knox (1984), Odin & Curry (1985), Aubry *et al.* (1986) and Mussett (1986).

Order of events are given by the numbered circles 1 — 8

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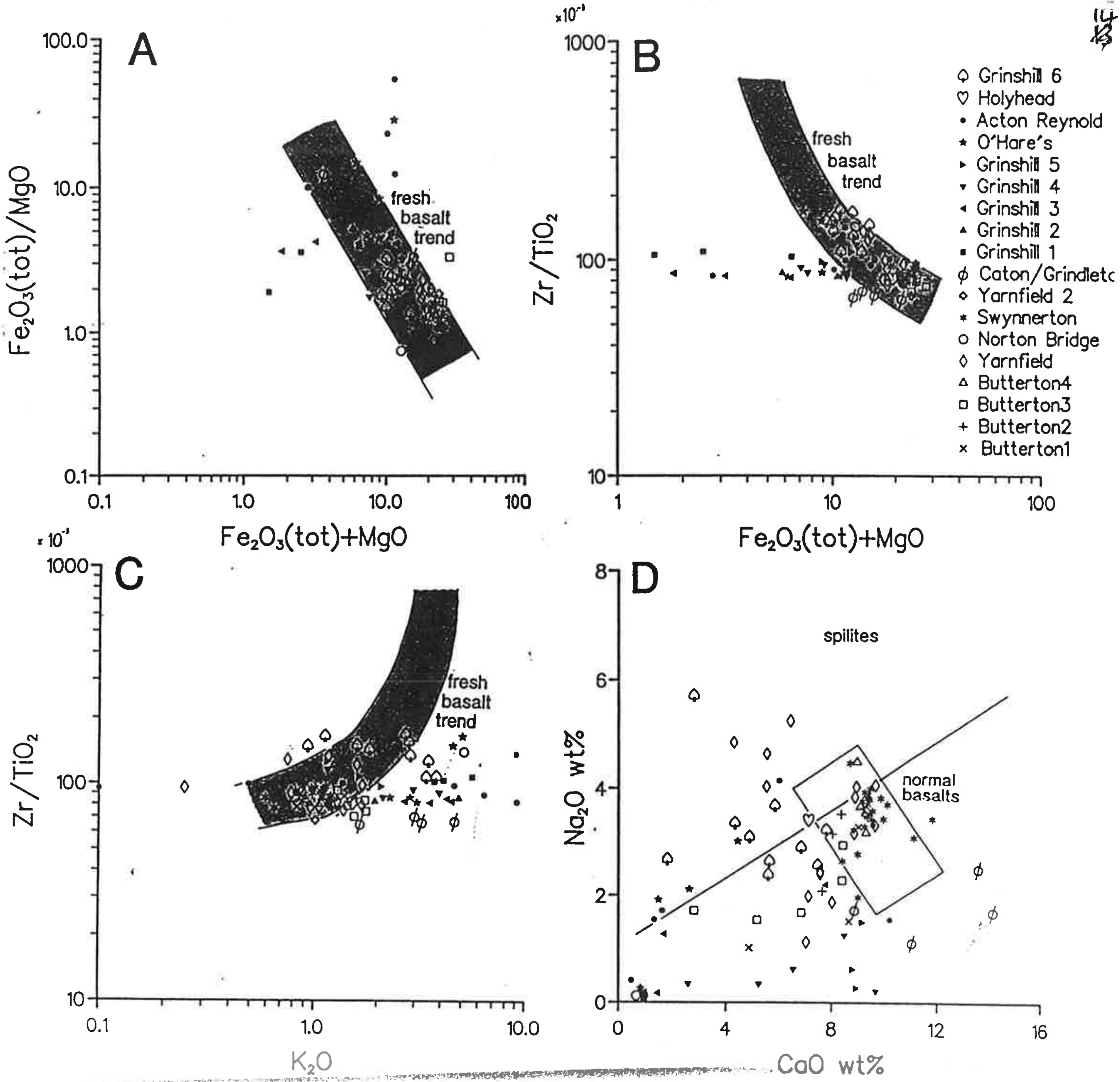
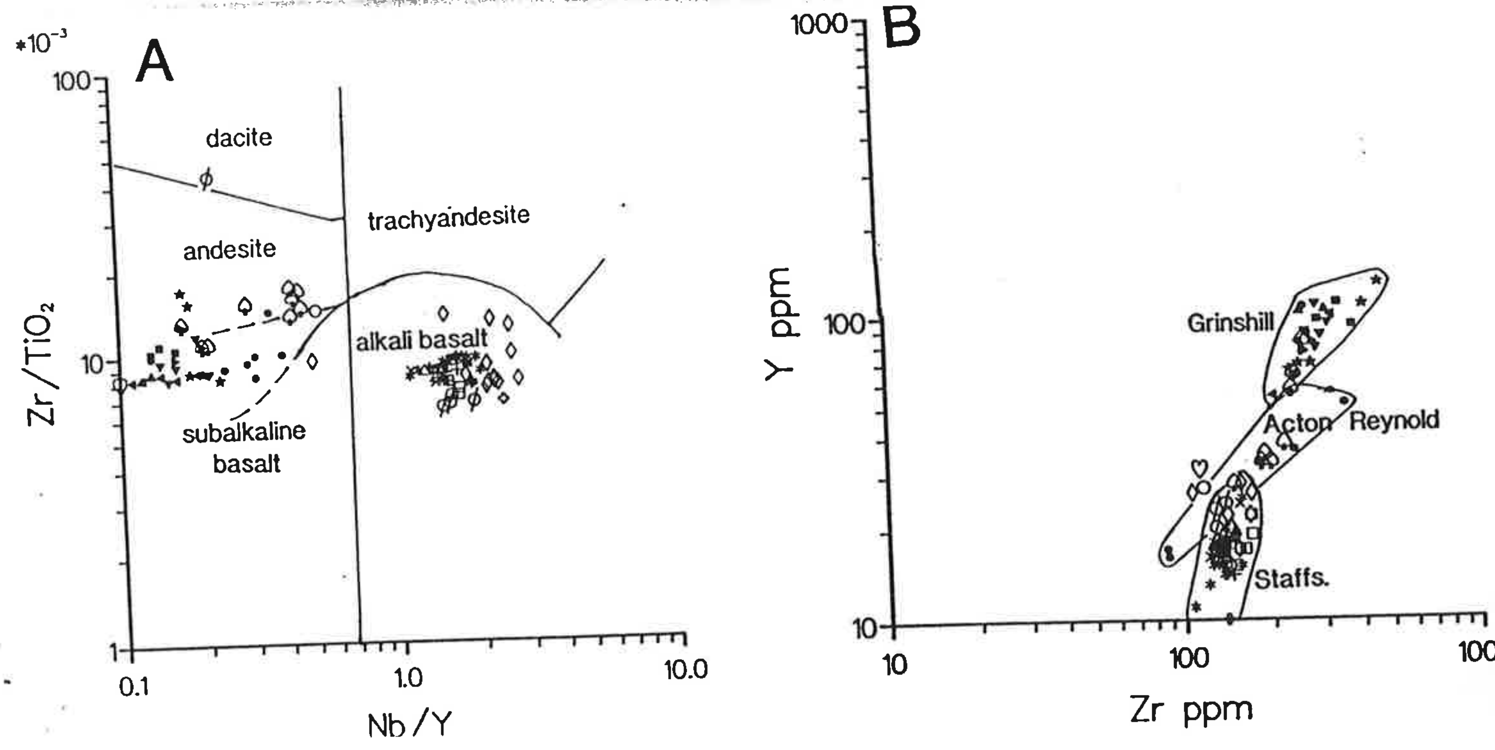
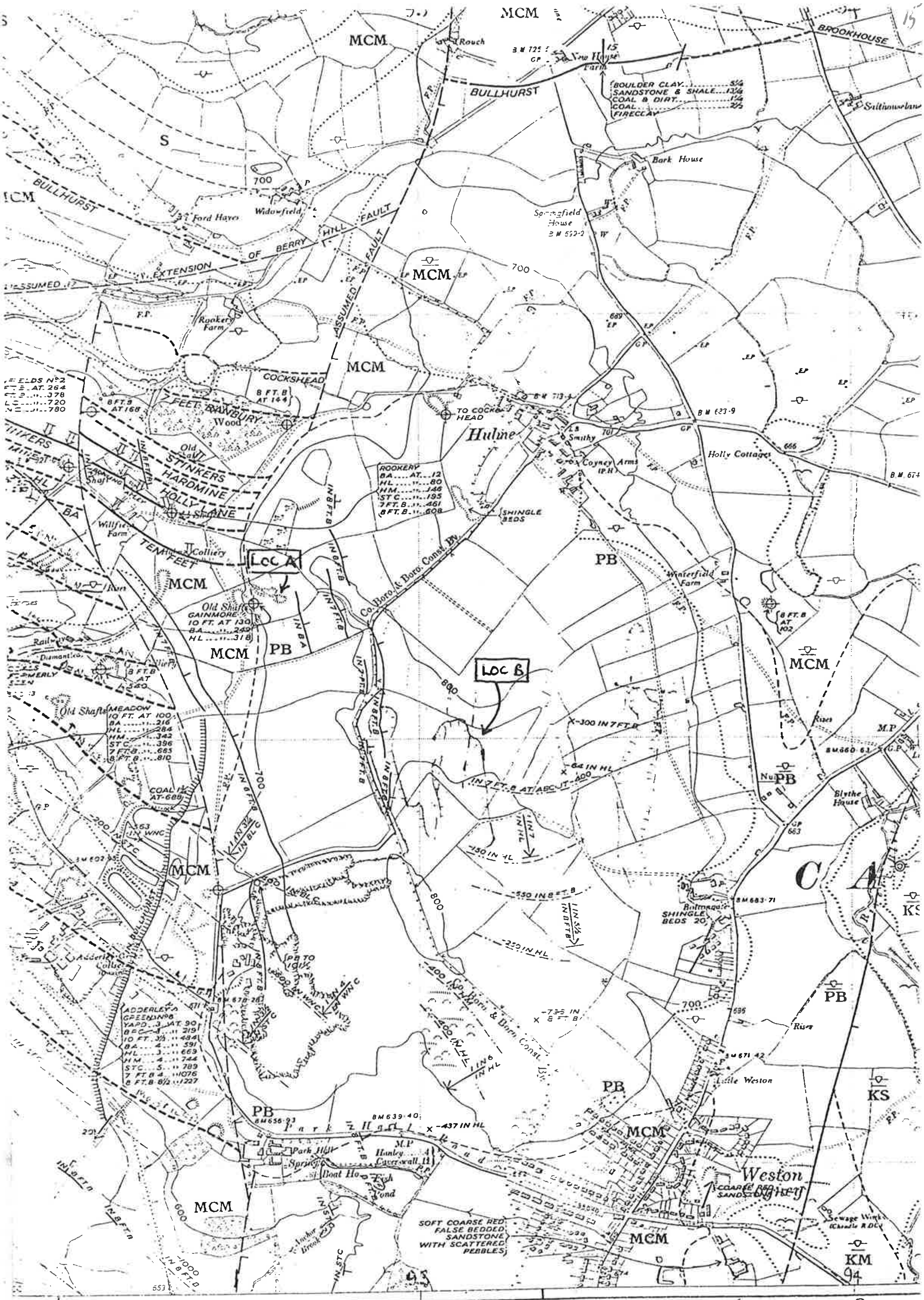

A
B
C
D
Fe2O3(tot)/MgO
Fe2O3(tot)+MgO
Zr/TiO2
K2O
Na2O wt%
CaO wt%
fresh basalt trend
spilites
normal basalts
Grinshill 6
Holyhead
Acton Reynold
O'Hare's
Grinshill 5
Grinshill 4
Grinshill 3
Grinshill 2
Grinshill 1
Caton/Grindletc
Yarnfield 2
Swynnerton
Norton Bridge
Yarnfield
Butterton4
Butterton3
Butterton2
Butterton1


A
B
Zr/TiO2
Nb/Y
dacite
andesite
trachyandesite
alkali basalt
subalkaline basalt
Y ppm
Zr ppm
Grinshill
Acton Reynold
Staffs.



MCM
Rouch
BROOKHOUSE
BULLHURST
BOULDER CLAY
SANDSTONE & SHALE
COAL & DIRT
COAL
FIRECLAY
Bark House
S
700
BULLHURST
Ford Hayes
Widowfield
Springfield House
EXTENSION OF BERRY HILL FAULT
ASSUMED FAULT
Rookery Farm
COCKSHEAD
FEET RANBURY
Wood
TO COCKSHEAD
Hulme
Smithy
Coyney Arms
Holly Cottage
STINKERS
HARDMINE
HOLLY LANE
ROOKERY
BA AT 12
HL 80
HM 146
STC 195
7 FT. B 461
8 FT. B 608
SHINGLE BEDS
Willfield Farm
TEN FEET
Colliery
LOC A
PB
Winterfield Farm
Old Shafts
GAINMORE
10 FT. AT 130
BA 249
HL 318
Co. Boro. & Boro. Const. Bdy.
LOC B
800
Old Shafts
MEADOW
10 FT. AT 100
BA 216
HL 284
HM 342
STC 396
7 FT. B 663
8 FT. B 810
COAL
AT 688
X-300 IN 7 FT. B
IN 7 FT. B AT ABOUT 400
Blythe House
-150 IN HL
-550 IN 8 FT. B
-250 IN HL
Adderley Green Colliery
ADDERLEY GREEN No 6
Bolton
SHINGLE BEDS
C
KS
Little Weston
PB
KS
Park Hall
MCM
Weston
Boat Ho.
Fish Pond
Hanley
Caverswall
SOFT COARSE RED FALSE BEDDED SANDSTONE WITH SCATTERED PEBBLES
Sewage Works
KM
94

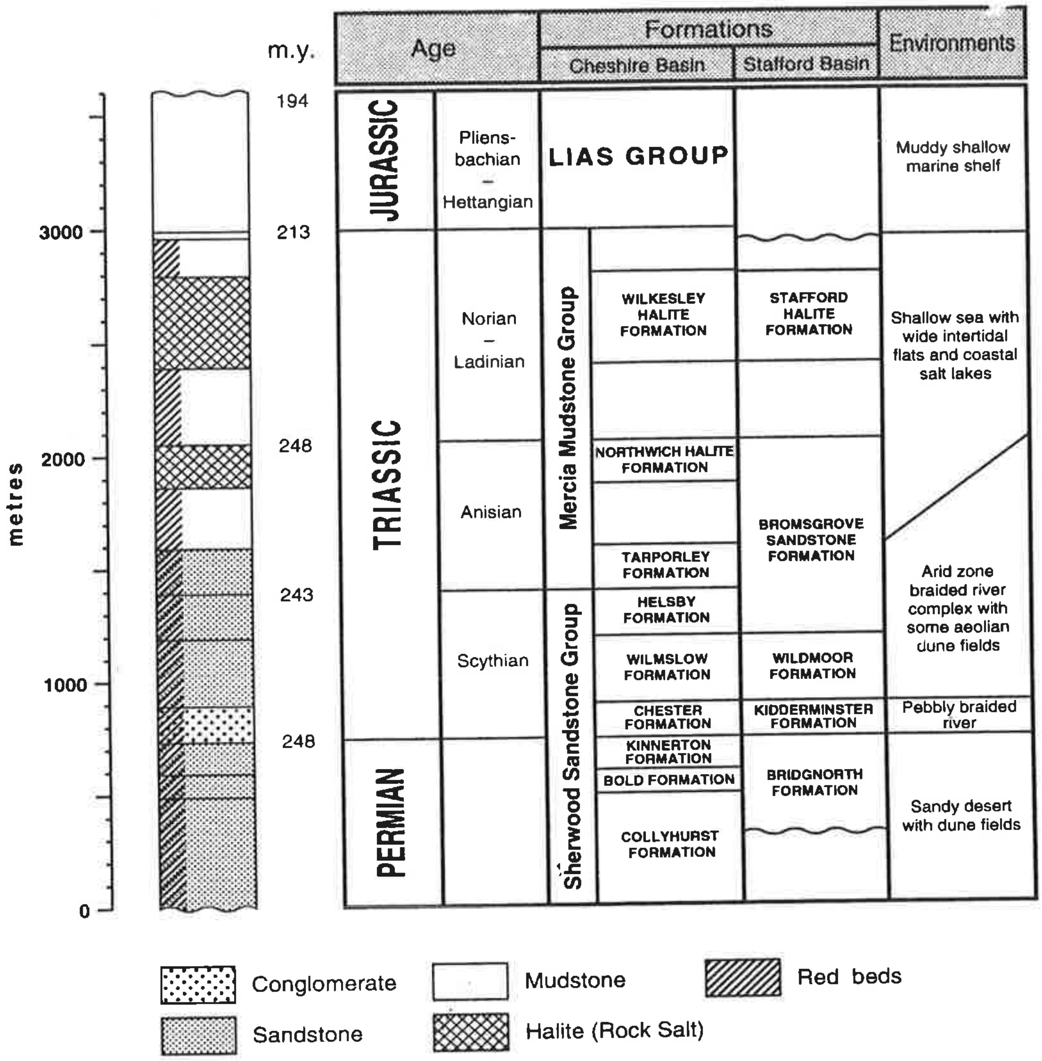


FIGURE 2.8 Generalized sequence of Mesozoic rocks present in the district.

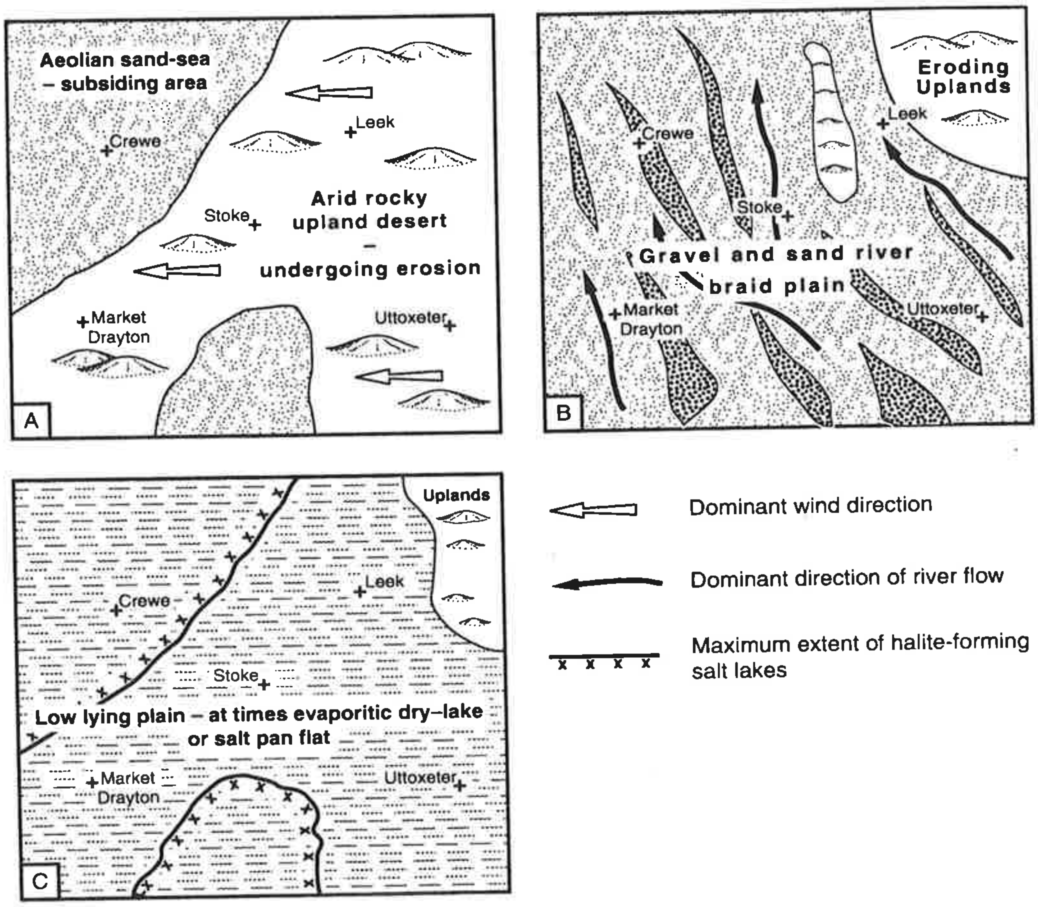
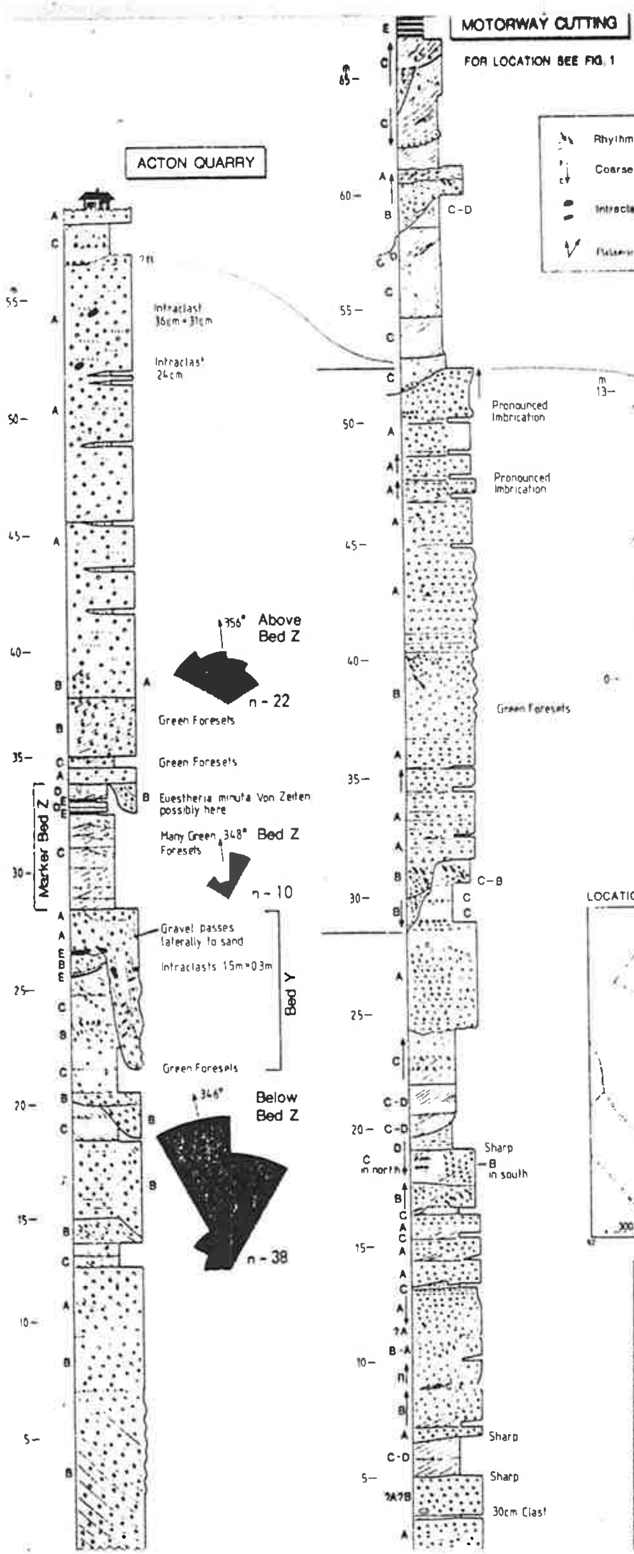
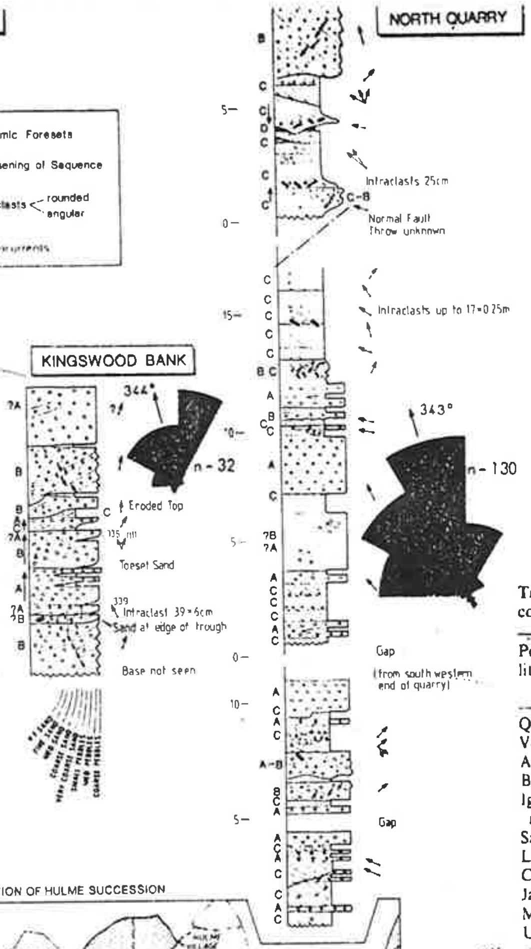
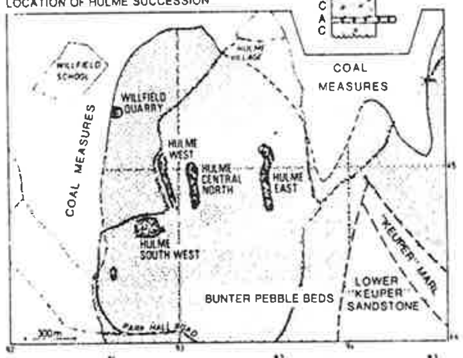
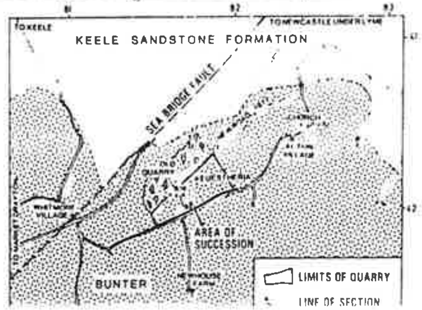


FIGURE 2.7 Generalized sketches of the palaeogeographic evolution of the district during Permian and Triassic time: A) late Permian; B) early Triassic; and C) late Triassic. Map areas as in Fig 2.1.









Lithofacies	Outline description of lithofacies	Percentage of succession at: Acton	Motorway Cut	Hulme
A	Horizontally stratified conglomerates: a spectrum of types, simple disorganized clast- or matrix-supported conglomerate to complexly organized rhythmically graded types with three parts (i) bimodal, often matrix-supported conglomerate separated by a discontinuity from (ii) finer clast-supported open-framework conglomerate, and (iii) small-pebble bimodal clast-supported conglomerate with a framework filled by sand, silt or clay. Imbrication is common (see Figs 4, 5, 6, 8, 14 and Buist & Thompson, 1982, plate 8a, b, c)	43·0	34·8	26·8
B	Cross-stratified conglomerates often with rhythmically developed textures and structures on the foresets, all bimodal. (i) planar types, (ii) trough types. The cross-strata may be related laterally to beds of lithofacies A (see Figs 9, 10, 11, 13, 14, and Buist & Thompson, 1982, plate 9a, b)	34·0	17·8	18·9
C	Pebbly (C1) and less pebbly (C2) cross-bedded medium-grained sandstones. Cosets of: (i) planar and (ii) trough type, with lenses and stringers of pebbles along internal erosion surfaces. Reactivation surfaces are common. Intraformational pebbles, cobbles, blocks lie above erosion surfaces at the base of cosets (see Buist & Thompson, 1982, plates 9a, 10)	20·0	36·1	52·0
D	Argillaceous, medium and fine-grained cross-bedded sandstone. Some intraformational pebbles. Soft sediment deformation structures. Gravel lenses and stringers of pebbles are much rarer	2·1	10·0	0·7
E	Horizontally stratified parallel-bedded interbedded fine-grained argillaceous sandstone, siltstone and mudstone and *Euestheria* (see Buist & Thompson, 1982, plate 10)	0·9	1·3	1·5
	Thickness of relevant sections used for calculations	c. 69 m	c. 80 m	c. 35 m

Table 2 Summary of pebble count analyses from 45 selected conglomerate samples from natural and quarry sections (CHEADLE AREA)

Pebble lithology	Mean (weight %) $n = 45$	Range (weight %)
Quartzite	72	40.0–88.0
Vein-quartz	19	8.9–50.0
Acid igneous	1	trace–11.0
Basic igneous	0.5	0.0–2.7
Igneous and metamorphic	1	0.0–16.1
Sandstone	4	0.5–9.8
Limestone	1	0.0–6.0
Chert	trace	0.0–0.3
Jasper	trace	0.0–0.1
Mudstone	1.5	0.5–6.0
Undifferentiated	trace	0.0–3.2

Table 3 Composition of the conglomerates (number per cent) in the STOKE GRAVEL RESOURCES SHEET AREA.

Lithology	Natural samples number %	Drilled samples number %
Quartzite	51	62
Quartz	24	24
Igneous	11	5
Metamorphic	trace	trace
Sandstone	5	3
Siltstone/Mudstone	4	2
Chert	5	3
Others	trace	1

Summary of lithostratigraphic divisions of the Trias of the Ashbourne district

Period	Series	Stage	Ma	Lithostratigraphic subdivisions			Equivalents in older nomenclature
JURASSIC	LOWER	HETTANGIAN	213				
TRIASSIC	UPPER	RHAETIAN	219	MERCIA MUDSTONE GROUP	Undivided		Keuper Marl
		NORIAN					
		CARNIAN					
	MIDDLE	LADINIAN	238 ?				
		ANISIAN			DENSTONE FORMATION		Waterstones (Hull 1869)
	LOWER	SCYTHIAN	243 ?	SHERWOOD SANDSTONE GROUP	HOLLINGTON FORMATION		Lower Keuper Sandstone below Waterstones (Hull 18)
					HAWKSMOOR FORMATION	LODGEDALE MEMBER	Bunter Sandstone and Pebble Beds (Hull 1869)
						FREEHAY MEMBER	
			? 248		HUNTLEY FORMATION		
PERMIAN	UPPER	TARTARIAN					

↑ MILLIONS OF YEARS; SCALE OF HARLAND et al 1983.

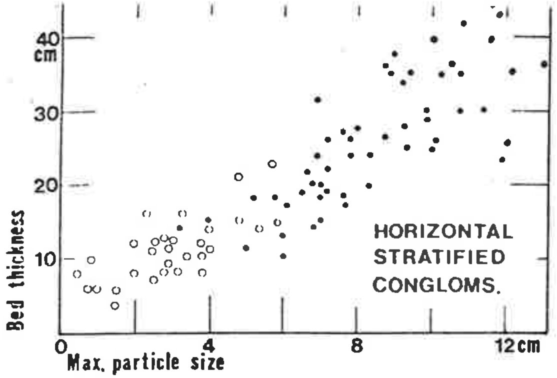


Fig. 7. Bed thickness and maximum particle size distribution (mean of 10 largest clasts near the point of measurement) in lithofacies A conglomerates. Dots represent the simple and crudely organized beds; open circles the well-organized beds.

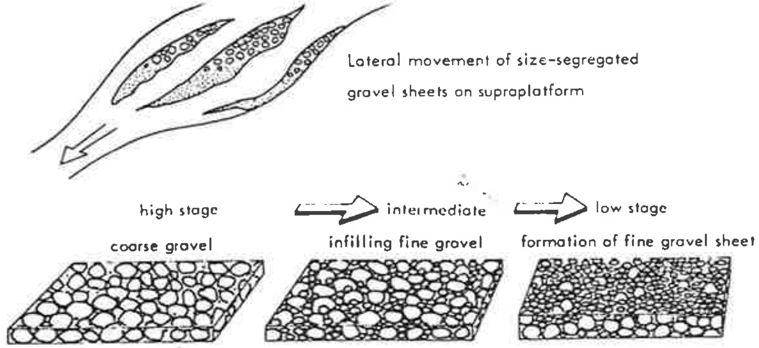


Fig. 6. Lithofacies A conglomerates which are well organized often show: (a) well developed coarse-tail normal grading (but note decreasing matrix percentage upwards on photograph) (Hulme South-west Quarry: Gulch Quarry) or (b) repeated sequences of coarse bimodal–coarse open framework–fine-filled framework conglomerate (Acton Quarry). Such organization is relatively rare in lithofacies A. Lens cap is 5 cm. (c) illustrates the possible origin of the textures and textural sequences in (a) and (b).

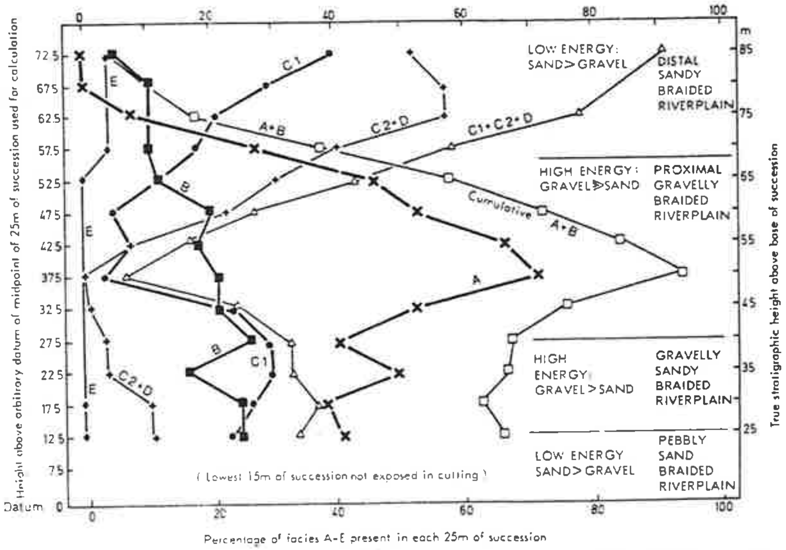


Fig. 16. Time-trend of sedimentation shown by the mean distribution of lithofacies A–E in Bunter Pebble Beds succession of the M6 Trentham motorway cutting (eastern side). The calculation of the mean incidence of facies is based on a moving average in which 25 m thick units overlap each other by 20 m.

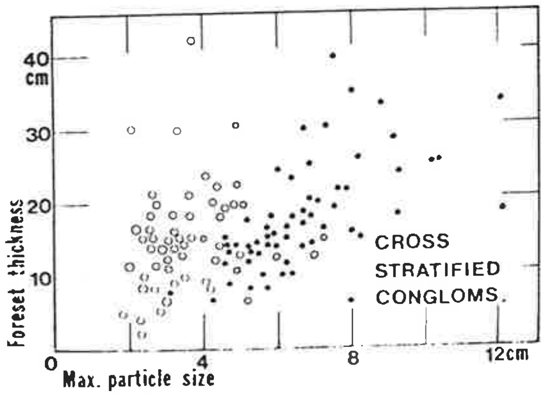


Fig. 12. Maximum particle size and unit thickness relationships for the cross-stratified conglomerates. Dots represent the bimodal types of unit in foresets (grain assemblages B1 in Fig. 9) while open circles are the tightly packed fine conglomerates (grain assemblage B2).

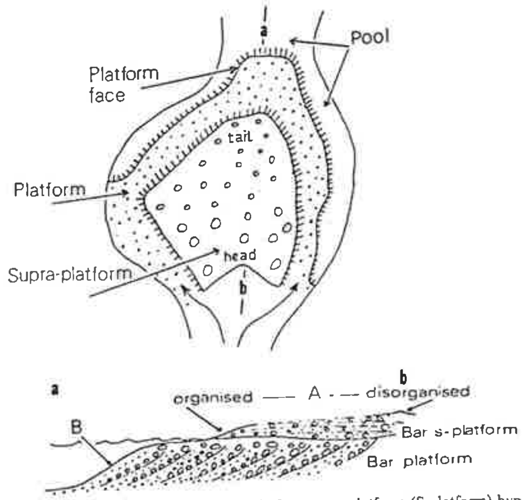
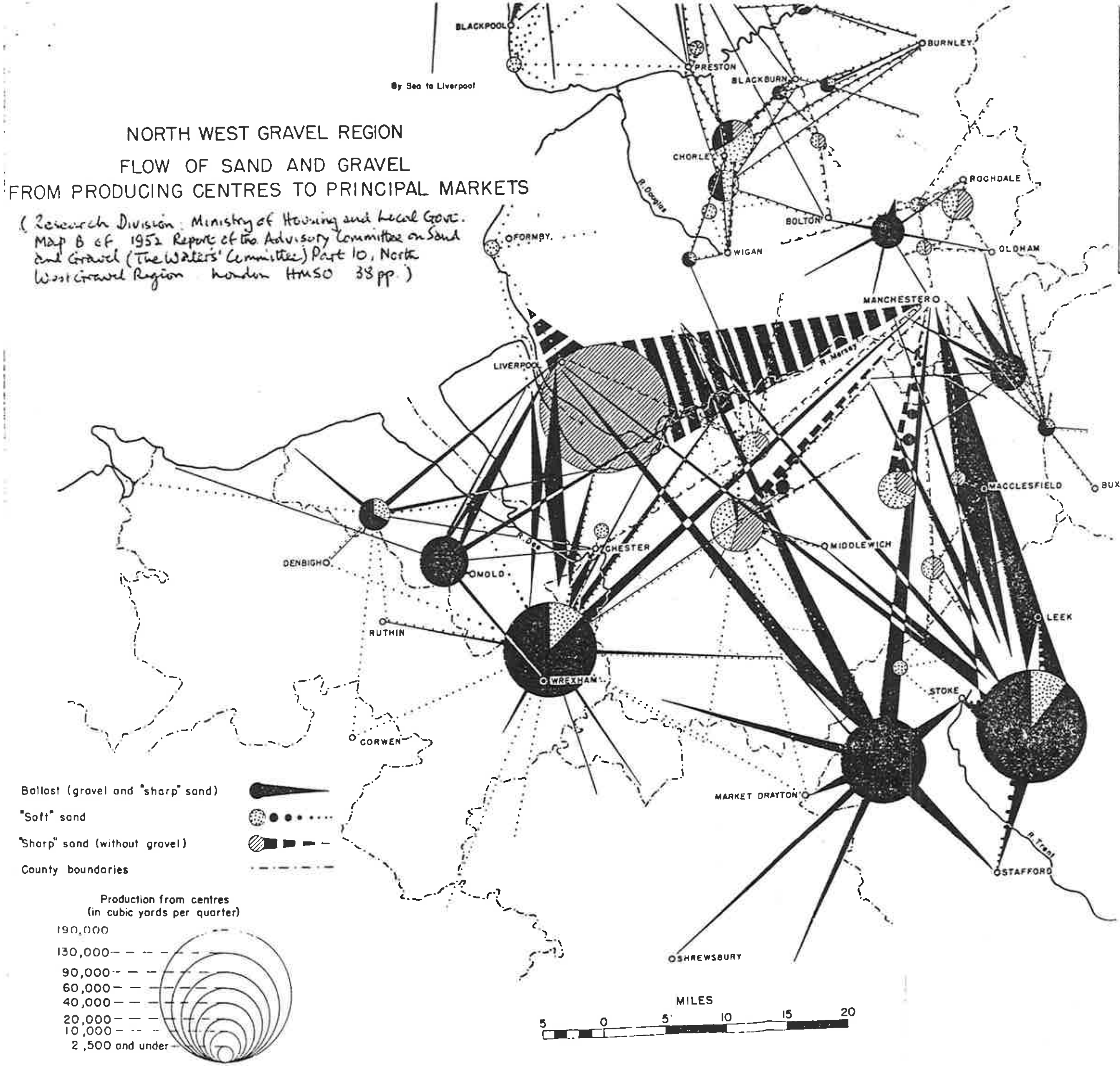


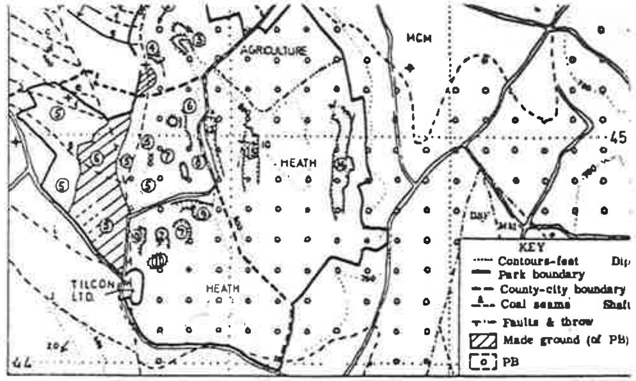
Fig. 15. The relationship of lithofacies A and B using the platform-supraplatform (S-platform) hypothesis of Bluck (1971, 1976).

NORTH WEST GRAVEL REGION

FLOW OF SAND AND GRAVEL FROM PRODUCING CENTRES TO PRINCIPAL MARKETS

(Research Division Ministry of Housing and Local Govt. Map B of 1952 Report of the Advisory Committee on Sand and Gravel (The Waters' Committee) Part 10, North West Gravel Region London HMSO 38 pp.)





Text-fig. 4: The restoration of abandoned quarries and sand in the area of the Park Hall Country Park, northeast of Longton (see inset on text-fig. 2). Geological boundaries are taken largely from the revision of the six inch (1:10560) sheet Staffordshire XVIII NE published in 1948 and in the case of the pebble beds should be regarded as somewhat approximate especially on the east site of the Park. A key to the coal seams a - j (all in the Middle Coal Measures) is as follows (oldest first):

a - Cockshead	f - Bowling Alley
b - Seven-foot Banbury	g - Ten Feet
c - Stinkers	h - Birches
d - Hard Mine	i - Yard
e - Holly Lane	j - Mossfield

BSF - Bromsgrove Sandstone Formation
MM - Mercia Mudstone Group
MCM - undifferentiated Middle Coal Measures
PB - Pebble beds

Ringed figures refer to the features of the Country Park which are cited and explained in table 1. The location of these features is taken from maps of the Department of Environmental Services, City of Stoke-upon-Trent.

Table 1: The relationship between the geological features of the former quarried areas of the Park Hall County Park, Longton, and their adaptation and use as a public amenity. (See text-fig. 4 for the location of the numbered features.)

Location on Fig.4	Feature of pebble beds and mineral extraction process	Amenity, adaptation and use
1	Smooth steep contours of west facing scarp; sand and gravel succession - mostly sandy.	Toboggan run.
2	Scarred steep contours of scarp.	Badger runs; nature area.
3	Natural rounded knoll at top of scarp.	"Maiden Castle" vantage point.
4	Sand quarry near base of succession (Facies C, D) restricted in extent by a major fault. Type area for studying lowest part of succession.	"The Quarry" picnic area and site of geological interest for training geologists (bedding, contrasting lithologies, faults, joints, crossbedding, etc.)
5	Old quarries, mostly of gravelly facies, worked in unorganised fashion in the early days and tipped into in an uncontrolled way.	Regraded, covered by excess sand and gravel; for use eventually as a municipal golf course.
6	Length of quarry in Facies A, B, C.	The "Kyber Pass" - part of a principal walkway.
7	Sand and gravel; Facies A, B, some C.	Picnic and kick-about bowl (similar on east side of road).
8	Eminence formed of former quarry walls; Facies A, B.	"Old Man of Hoy" vantage point.
9	Quarries in Facies A, B, C crossed by faults.	The Gulch Car Park; Picnic Hollow.
10	Abandoned headworks and approaches plus former quarry face in faces B and C	Hopper Fort and Rough Hill Car Park.
11	Abandoned mounds of unused product.	The Sand Heap (grassed).
12	Elongate quarries with fault lines controlling abandonment of mining along certain walls.	Amphitheatre; circular wall and 'bandstand' at north end. Sides of quarry smoothed and lowered.
13	North central quarry; west side fault controlled. Type area for main succession. Site of special scientific interest for study of sand and gravelly braided river deposits.	Adventure playground. - The Play Canyon Site for training geologists.
14	North eastern quarry; fault controlled.	Skinners Canyon Walk along "Canyon" to pond.

FIG 1
MEETING PLACE
NEWCASTLE UNDER-LYME
Wrinehill
Ravenshall
Adderley Green
Betley
Leycett
Silverdale
Madeley Heath
Little Madeley
Keele
Madeley
Middle Madeley
Onneley
Bar Hill
Stony Low
Service Area
Seabridge
Clayton
Westlands Golf Course
Hey Sprink
Whitmore
Whitmore Wood
Madeley Park Fm
Butterton
Shutlanehead
Moathouse
Acton
Hanchurch
Northwood
Hargreaves Wood Golf Course
Trentham
Trentham Park
Aston
Minnbank
Slymansdale Camp Hill
Maer Hills
Baldwin's Gate
Chorlton Moss
Coney Green
Newhouse Fm
Swynnerton Old Park
Shelton under Harley
Blackbrook
Maer
The Bogs
Chapel Chorlton
Stableford
The Rowe
Beech
Upper Hatton
Cliffords Wood
Lodgebarn
Lower Hatton
Ashley
Podmore
Standon
Cranberry
Cotes Heath
Swynnerton
Cotes
Chatcull
Walford
Broughton
Charnes Hall
Whittington
Foxley
Aspley
Millmeece
Wetwood
Fairoak
Croxtonbank
Highlanes
Slindon
Croxton
Little Sugnall
Brockton Hall
Woodwall Green
Sugnall
Drake Hall (HM Prison)
Sturbridge
Offleybrook
Outlands
Coldmeece
Yarnfield
Heamies
Baden Hall
Ankerton
Cat's Hill Cross
75
76
77
78
79
80
81
B 5026 Eccleshall 1 mile
A 519 Newport 10 miles
83
84
85
A 520 Newport 10 miles
86
87