To ETHOS Admin.

Besly, Bernard Maurice

The sedimentology and stratigraphy of red beds in the Westphalian A to C of Central England

(2 volumes)

Ph.D. 1983

REDATIONS:

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Volume 2, Fig. 7, pp. 11.
Volume 2, Fig. 9, pp. 15
Volume 2, Fig. 10, pp. 17
Volume 2, Fig. 11, pp. 19
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CONTAINS MAPS IN BACK POCKET
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TEXT IN ORIGINAL IS CLOSE TO THE EDGE OF THE PAGE
Fig. 1. Map of Central England, showing outcrops of Etruria and other Westphalian Formations, and areas studied.
Localities of measured sections in Stoke and Birmingham areas shown in Figs 3 - 5.

Large letters and bracketed marginal figures relate to National Grid 100 km. squares.
Other marginal figures relate to 10 km. Grid squares.
Fig. 2. Names of Westphalian depositional areas used in text; approx. Westphalian subcrop.
Documented
Inferred
Arbitrary (i.e. no data)
Base Westphalian outcrop
"" subcrop
Base Trias

MAY BE COMBINED WITH OUTCROPI SUBCROP SYMBOLS
LEGEND

- Pre-Westphalian
- Productive Coal-measures Westphalian A to C
- Blackband Formation Westphalian C
- ETRURIA FORMATION Westphalian C/D
- Newcastle and Keele Formations Westphalian D
- Base of Trias

NORTH STAFFORDSHIRE - Outcrop geology and location of measured sections

Fig. 3
CANNOCK CHASE - outcrop geology and location of measured sections

Fig. 4
SOUTH STAFFORDSHIRE (WEST MIDLANDS)
Outcrop geology and location of measured sections

LEGEND
- Halesowen, Keele and Enville Formations
- ETRURIA FORMATION
- Productive Coal-measures
- Pre-Westphalian
- Dolerite (Westphalian)

Fig. 5
Fig. 6. Evolution of biostratigraphic classification of the Westphalian of Central England.
<table>
<thead>
<tr>
<th>KIDSTON</th>
<th>DIX &amp; TRUEMAN</th>
<th>STUBBLEFIELD &amp; TROTTER</th>
<th>RAMSBOTTOM et al.</th>
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<tr>
<td>1894, 1905</td>
<td>1937</td>
<td>1957</td>
<td>1978</td>
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<td>UP...COAL MEASURES</td>
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<td>CONGRESS CLASSIFICATION</td>
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<td>STEPHANIAN</td>
<td>Prolifera</td>
<td>Proli...</td>
<td>Base of Westphalian D</td>
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<td>MORGANIAN</td>
<td>Tenuis</td>
<td>Tenuis</td>
<td>marked by appearance of Thamnosp...</td>
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<td>AMMANNIAN</td>
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<td>Phillipi (Top) M.B.</td>
<td>Neuropteris ovata etc.</td>
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<td>MIDDLE COAL MEASURES</td>
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<td>Upper Similis-Pulchra</td>
<td>Laveine 1977</td>
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<td>Madiolaris</td>
<td>(Mansfield)</td>
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<tr>
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<td>Communis</td>
<td>Lower Similis-Pulchra</td>
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<td>Lensulcata</td>
<td>Madiolaris</td>
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<td></td>
<td>Vanderbecki M.B.</td>
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<tr>
<td>LOWER COAL MEASURES</td>
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<td>(Clay Cross)</td>
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<tr>
<td>LANARKIAN</td>
<td></td>
<td>Communis</td>
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<td></td>
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<td>Lensulcata</td>
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<tr>
<td></td>
<td></td>
<td>Subcrenatum M.B.</td>
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Fig. 7. Lithostratigraphical nomenclature currently employed for the Westphalian of Central England (after Ramsbottom et al., 1978 and others).

Notes:

1. Kinlet Formation as defined by Mitchell et al., 1962, includes the whole Westphalian A to C (everything below the unconformable base of the Highley Fm.). Ramsbottom et al. (1978) use Kinlet Formation solely to describe the red beds overlying the Aegirianum Marine Band (= Etruria Fm.).

2. Age of the upper part of the Etruria Fm. not known.

3. Halesowen Formation locally rests unconformably on Productive Coal Measures.

4. Age of the upper part of the Etruria Fm. not known.

5. Halesowen Fm. locally rests unconformably on Productive Coal Measures.

6,7. Age of the upper part of the Etruria Fm. not known.

8. Westphalian D age for upper part of Etruria Fm. found by Butterworth and Smith (1976).

9. Hadley Formation introduced for Etruria Formation facies by Geological Survey (1978); this Formation was previously referred to as the lower part of the Coalport Formation.


11. A Westphalian C age has been obtained for the basal part of the Coalport Formation by B. Owens (personal communication).

12. Ruabon Formation rests unconformably on pre-Carboniferous in southern part of this area, and possibly unconformably on P.C.M. elsewhere. Unconformity at base of Coed-yr-Allt Formation not certain.

13. Age and facies of lower part of Ardwick Formation after Poole and Whiteman (1954), Wills (1956), and by analogy with the basin centre succession in North Staffordshire.

14. Upper part of Ardwick Fm. consists of fresh water limestones and mudstones. Correlation (after Wills 1956) not certain.
Fig. 8. Lithostratigraphic nomenclature employed for all areas in this thesis.
South

BASE OF WESTPHALIAN D HALESOWEN FORMATION & EQUIVALENTS

Local unconformity

ETRURIA FORMATION RED BED FACIES

Cambric M.B.

Aegirianum M.B.

PRODUCTIVE COAL MEASURES

Vanderbecki M.B.

Subcrenatum M.B.

Halesowen / Wyre Forest

Cannock

Stoke on Trent

North
Fig. 9. Generalized Westphalian palaeogeography (from Ziegler, 1981). Note that outlines of Welsh Massif and London Brabant Massif are not representative of the whole Westphalian: prior to Westphalian D these massifs were probably fused.
Fig. 10. Westphalian depositional provinces in the British Isles (from Calver 1969).
Fig. 11. Late Carboniferous (Westphalian CD) palaeogeography. Mollweide projection ("front view"). Deep oceans, unshaded; shallow seas, light shading; low land, intermediate shading; mountains, dense shading. From Scotese et al. 1979.
Fig. 12. Idealized models of continental precipitation patterns (from Ziegler et al. 1979, based on Robinson 1973 with addition of mountains and surface winds).
Fig. 13. Conceptual differences in width and location of the Earth's air pressure belts in relation to the size of the Polar ice caps (from Glennie 1981). Note narrowing of equatorial belt at times of glaciation.
Fig. 14. Key to symbols employed in sedimentary graphic logs in Chapter 3 to 5 and Appendix 1, and in stratigraphic correlation diagrams in Chapter 9.
**LITHOLOGY & SEDIMENTARY STRUCTURE**

**CHAPTERS 3 - 6**

**APPENDIX 1**

- Mudstone
- Silty mudstone
- Siltstone
- Sandstone
- Pebby sandstone
- Conglomerate
- Shale clast conglomerate
- Coal
- Carbonaceous mudstone
- Bedded ironstone
- Gradational boundary
- Horizontal lamination
- Cross lamination
- Cross bedding
- Erosive boundary
- Evolved palaeosol
- Calcareous concretions
- Desiccation cracks
- Lateral accretion sets
- Seat earth palaeosol
- Listic texture
- Sphaerosiderite
- Plant root traces
- Plant fragments

**PALAEOSOIL SECTIONS**

**CHAPTERS 3 - 6**

- Grey leached upper horizon
- Veins of purple pigment
- Diffuse purple pigment (v. fine grained haematite)
- Goethite root concretions
- Discrete haematite nodules
- Diffuse haematite concretions
- Gradational basal horizon
- Red mudstone
- Carbonaceous horizon
- Listic texture
- Stigmaria roots
- Siderite nodules
- Patchy red colouration
- Oxidized sphaerosiderite
- Grey mudstone

**ABBREVIATIONS USED IN GRAPHIC LOGS**

**FACIES:** codes as listed in Table 1

**COLOURS:**

- R - red
- V - variegated, mottled
- G - green
- GY - grey (organic rich)
- (R) - red patches, reddish
- (B) - brownish

**STRATIGRAPHIC SECTIONS**

**CHAPTER 9**

- Halesowen Formation (and correlatives)
- Unconformity
- Continuous red bed sequence
- Interbedded red beds and coal measures (uncored)
- Interbedded red beds and coal measures (cored)
- Brown pigmented zone
- Limestone marker
- Coal seams
- Marine band
- Dolerite
- Pre-Carboniferous
- Extract from longer borehole penetration
- Fault

- TR - Triassic
- P - Permian
Fig. 15. Possible effects of intermittent deposition and pedogenesis on the formation and preservation of soil profiles in an alluvial sequence (in part after Freytet 1971).
Partial erosion and burial - preservation of truncated palaeosol profile.

No sediment increment, change in climate or drainage conditions - polyphase palaeosol.

Small sediment increment, interference between soil profiles - stacked palaeosol.

Larger sediment increment, no interference between soil profiles.
Fig. 16. Ibstock Himley quarry (SO 896902), deep trial pit, west face. Sheet sandstones Facies 3 surrounding upright lycopod trunk. Scale = 2m.
Fig. 17. Lateral passage of sheet sands (Facies 3) into channel fill (described in Facies 4).

A - rooted horizons and palaeosols; B - rolled Logs; C - thin coal; D - tree illustrated in Figs. 20, 21; E - tree illustrated in Fig. 16.
IBSTOCK HIMLEY WORKS - Deep section (Section I) - North end of west face.

Coarse sandstone? truncating upright trees

Position of measured section

0 metres 5 10 15 20
Fig. 18. Lateral passage of sheet sand (Facies 3) into channel deposit (Facies 4). Correlative sections from Rosemary Hill (SJ 830460) boreholes 9 (sheet sands) and 5 (channel).
Fig. 19. Channelised sandstone, Facies 4, east side of deep trial pit at Ibstock Himley quarry, showing large scale cross bedding at base of sand body. C is thin coal seam correlating with C in Fig. 17. (This channel and its associated grey, Facies Association I, sediments form an intercalation near the base of the Etruria Formation – the sequence is red beneath F).
Fig. 20.  *In situ* upright *Sigillaria* tree, surrounded by sandstone at base of channel fill. West face of deep trial pit at Ibstock Himley quarry (see Fig. 17). Scale pole = 2m.

Fig. 21. Detail of above, showing bark of tree preserved *in situ* as coal, and external mould of the trunk's leaf scar pattern. Scale in cm. and in.
Fig. 22. Vertical sequence of typical Type 1 palaeosol (seat earth).
Based on section between 56.70m and 58.70m in Playground No.8 borehole. Parent material is silty mudstone. For symbols see Fig. 14.
Predominant colours

- Medium grey
- Black
- Pale grey
- Bluish grey
- Medium grey
Fig. 23. Listric texture in carbonaceous palaeosol horizon; vertical thin section.

a) in plane polarized light, showing strongly oriented clots of organic matter in clay matrix.

b) under crossed polars, strongly oriented clay aggregates showing strong birefringence (unistrial fabric).

Sample from partially oxidized palaeosol, Metallic Tileries (illustrated in Fig. 41b).
Fig. 24. Sub vertical cylindrical roots showing occasional downward branching - preserved as siderite concretions. Brown type 2 palaeosol at 11.00m, Ibstock Himley quarry, section 1. Scale = 30cm.
Fig. 25. Vertical sequence of typical Type 2 palaeosol (seat earth with hydromorphic mottling). Based on section between 53.20m and 55.40m in Playground No. 8 borehole. For symbols see Fig. 14.
Predominant colours

Medium grey

Dark grey - black

Dark grey

Medium grey, red pigment in 1 cm patches, and on slickensides

Medium grey, many red patches especially around roots and sphaerosiderite aggregates

Medium grey
Fig. 26. Idealised succession of facies present in lacustrine deposits overlying a coal seam, Blackband Formation, North Staffordshire. There is considerable lateral variation in thickness of individual facies, and not all facies are always present (modified from Boardman 1981).
VARVED MUDSTONE

LACUSTRINE - DEEPEST PHASE
(high clastic input)

OIL SHALE

LACUSTRINE - TRANSITIONAL
(low clastic input - high organic production)

BLACKBAND IRONSTONE

LACUSTRINE - SHALLOW
(low clastic input - high organic production)

CANNEL

POOLS ON SUBSIDING PEAT SURFACE

COAL

PEAT ACCUMULATION
(organic phase, polyphase soil)

SEATEARTH

PALAEOSOL TYPE 1
(alluvial phase, polyphase soil)
Fig. 27. Typical vertical sequence in Facies Association I, Rosemary Hill No. 11 borehole, 6 m - 20 m (T.D.).
Slow swamp sedimentation, pedogenesis dominant, frequent peat formation

More rapid phase of sedimentation, initiated by crevassing. Sequence capped by palaeosols indicating better drainage than in overlying section

Slow swamp sedimentation

More rapid phase of sedimentation, initiated by crevassing
Fig. 28. Typical vertical sequence in Facies Association I, Rosemary Hill No. 3 borehole, 14 m - 33.80 m (T.D.).
<table>
<thead>
<tr>
<th>Colour</th>
<th>Facies</th>
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<tr>
<td></td>
<td>Swamp</td>
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<tr>
<td>15</td>
<td>P1</td>
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<td>Alluvial soil</td>
</tr>
<tr>
<td></td>
<td>Swamp</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>P2</td>
</tr>
<tr>
<td></td>
<td>Alluvial soil (improved drainage)</td>
</tr>
<tr>
<td></td>
<td>Swamp</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>P2</td>
</tr>
<tr>
<td></td>
<td>Alluvial soil (improved drainage)</td>
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</tr>
<tr>
<td></td>
<td>Crevasse splay deposits, forming base of f.u. sequence marking more rapid phase of deposition</td>
</tr>
<tr>
<td></td>
<td>Swamp, thick unrooted sequence - ? proximal to channel</td>
</tr>
</tbody>
</table>
Fig. 29. Typical vertical sequence in Facies Association I, Blackband Formation, Mitchell's Wood opencast site, North Staffordshire (drawn from data in Boardman 1981).
Colour Facies

1
6 (ironstone)

RED SHAGG COAL

P1

(stack)

GY P1

(stack)

1

Swamp
Shallow lake, low clastic input, high organic production

Slow swamp deposition, constant alluvial soil formation occasionally with polyphase evolution to organic (peat) soils

Lake fill
Shallow lake, low clastic input, fluctuating, initially high, organic production

Alluvial soil

Lake fill (as above)

Alluvial soil, polyphase

RED MINE COAL

P1

7
6 (oil shale)

6 (ironstone)
Fig. 30. Typical red mudstones (Facies 8) interbedded with thin and poorly developed palaeosols (P). Metallic Tileries quarry (SJ 840498) north west corner, 1977 (exposure now covered). Scale pole = 2m.

Fig. 31. Oxidized trace of *Stigmaria* appendage in Facies 8 mudstone, Kibblestone borehole (SJ 911361).
Fig. 32. Desiccation cracks preserved as grey mudstone traces in red mudstone. Floor of Wilnecote quarry (SK 220000) 1977 (now removed). Bars on scale = 0.5 m.
Fig. 33. Facies 9: horizontally laminated silt rich (pale grey) and silt poor (dark red) interlaminated lithology. Redhurst Wood west quarry (SJ 969052), section 1. Scale in cm.

Fig. 34. Facies 9: small scale trough cross lamination in interlaminated lithology. Light grey laminae are silt rich. Redhurst Wood west quarry, section 1. Scale in cm.
Fig. 35. Facies 10: parallel sided thin sheet sandstones, Knutton Quarry (SJ 828468), NE face, 3 m above base, ca. 30 m S of sand body illustrated in Figs. 36, 37. Scale divisions = 0.5 m.

Fig. 36. Facies 11: small sand filled channel. Individual units of fill pass laterally into Facies 10 sheet sands (top right) or erode into them (bottom left). Knutton quarry, NE face, 4 m above base, 1977 (now removed). Scale pole = 2 m.
Fig. 37. Small channel (Facies 11) illustrated in Fig. 36: detail of relationships of fill to Facies 10 sand sheets. Drawn from photographs and field sketches.
KNUTTON QUARRY - small channel sandbody exposed in NE side, lowest face, 1977
Fig. 38. Facies 11: typical isolated small channel in red overbank mudstones, filled with unstratified coarse sand and granules. Springfield south quarry (SJ863442), north face. Scale pole = 2 m.

Fig. 39. Part of isolated small channel fill composed of interbedded silt and mudstone, with strong depositional dip (regional dip above and to right of scale pole). Chesterton quarry (SJ827493), at ca. 24 m in section. Scale pole = 2 m. Photographed in 1977 (now covered).
Fig. 40. Facies 9: silt- and mudstones immediately overlying a sand body composed of Facies 13 and 14, the latter containing lateral accretion sets. A and B are small channels (Facies 11) with symmetrical silt- and mudstone fills. Drawn from field measurements of excavations in very degraded exposure above channel sand body, northern part of face, Spoutfield quarry (SJ 863464), 1976.
Fig. 41. Palaeosols of Type 3, showing intense listric texture and relict carbonaceous horizons.

a) Manor quarry (SJ 885451), section 1.

b) Metallic Tileries quarry, sump section, 1.50 m above base, 1977 (now covered).
Fig. 42. *Stigmaria* root form preserved by different pigments in Type 3 palaeosol. Main root, ochre; appendages, dark red. Playground No.8 borehole (SJ972124), 41.50m.
Fig. 43. Typical vertical sequence through Type 3 palaeosol (post depositionally oxidized seat-earth). Based on several examples.
Predominant colours

- Red
- Bright red (ironstone)
- Dark grey
- Red, ochre nodules & *Stigmaria* fills

Red
Fig. 44. Typical prominent banding of grey, purplish, and ochre colouration in a Type 4 (evolved) palaeosol. Redhurst Wood west quarry, west face, 8-10 m in section 1 (see Fig. 106). Scale pole = 2 m.

Fig. 45. Type 4 palaeosol, showing three distinct colour horizons typically developed:

1) upper horizon of grey mudstone;  2) intermediate horizon, variegated and mottled mudstone;  3) lower horizon forming transition into underlying red mudstone. Manor quarry, section 1. Scale divisions = 0.5 m.
Fig. 46. Upper horizon of Type 4 (evolved) palaeosol: typical grey colouration with diffuse patches of purple pigment, showing strong weathering contrast with overlying silty mudstones which have not been affected by pedogenesis. Chesterton quarry, 20-22m, 1977 (now covered). Scale pole = 2 m.

Fig. 47. General view of colour mottling in intermediate horizon of Type 4 (evolved) palaeosol. For detail see Fig. 49. Manor quarry, section 1. Lens cap = 6 cm.
Fig. 48. Fissure or crack in intermediate horizon of Type 4 palaeosol.
Knutton quarry, ca. 1.50 m in section. Scale = 30 cm.

Fig. 49. Detail of colour mottling in Fig. 47. Greyish areas (top and channels in centre) are zones of net haematite loss, while deep red areas are zones of net haematite accumulation, and represent incipient concretions. Scale in cm. and in.
Fig. 50. Sub vertical goethite filled root traces, intermediate horizon of Type 4 palaeosol, Redhurst Wood west quarry (palaeosol at 13-15m., section 1). Scale = 29 cm.

Fig. 51. Nodular haematite concretions, intermediate horizon of Type 4 palaeosol, Chesterton quarry near base of section 1977 (now covered). Coin = 1.7 cm.

Photograph also shows sporadic root traces (ochre) and colour mottling (cf. Fig. 49).
Fig. 52. Lower horizon of Type 4 palaeosol, with prominent bleached root scars. Lightwood quarry, at 14 m in section. Scale in cm. and in.

Fig. 53. Diffuse haematite concretions in intermediate horizon of Type 4 palaeosol. Concretions represent further aggradation of haematite into initially iron enriched mottles (cf. Fig. 49). Atlas quarry: ca. 12 m. in northern section.
Fig. 54. Diffuse haematite concretions in intermediate horizon of Type 4 palaeosol: these concretions are riddled by veins of pale clay giving rise to a brecciated appearance. Horizontal section, Playground No. 8 borehole, 48 m.

Fig. 55. Field appearance of diffuse haematite concretions, showing veining and iron depleted haloes. Chesterton quarry, 18.50 m (see Fig. 59). Photographed in 1977, now covered. Coin = 1.7 cm.
Fig. 56. Diffuse haematite concretions with iron depleted haloes, separated by vertical ?root channels. Lightwood quarry, at ca. 15m. in section. Coin = 1.7 cm.

Fig. 57. Diffuse haematite concretions mainly replaced by goethite. Chesterton quarry, ca. 19.50m. in section (see Fig. 59). Photographed in 1977 (now covered). Coin = 1.7 cm.
Fig. 58. Vertical sequence of typical Type 4 palaeosol, probably representing only one phase of pedogenesis. Goldendale quarry (SJ 850519), ca. 6 to 10 m above base of section. For symbols see Fig. 14.
Predominant colours

- Red
- Pale grey
- Pale grey, much ochre, brown, purple mottling
- Mainly ochre, purple veins
- Red, grey and ochre veins
- Red, ochre veins
- Red
Fig. 59. Vertical sequence of Type 4 palaeosol showing two successive phases of profile development. Chesterton quarry, 18-22 m. For symbols see Fig. 14.
Predominant colours

Red
Pale grey
Pale grey, some ochre and purple
Pale grey/purple, much puce
Pale grey
Pale grey/purple, purple decreases upward, red mottles, some ochre
Purple, many red concretions
Red, purple veins
Red

Later Profile

Earlier Profile
Fig. 60. Vertical sequence of Type 4 palaeosol showing two or more phases of profile development. Keele quarry, 5.50 to 14m. in section. For symbols see Fig. 14.
Predominant colours

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Predominant Features</th>
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<tr>
<td>0-1</td>
<td>Red, grey, purple, red</td>
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<tr>
<td>2</td>
<td>Ochre, red, grey pipes</td>
</tr>
<tr>
<td>3</td>
<td>Purple, red concretions, ochre root tubes</td>
</tr>
<tr>
<td>4</td>
<td>Red, ochre, purple veining</td>
</tr>
<tr>
<td>5</td>
<td>Ochre</td>
</tr>
<tr>
<td>6</td>
<td>Ochre, purple veins</td>
</tr>
<tr>
<td>7</td>
<td>Grey, purple, abundant red concretions, ochre roots</td>
</tr>
<tr>
<td>8</td>
<td>Red</td>
</tr>
<tr>
<td>9</td>
<td>Grey</td>
</tr>
</tbody>
</table>

LATER PROFILE
EARLIER PROFILE
Fig. 61. Iron/silica plots for Etruria Formation palaeosols.

a) profiles showing positive correlation: EM4-6, Utopia quarry; HLC 14-17, Rosemary quarry; EM 34-38, Manor quarry; remaining data from Holdridge 1959).

b) profiles showing negative correlation (data from Holdridge 1959).

Open circles, grey upper horizons; circles with vertical lines, intermediate horizons; black circles, parent material.
Fig. 62. Lithological and chemical profile, Type 4 palaeosol, Rosemary quarry.
Fig. 63. Lithological and chemical profile, stacked Type 4 palaeosols, Manor quarry, section 1.
Massive red mudstone no palaeosol features

Pale grey mudstone, leached appearance, slickensided palaeosol texture

Concretionary haematite

?Goethite root concretions

Purple and red pigment forming veins and matties in palaeosol

Graph of % GREY % RED vs. % SiO₂, % Al₂O₃, % Fe₂O₃
Fig. 64. Comparison of iron/silica contents of three Etruria Formation palaeosols (data from Holdridge 1959) and a recent ultisol (data from Mohr et al. 1972, Slager and Van Schnylenborgh 1970).
15
10
5

% Fe₂O₃

40 50 60 70 % SiO₂

Inferred palaeosols, Goldendale Quarry (data from Holdridge 1959)

Kennedy Highway Profile (Slager & Van Schuyenborgh 1970)
Fig. 65. Vertical sequence through polyphase palaeosol. Knutton quarry, base of section. For symbols see Fig. 14.
Predominant colours

Red

Red, bright red rafts of oxidized bedded ironstone

Carbonaceous, dark grey

Pale red, ochre, red diffuse concretions

Pale red, extensive ochre & purple patches

Red
Fig. 66. Evolutionary sequence leading to formation of polyphase palaeosol of the type illustrated in Fig. 65.

a) Latosol phase
b) Swamp phase
c) Burial
d) Post burial oxidation

b), c) and d) on succeeding pages.
a) LATOSOL PHASE

Soil water movement

Behaviour of Fe and Si

pH > 7 throughout

Fe III complex aq.

SiO₂ aq.

Fe III concretionary haematite

SiO₂ ? kaolinite

to groundwater

Horizons of Latosol Phase soil. Reconstruction of

Leached grey clay, little organic material.

Variegated red, purple, etc. mudstone. Haematite concretions up to 50 mm.

Red mudstone, mottled and brecciated.

Red/brown mudstone. Some mottling.
b) SWAMP PHASE superimposed on Latosol profile

- **pH < 7**
  - Humic acids
  - Fe II aq.
  - No groundwater migration below B horizon.

- **pH > 7**
  - Fe II concretionary siderite

Horizons of previous Latosol

- A 1: Peat
- A 2: Grey carbonaceous clay with Stigmarian roots.

Horizons of swamp phase soil

- A: Grey clay with siderite concretions usually infilling root channels. Soil matrix reduced.
- B: Lower parts of Latosol profile not affected by subsequent swamp phase soil processes.

Reconstruction of soil
c) BURIAL

Maximum thickness deposited before renewed pedogenesis
> 12 m. (pre-compaction)

Whole sequence below water table.
No groundwater movement.

Silt- and mudstone deposited during renewed alluviation; Fe? mainly Fe II. Some roots and plant fragments.

Siderite/sapropel ironstone - lacustrine.

Peat

Swamp phase soil horizons

A horizon sometimes completely oxidised, sometimes preserved as carbonaceous, highly lenses of siderite concretions in B horizon usually oxidised to haematite.
d) EARLY POST-BURIAL DIAGENESIS

Sediment overlying soil completely oxidised. Rare impressions of roots and plant fragments.

Ironstone partly or completely oxidised to massive haematite.

A horizons sometimes completely oxidised; sometimes preserved as carbonaceous, heavily listric mudstone.

Siderite concretions in B horizon usually oxidised to haematite.

Oxidising conditions during phase of free drainage associated with latosol formation on overlying sediment.
Fig. 67. Typical sequence of complex palaeosol textures produced by stacking of soil profiles. Playground No. 8 borehole, section between 38 m. and 43 m.
Predominant colours

Ochre

Ochre, purple patches

Diffuse areas of ochre, red, purple.

Purple, grey, red diffuse concretions

Puce, grey, ochre patches

Grey, puce flecks

Pale red, ochre

Mainly ochre

Purple concretions, grey & ochre veins

Purplish grey, purple veins, ochre increases downwards

Ochre root replacements, purple

Ochre, puce flecks

Pale red, grey, red concretions

Red
Fig. 68. Thin and poorly developed palaeosol. Springfield north quarry.
Predominant colours

Red

Pale grey

Khaki, grey root channels

Red
Fig. 69. Summary of possible evolutionary paths for palaeosols in Productive Coal Measures and Etruria Formation sediments.
GOOD

DRAINAGE

POOR

HEAVY ARROWS DENOTE DEPOSITION

Facies 8, 9
Evolved soil
PALAEOSOL
Type 4

Alluvial soil
(mottled gley)
PALAEOSOL
Type 2

Polyphase PALAEOSOL

Postburial oxidation

PALAEOSOL
Type 3

Facies 1, 2

Improvement in drainage
Climate change, etc.
P1 & 2 FEATURES DESTROYED

Degradation of drainage
(Sudden rise of water table)

Alluvial soil
PALAEOSOL
Type 1
Fig. 70. Thin bedded haematite rock (dark red band) overlying dark grey remnant of organic surface horizon of Type 3 (post depositionally oxidized) palaeosol. Manor quarry.
Fig. 71. Sand body formed entirely of Facies 13 massive sandstones. Metallic Tileries quarry, eastern and central part of north face. Drawn from field sketches (now covered).
METALLIC TILERIES  Sandbody I

Channel edge  c.320 - 330°
Face strikes c. 270°
TXB sets
Limit of exposure
Fig. 72. Facies 13: dm. scale trough cross bedding. Road cutting by Potteries D road (A500) adjoining Chatterley quarry.
Scale divisions = 0.5 m.

Fig. 73. Detail of bottom RH corner of Fig. 72. Intercalation of cm. scale cross lamination within sequence of large scale cross bedding in Facies 13 sandstone. Tape extended 35 cm.
Fig. 74. Facies 13: large scale dipping surfaces, interpreted as lateral accretion surfaces, in massive sandstone. Manor quarry, sand body 2. This sand body forms the highest part of the exposed section. (This exposure now removed).
Fig. 75. Facies 14: interbedded sand/silt and mudstone containing lateral accretion sets. Knutton quarry, top of face, north corner 1977 (now considerably degraded).

Quarry faces to the left (west) of G-G' and to the right (east) of H-H' are oriented at approx. 90° to each other.

This photograph illustrates: (i) the generally sigmoidal form of the lateral accretion sets (S); (ii) the tendency for individual sets to thin in their upper parts; (iii) the angular erosive relationship (E) between the lowest lateral accretion set in the sand body in the corner of the quarry, and an earlier laterally accreted unit to the east.

Scale poles (arrowed) = 2 m.
Fig. 76. Facies 14: relationship between three laterally accreted units, north end of Knutton quarry. Figure includes field of view to the right of H-H', and extends ca. 20 m. beyond the right hand edge of Fig. 75. Drawn from field sketches.
KNUTTON WORKS - Top faces, North end of quarry.

Silty mudstone

i/b sandstone & siltstone

i/b sandstone & siltstone

siltstone, very poor exposure shows depositional dip

Covered

Mudstone with prominent palaeosol

0 metres 10 20 30 40 50
Fig. 77. Detail of Fig. 75: Facies 14, Knutton quarry.

Note: i) amalgamation and thickening of accretionary units towards base of sand body (J); ii) angular erosive relationship with earlier interbedded sand/siltstone unit (K); iii) angular non sequence within the lower part of the laterally accreted unit (L) of type A (Fig. 87); iv) cuspate thickenings within lateral accretion sets (M and N - see also Fig. 84), with associated thickening and draping of overlying lateral accretion sets; v) soft sediment deformation within lateral accretion sets (P - see also Fig. 92).

Scale poles = 2 m.
Fig. 78. Descriptive terminology for Facies 14; types of sand body formed of this Facies.
Lateral accretion sheet

Laterally accreted sand body

Simple/isolated L.A. sand body

Composite L.A. sand body
Fig. 79. Facies 14: simple isolated laterally accreted sandbody, eroded into palaeosol, mudstones and sheet sandstones of Facies Association IIA. \( E = \) basal erosion surface. Metallic Tileries quarry, sand body 2, top of western part of north face, 1977 (now covered). Scale pole (arrowed) = 2 m.
Fig. 80. Detail of right hand (eastern) part of sand body illustrated in Fig. 79. Lateral accretion sets composed of interbedded sand/siltstone and mudstone in upper part of sand body. E is basal erosion surface. Scale poles = 2m.
Fig. 81. Facies 14: sandbody illustrated in Figs. 79, 80; section and plan drawn from field sketches. Note: i) amalgamation of lateral accretion sets (as in Fig. 80); ii) high angle of palaeocurrents to deposition dip of accretionary sets; iii) approximate shape of clay plug P (Facies 15: see Fig. 98).
? POSITION OF CUT-BANK (NOT EXPOSED)

? HCR. LAM.

TXB

? LATERAL ACCRETION SET BOUNDARIES

EROSIONAL CONTACTS SEEN IN PATCHY EXPOSURES

WHITE SILTSTONE MARKER HORIZON

LIMITS OF EXPOSURE

0 metres 10 20 30 40 50

TREND OF ACCRETIONARY MARGIN OF SANDBODY

?? ORIENTATION OF CUT-BANK

MOST LIKELY ORIENTATION OF ABANDONED BAR SURFACE

P

North

TXB (@ ABOVE) PXB (@ ABOVE)
Fig. 82. Facies 14: lateral accretion sets composed of interbedded sand and siltstone amalgamating to form a massive sandstone at the base of the laterally accreted unit. (Contortion in upper part of exposure results from solifluction). Lightwood quarry, sand body at top of exposure. Scale pole = 2 m.
Fig. 83. Facies 14: 0.20 m – ca. 1.00 m thick sand sheets formed by lateral accretion, near base of sand body illustrated in Fig. 75. Sheets in centre of photograph amalgamate to left. Knutton quarry, top sand body. Scale = 2 m.

Fig. 84. Facies 14: showing decrease in sand content and general thinning of sand lateral accretion sets up the depositional slope. Q and R are cusped thickenings in individual sandy sets. Sets overlying Q drape the feature formed by Q. Knutton quarry, top sand body. Scale = 2 m.
Fig. 85. Facies 14: interbedded sand and siltstone lateral accretion sets; whole thickness of sandstone set formed by one crossbedded set. Spoutfield quarry, sand body near the base of section, 1976 (now covered). Tape case = 5 cm.

Fig. 86. Facies 14: trough cross bedding visible in weathered sand and siltstone lateral accretion sets. T marks the cross section of an obliquely exposed trough. Spoutfield quarry, sand body near base of section, 1976 (now covered). Visible part of scale = 1 m.
Fig. 87. Two forms of erosion surface found within laterally accreted sand bodies, Facies 14.
Fig. 88. Facies 14: type A erosion surface (arrowed) within lower part of laterally accreted sand body. Detail of left side of Fig. 82. Lightwood quarry top sand body. Scale = 2 m.

Fig. 89. Facies 14: type B erosion surface (arrowed) overlain by thick sandstone lateral accretion sheets. Rosemary Hill quarry, old access road, north side. Scale pole = 2 m (see also Fig. 90).
Fig. 90. Facies 14: sand body illustrated in Fig. 89. Face orientation changes at A-A'. Type B erosion surface between B-B'. Redrawn from photographs.
ROSEMARY HILL QUARRY - Sandbody exposure on north side of access road

UPPER EXB UNIT

LOWER EXB UNIT

Sandbody base (approx. position)
Fig. 91. Facies 14: face exposed parallel to palaeocurrent, illustrating lenticularity and internal erosion in lateral accretion sets in down/up current direction. Knutton quarry, detail of left (west) side of Fig. 75. Scale pole = 2 m.
Fig. 92. Facies 14: down slope slump folding of sandstone lateral accretion set, overlain by undisturbed sets. Detail of Fig. 77, Knutton quarry, top sand body. Visible part of scale = 1.5 m.
Fig. 93. Facies 14: lateral accretion sets containing high sand: fines proportion. Himley Wood quarry, north face. Drawn from photographs.
Fig. 94. Facies 14: laterally accreted unit containing sandstone only near the base, otherwise consisting mainly of siltstone. Springfield north quarry main sand body, forming upper part of north face. Scale pole = 2 m.
Fig. 95. Facies 14 in composite sand body. Earlier laterally accreted unit is composed predominantly of silt- and mudstone, with only thin sandstone at the base. Later sand body contains Facies 15 channel abandonment clay plug. Redrawn from photographs and field sketches, Springfield north quarry, upper part, eastern end of north face. See also Fig. 96.
COLOUR MOTTING IN RED SILT- AND MUDDSTONE, PRODUCED BY SOIL DEVELOPMENT ON TEMPORARILY ABANDONED MEANDER BELT SURFACE.

NON-MOTTLED RED MUDDSTONE: ABANDONMENT FILL OF LATER CHANNEL.

INTERBEDDED SAND AND SILT L.A. SETS OF LATER SANDBODY, DIPPING INTO FACE.

LATERAL ACCRETION SETS COMPOSED, AT BASE, OF SAND, PASSING LATERALLY INTO MUDD- AND MUDDSTONE IN HIGHER PARTS OF L.A. SETS. SETS DIP INTO FACE.

BASE OF LATER L.A. BEDDED SANDBODY PROBABLY EROSI

2m. scale pole

c. 60 m
Fig. 96. Facies 14 and 15: sand body illustrated in Fig. 95. Pale mottled silt- and sandstone is lower sand body (U). Upper sand body formed by lateral accretion sets (V) and prominent dark red mudstone abandonment plug (W). Springfield north quarry. Scale pole (arrowed) = 2 m.

Fig. 97. Facies 15: abandonment plug (X) overlying relict point bar surface (Y). Metallic Tileries quarry, sand body 2, 1977 (now covered), see Figs. 79-81. Dip of point bar surface exaggerated by differential compaction. Scale = 2 m.
Fig. 98. Facies 15: small channel cut through upper part of massive, Facies 13, sand body. Channel has symmetrical interbedded sand/mudstone fill. Chesterton quarry, top of sand body 1, ca. 35 m in section. Photographed in 1977 - now covered. Scale pole = 2 m.
Fig. 99. Facies 15: small mudstone filled channel cut through Facies 14 laterally accreted sand body. Note discordant relationship to lateral accretion sets on left hand margin. Manor quarry, south east face, sand body 1 (now removed).
MANOR QUARRY Section 4, Part of sand body as exposed in 1980

Red mudstone fill
Fig. 100. Model for generation of spiral eddies downstream from flow separation point in a meandering channel (after Bridges and Leeder 1976).
Separation point
Stagnant zone
Generation of spiral vortices
Fig. 101. Conceptual origin for type A erosion surfaces:

a) normal deposition of laterally accreting sets;

b) scour of lower point bar surface during high discharge event;

c) healing of scour thus produced by further lateral accretion.
Fig. 102. Conceptual origin for type B erosion surfaces:

a) normal lateral accretion;

b) erosion of chute channel during high discharge event, followed by rapid outward migration to form a bench;

c) healing of feature thus formed by renewed lateral accretion under conditions of less extreme discharge.
Fig. 103. Sequence of mudstones containing both evolved (type 4) and post depositionally oxidized alluvial (type 3) palaeosols, Kibblestone borehole. Base of section ca. 30 m. above local base of Etruria Formation. Figures refer to depth of borehole in metres. For discussion see 4.6.1. i).
Colour | Facies
---|---
R 8 | Floodplain - well drained
GY P1/3 | Swamp
R 8 | Floodplain
GY P1/3 | Swamp
V P4 | Floodplain
R 8 | Swamp
GY 1 | Swamp
GY P3 | Floodplain
GY P3 | Swamp
R 8 | Floodplain
GY 1 | Swamp
R 2 | Floodplain
Fig. 104. Sequence of mudstones containing dominant evolved and polyphase palaeosols, Playground No. 8 borehole. Base of section ca. 3 m. above local base of Etruria Formation. Figures refer to depth of borehole in metres. For discussion see 4.6.1. i).
Alluvial plain - persistent good drainage and low rate of deposition giving rise to thick stacked evolved palaeosols.

Minor phases of poor drainage indicated by polyphase palaeosols near base of Formation.
Fig. 105. Sequence containing alternating mudstones and evolved palaeosols with minor silt- and sandstone sheets; Redhurst east quarry, entire section. For discussion see 4.6.1. ii).
Facies Association III

Alluvial plain, well drained

Alternate phases of high and low clastic input giving rise to units (arrowed) of mudstone capped by palaeosols
Fig. 106. Siltstones, silty mudstones and mudstones (Facies 9 and 8) forming fining upward units capped by palaeosols. Redhurst Wood west quarry, section 1, from base of sump to base of main Facies Association III unit. For discussion see 4.6.1. ii).
Alluvial plain - well drained.

Alternating deposition and pedogenesis giving rise to fining upward sediment units capped by palaeosols
Fig. 107. Lower part of Etruria Formation, Street's Lane No. 1083 borehole, showing variation in thickness and style of fining upward sequences in overbank sequences composed of Facies 8 to 10. For discussion see 4.6.1. ii). (Figures refer to depth of borehole in metres).
Fig. 108. Thick fining upward sequences composed mainly of silty mudstone (Facies 9) capped by palaeosols. Springfield south quarry. For discussion see 4.6.1. ii).
Alluvial plain - alternating deposition and pedogenesis.

Fining upward sequences are thicker than those in Figs. 105, 106, and contain increased proportion of Facies 9 and 11, suggesting more proximal position to channels.
Fig. 109. Fining upward sequence containing fluvial channel deposits, Rosemary Hill borehole No. 10. Figures refer to depth of borehole in metres. For discussion see 4.6.1. iii).
Fining upward sequence - channel deposits overlain by floodplain deposits and palaeosol.

Alluvial plain - well drained
Fig. 110. Fining upward sequence containing fluvial channel deposits, Allotment borehole. Figures refer to depth of borehole in metres. For discussion see 4.6.1. iii).
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<thead>
<tr>
<th>Colour</th>
<th>Facies</th>
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Alluvial plain, well drained, proximal

Meandering channel deposit

Alluvial plain deposit, well drained at base, becoming poorly drained at top
Fig. 111. Fining upwards sequences, probably all containing channel deposits at their bases, Kibblestone borehole. Figures refer to depth of borehole in metres. For discussion see 4.6.1. iii).
Colour  Facies

Floodplain - well drained

Channel or very proximal overbank sand sheet

Floodplain

Channel

Floodplain

Channel or very proximal overbank sand sheet

Swamp
Fig. 112. Sandstone dominated Etruria Formation sequence, Bayton Works, Wyre Forest. For discussion see 4.6.1. iv).
Dominantly alluvial deposits - minor meandering channel deposits. Interbedded well-drained alluvial plain deposits - fining upward sequences.
Fig. 113. Inferred proximal to distal relationships in the various types of vertical sequence encountered in Facies Association II, Etruria Formation.
Thick f.u. sequence, channel deposits, erosive base

Thick f.u. sequence, crevasse splay and channel deposits.

Thinner f.u. sequence, no sand bodies.

No f.u. sequence, predominance of palaeosols.
Fig. 114. Reconstruction of relationships between Facies in Facies Association II at time of deposition. Section drawn normal to channel direction.
Distances compressed and thicknesses exaggerated

Floodplain  Proximal floodplain / ? levée  Channel  Levée with crevasse channels and splays  Floodplain
Fig. 115. Conceptual sections illustrating the deposition of typical Facies Association II sequences. For discussion of water table behaviour see 8.5.


4. Formation of poorly drained soils following major avulsion of channel system and subsidence. Vertical section cf. Fig. 103.

5. Sedimentation at distal end of active floodplains. Vertical section cf. Fig. 105 - 106.

6. Prolonged latosol formation during low clastic input. Good drainage reflects channel incision or period of dryer climate. Vertical section cf. Fig. 103.

7. Distal floodplain sedimentation. Thickness affected by differential subsidence over burial channel sand bodies. Vertical section cf. Fig. 103.

8, 9. Renewed channel activity.
Fig. 116. Facies 16: para conglomerate of rounded boulders of acid lava and tuff and intraclasts in silty mudstone matrix. Below Z clasts are intra formation only. Redhurst Wood, west quarry (SJ 969052), section 2, eastern part of north face (see Figs. 120, 148) - now covered. Scale = 2 m.
Fig. 117. Facies 16: paraconglomerate of angular pebbles and cobbles of igneous and metamorphic material in muddy sand matrix. Blockley's quarry (SJ683118), top conglomerate body in main face (T in Fig. 146). Pen = 15 cm.

Fig. 118. Facies 16: paraconglomerate of angular to well rounded pebbles and cobbles in muddy sand matrix, with framework supported lenticles near base. Blockley's quarry, top conglomerate body in main face (U in Fig. 146). Tape extended 50 cm.
Fig. 119. Facies 16: matrix supported conglomerate with irregular, scoured, subhorizontal base, locally eroding in underlying palaeosol. Donnington Wood quarry (SJ710113), west face. Drawn from field sketches.
DONNINGTON WOOD QUARRY - matrix supported conglomerate bodies in west face
Fig. 120. Large erosive scour or valley, Redhurst Wood, west quarry, north face, 1977 (now partly covered).

Annotation of Facies in lower photograph:

A. mudflow Facies 16; B. framework supported conglomerate Facies 17; C. sheet sandstones and conglomerates, Facies 18.

For scale see Fig. 148.
Fig. 121. Facies 16: vertical section through matrix supported conglomerate in base of large erosive feature illustrated in Figs. 120, 148. Redhurst Wood, west quarry.
Base of framework supported conglomerate, filling upper part of ‘valley’.

Dark grey and purplish grey sandy and silty mudstone, supporting rounded pebbles to small boulders of extraformational origin, and pebble to large boulder size intraclasts, often heavily deformed.

Dark grey sandy and silty mudstone, containing red mudstone intraclasts (up to cobble size).

Palaeosol - ? deformed

Red mudstone
Fig. 122. Facies 17: massive framework supported conglomerate, showing crude horizontal bedding (E), and containing a lenticular sandstone unit (D). Redhurst Wood, west quarry, upper part of 'valley' fill, north face. Scale = 2 m.
Fig. 123. Facies 17: massive framework supported conglomerates and sandstones in upper part of 'valley' fill. Drawn from photographs. Redhurst Wood west quarry, north face.
REDHURST WOOD WEST QUARRY - internal structure in conglomerate 'valley' fill

- Coarse grained pebbly sandstone
- Framework supported conglomerate
- Distinct bedding surface
- Indistinct bedding surface
- Traces of poorly defined horizontal bedding in conglomerates
- Lenticular siltstone
- Limit of exposure
- Extent of Fig. 122
Fig. 124. Facies 17: lenticular sandstone unit (F) in framework supported conglomerate, and siltstone drape (G) over conglomerate unit. Redhurst Wood, west quarry, upper part of 'valley' fill in north face. Scale = 2 m.

Fig. 125. Facies 18: graded unit in sheet conglomerate, illustrating upward decrease in clast size and transition from framework supported conglomerate to pebbly sandstone. Fallen block, Highfield quarry (SK 043026). Scale = 30 cm.
Fig. 126. Facies 18: sheet conglomerate, overlain by interbedded sand- and siltstone. Base of conglomerate infills a scoured surface (H). The conglomerate consists of a single graded unit. The overlying sand- and siltstone shows depositional dip resulting from lateral accretion. Utopia quarry (SK046026), south face. Scale = 1.50 m.

Fig. 127. Groove casts at the base of a Facies 18 conglomerate sheet. Atlas quarry (SK044021), north face. Scale divisions = 50 cm.
Fig. 128. Facies 18: pebbly sandstone sheet, consisting of cosets of cross bedded sandstone with concentrations of granules and pebbles at the base of each set. Empire quarry (SK 043023), north face. Scale = 1m. (see also Fig. 141).
Fig. 129. Possible 'bar' forms composed of framework supported conglomerate in a pebbly sandstone sheet, Facies 18. Utopia quarry, north face. Drawn from field sketches. For location see Fig. 143.
Fig. 130. Facies 18: conglomerate filled channel (J) in complex body formed by several graded conglomerate sheets. Utopia quarry, west end of north face (see Fig. 143). Scale pole = 2 m.

Fig. 131. Facies 18: conglomerate filled channel, which passes laterally, or erodes, into a thin conglomerate sheet. Blockley's quarry, west end of main face (V in Fig. 147). Scale pole = 2 m.
Fig. 132. Small conglomerate filled channel, Facies 18, with overhung edge showing possible soft sediment intrusion. Blockley's quarry, east end of main face (R in Fig. 146). Scale = 1m.

Fig. 133. Small channel, Facies 18, with pebbly sandstone fill. This channel has a very low width to depth ratio, and overhung?deformed margins. Overlain by Facies 18 sheet conglomerate. Redhurst Wood west quarry, north face. Scale = 2m. See also Fig. 134.
Fig. 134. Redhurst Wood west quarry, north face. A packet of sheet conglomerates and pebbly sandstones, Facies 18. For relationship to 'valley' see Figs. 120, 148.

The small channel (K) is that illustrated in Fig. 133; in this photograph the single phase of fill associated with the overlying sheet sandstone is clearly seen. L marks the eastern margin of a wider channel (Fig. 135). At this margin the channel base is draped by a single 0.40m thick sandstone bed. The channel is otherwise filled with mudstone. Width of field ca. 30m; height of face containing sandstone beds ca. 10m.
Fig. 135. Supposed form of a channel associated with a group of sheet conglomerates and pebbly sandstones (Facies 18). Redhurst Wood west quarry, north face. See Figs. 134, 136 for details of fill. Drawn from field sketches.
REDHURST WOOD WEST QUARRY - channel near base of a group of sandstone and conglomerate sheets, with fill of mudstone and steeply dipping sandstone sheets, north face, old section.

Inclined thin sandstone/siltstone sheets, filling western end of channel

?Position of channel base

?Position of underlying palaeosol

60 m
Fig. 136. Detail of steeply inclined fine sandstone and siltstone banked up against western margin of the channel illustrated in Fig. 135. Drawn from photographs.
REDHURST WOOD WEST QUARRY - detail of margin of small channel associated with conglomerate/sandstone sheets

Margin of channel - inclined layers of fill show slight deformation

Steeply inclined layers of fine sandstone and siltstone

LIMIT OF EXPOSURE
Fig. 137. Facies 19: sheet sandstone composed of sets of planar tabular cross bedding. Empire Quarry, north face. Scale = 2 m. (see also Fig. 141).

Fig. 138. Facies 20: isolated massive sandstone filled channel. Ketley quarry, bench at southern end of quarry, looking east, 1979.
Fig. 139. Facies 20: isolated massive sandstone filled channel, at a slightly higher stratigraphic level than the channel (L) illustrated in Fig. 138. M is the 'wing' of the earlier channel body. Ketley quarry. Scale = 2 m.

Fig. 140. Sedimentary dyke composed of pebbly sandstone, sourced by sheet conglomerate of Facies 18, cutting through ca. 8 m. of mudstone, conglomerate sheets, and palaeosols. The dyke shows some ptygmatic folding owing to differential compaction. Blockley's quarry, east part of main face. Scale = 2 m (see also Fig. 145).
Fig. 141. Relationship between sheet conglomerates and sandstones in Highfield and Empire quarries. Sheets are mainly laterally extensive. N is the sandstone sheet (Facies 19) illustrated in Fig. 137. P is the pebbly sandstone sheet illustrated in Fig. 128. Note small channels in western section: one passes laterally into sheet sandstone; the other has an erosive relationship. Drawn from field sketches of north face of Empire quarry and south and west faces of Highfield quarry.
HIGHFIELD AND EMPIRE QUARRIES - occurrence of laterally extensive sandstone and conglomerate sheets

Western section (Butterley)

Eastern section (Polymeric Treatments)

Highfield Quarry (lower part)

Empire Quarry
Fig. 142. Arrangement of Facies 18 conglomerate sheets in Wilnecote and Averill quarries. Conglomerate filled channels are here truncated by an overlying sheet (T) or occur in isolation (I). Drawn from field sketches of east faces of both quarries.
WILMECOTE AND AVERILL QUARRIES - occurrence of conglomerates in laterally extensive sheets and isolated channels

North

Wilnecote Quarry

Averill Quarry

South

Coal seam (marker horizon)

0 50 100 150 200 250 270 metres
Fig. 143. Lateral relationship of Facies 18 sheet conglomerate units. Utopia quarry. Sheets thicken laterally, and pass into more complex body of stacked sheets and channels to the west (left). This body is illustrated in Fig. 130. Bar structures (Fig. 129) were observed at A.
UTOPIA QUARRY - NORTH FACE

Sandbodies in Etruria Fm.

HALESOWEN FM.

TOP OF ETRURIA FM. MARKED BY THICK PALAEOSOL

Section 5

Section 1

0 metres 50 100 150 200

m

0 10 20
Fig. 144. Facies 18 sandstone and conglomerate bodies, Blockley's quarry, eastern part of main face. Scale (arrowed) = 2m. (see Fig. 146).

Fig. 145. Detail of Fig. 144, showing variety of forms of sandstone and conglomerate bodies: laterally extensive thick (W) and thin (X) sheets; channels with one (Y) and several (Z) phases of fill; in a matrix of mudstones and palaeosols (B). Scale = 2m (see Fig. 146).
Fig. 146. Arrangement of sandstone and conglomerate sheets and channel fills (Facies 18), eastern part of main face. Blockley’s quarry. T is location of Fig. 117; U of Fig. 118; R is illustrated in Fig. 132. Whole face is illustrated in Figs. 144, 145. Remaining letters refer to text. Drawn from photographs and field sketches: view slightly oblique to face.
BLOCKLEY'S QUARRY - conglomerate bodies, east end of main face

LIMIT OF EXPOSURE

PALAEOSOLS

C

S

T

U

E

R

c. 60 m

10 m

(approx)
Fig. 147. Arrangement of sandstone and conglomerate sheets and channel fills, Blockley's quarry, western part of main face. V is illustrated in Fig. 131. Other letters refer to text. Drawn from photographs and field sketches.
BLOCKLEY'S QUARRY - sandstone and conglomerate bodies, west end of main face
Fig. 148. Redhurst Wood, west quarry. Relationship of 'valley' filled with Facies 16 and 17 to packet of sheets and channels of Facies 18. (Correlation by means of palaeosol horizon was verified after further excavation, although the exact relationship was not measured up). Drawn from field sketches (see also Fig. 120).
REDHURST WOOD WEST - Old pit, North face
Possible relationship between sandbodies
Fig. 149. Typical vertical sequence in Facies Association III; Blockley's quarry, western and northern faces.
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**Fan surface - distal to active fan channels, deposition sufficient to allow only intermittent soil profile development.**

**Alternation of débris flows, overbank fines and soils - no major bedload transport of conglomerate. ?C.U. unit, reflecting perhaps extrabasinal influence.**

**Fan surface - alternating deposition and soil profile formation.**

**Débris flow.**

**Pebbly sandstone sheet, pronounced upward fining - ?fan channel deposit.**

**Fan surface, distal - little deposition, prolonged pedogenesis.**

**Fan surface, proximal to channel system, several sheet flow deposits.**

**Fan surface, near enough to active channel for deposition rate to be sufficient to prevent pedogenesis.**

**Fan surface - intermittent deposition**
Fig. 150. Alluvial fan of the Erap River, Markham Graben, eastern Papua, New Guinea (from Knight 1975).
Gravelly fan sediments

Non-gravelly fan sediments (Lacms, silty and sandy clays)

Markham River alluvium

Valley margin

Pre-1943 channel

Active braided channel

Limits of fan incision

Channel formed in 1973

MARKHAM RIVER

0 1 2 3 Kilometres
Fig. 151. Block diagram illustrating conceptual model for deposition of Facies Association III in a complex of mud dominated, humid tropical alluvial fans.

Three principal zones of sedimentation are:

A: most proximal, with abundant locally sourced debris flows (cf. Blockley's quarry); B: main fan surface, dominated by deposition of fines, and by stream flow and flood processes (cf. Utopia, Highfield, Empire quarries); C: infilling of valleys incised as a result of fan toe degradation (cf. Redhurst Wood quarry).
Upland vegetation
Vegetation of well drained alluvium
Swamp vegetation

FACIES ASSOCIATION III

FACIES ASSOCIATION II

ca. 10 km.
ca. 20 m.

PALAEOSOL TYPES
1 & 2 (alluvial)
3 (post depositionally oxidized)
4 (evolved - "lateritic")
Polyphase
Weathered mantle in source area
Fig. 152. Schematic illustration of 'thin' and 'thick' red bed intercalations found at the boundary between the Productive Coal Measures and the Etruria Formation.
Red pigment present only in Palaeosols of Type 2 and immediately underlying sediment

e.g. PLAYGROUND No. 8 BOREHOLE (Fig. 153)

N.B. Vertical scale for 'thin' diagram = 2 x that for 'thick' diagram

THICK INTERCALATIONS

Red pigment present in Facies 8 & 9 and in Palaeosols of Types 2, 3, & 4

Bases of 'thick' intercalations contain 'thin' intercalations

e.g. IBSTOCK HIMLEY (Fig. 154)
Fig. 153. Succession at the boundary between the Etruria Formation and Productive Coal Measures, Playground No. 8 borehole.

The upward transition into red beds here takes the form of a transitional sequence containing 'thin' red intercalations (see 6.1.1).
Red mudstone with sporadic mottles

Mudstone, 50% red, 50% grey, with plant fragments

Coal and seat-earth

Red mudstone, with intense mottling and haematite concretions

Red mudstone with sphaerosiderite

Carbonaceous mudstone with red flecks

Red mudstone with sphaerosiderite

Grey mudstone with red patches decreasing downward and sphaerosiderite

Seat-earth, grey, patchy red coloured horizon with siderite, carbonaceous roots

Seat-earth, patchy red colouration

Seat-earth, patchy brown colouration

Seat-earth, no red or brown colouration

Laminated grey mudstone with plant fragments

Siderite concretion

Sphaerosiderite

Plant debris

Stigmaria root

Other root

Coal, argillaceous

Carbonaceous mudstone

Slickensided texture

Red pigment
Fig. 154. Succession in a possible 'thick' red bed intercalation at base of Etruria Formation. Ibstock Himley quarry, deep trial pit (section measured 1979). See 6.1.1. for discussion.
Colour | Facies
---|---
GY | 3
| Poorly drained floodplain swamp

Polyphase palaeosol

THICK INTERCALATION

Meandering channel deposit

?Poorly drained floodplain

Well drained floodplain

Swamp
Fig. 155. 'Thick' red bed intercalations forming lateral and vertical transition between the coal bearing Blackband Formation and the Etruria Formation, North Staffordshire. In part after Boardman (1978).
Fig. 156. Geographical distribution of coal seams and red beds in the interval between the Winghay and Peacock Coals, North Staffordshire. For stratigraphic framework see Figs. 181–184.
Figs. 157. Geographical distribution of Bassey Mine Coal and underlying red beds, North Staffordshire. Data points as in Fig. 156. For stratigraphy see Figs. 155 and 181-184.
Fig. 158. Geographical distribution of Hoo Cannel coal and underlying red beds, North Staffordshire. Data points as in Fig. 156. For stratigraphy see Figs. 155 and 181-184.
Fig. 159. Geographical distribution of Clod Coals and underlying red beds, North Staffordshire. Data points as in Fig. 156. For stratigraphy see Figs. 155 and 181-184.
Fig. 160. Geographical distribution of Red Mine Coal and underlying red beds, North Staffordshire. Data points as in Fig. 156. For stratigraphy see Figs. 155 and 181-184.
Fig. 161. Geographical distribution of Red Shagg Coal and underlying red beds, North Staffordshire. Data points as in Fig. 156. For stratigraphy see Figs. 155 and 181-184.
Geographical distribution of Blackband and E1 to E3 coals, and of red beds below Blackband Coal, North Staffordshire. Data points as in Fig. 156. For stratigraphy see Figs. 155 and 181-184.

E1, E2, and E3 are arbitrary groupings of reasonably easily correlated thin coal seams above the Blackband Group. This terminology has been adopted by the present author.
AXIHUH EXTENT OF BLACKBAND (=ETHEL) COAL

MAXIMUM EXTENT OF RED BEDS BELOW BLACKBAND COAL

APPROX. MAXIMUM EXTENT OF E1 TO E3 COALS

MAXIMUM EXTENT OF BLACKBAND (=ETHEL) COAL

0 km 5 km
Fig. 163.  Inferred lateral relationships between co-existing palaeosols.
Facies Associations I and II.
Perenially well drained latosols

Intermittently (?seasonally) waterlogged alluvial soils
with hydromorphic gley

Permanently waterlogged alluvial and organic soils

TOPOGRAPHIC RELATIONSHIP DURING FORMATION

Fluctuation of water table

SLOPE PRODUCED BY PROGRADATION OF WELL DRAINED FACIES ± DIFFERENTIAL SUBSIDENCE
Fig. 164. Isopach map of the interval between the Great Row and Bassey Mine Coals, North Staffordshire, contoured at 20m. intervals. Note: i) moderate concordance between isopach pattern and extent of pre-Bassey Mine red beds; ii) discordance between isopach pattern and distribution of pre-Red Shagg red beds.

For stratigraphy see Figs. 181-184.

Key to data points, Figs. 164 and 165.

1 Wolstanton 3 shaft
2 Bowsey Wood
3 Highway Lane
4 Barker's Wood
5 Penkhull
6 Stony Low
7 Werburgh
8 Bromley
9 Hey Sprink
10 Swallowcroft
11 Seabridge
12 Whitmore
13 Radwood
14 Peacock's Lane
15 Hem Heath 2 shaft
16 Florence 3 shaft
17 Harley
18 Clifford's Wood
19 Stabhill
20 Groundslow
21 Meaford Hall 1
22 Hobbergate
23 Schoolhouse
24 Holt's Barn
25 Kibblestone
26 Moddershall

For locations see Enclosure 1.
Red beds below Red Shag coal

Red beds below Bassey Mine coal

Limit of Bassey Mine coal

Transition to red beds at Bassey Mine horizon
Fig. 165. Isopach map of the interval between the Great Row Coal and the top of the Etruria Formation, North Staffordshire, contoured at 50m. intervals. Note discordance between isopach pattern and distribution of red beds.

For stratigraphy see Figs. 181-184.
Fig. 166. Proposed facies model for lobate intercalations of red beds in the Blackband Formation of North Staffordshire.
Well drained alluvium with evolved soils - Facies Association II

Poorly drained alluvium with alluvial soils - Facies Association I

Middle of prograding lobe, permanently well drained - evolved soils + penetrative oxidation giving rise to thick red intercalations

Toe of prograding lobe, fluctuating drainage - Type 2 soils forming thin red intercalations

Tectonically controlled hinge line
Fig. 167. Sand grains in Etruria Formation sandstone showing recrystallization textures characteristic of varying grades of regional metamorphism. Samples from displaced core pieces, Rosemary Hill No. 10 borehole.

a) Polycrystalline quartz grains showing elongated original crystals, and crenulated and sutured crystal-crystal boundaries.

b) Polycrystalline grain as in a) showing pronounced elongation of original crystals and recrystallization.

c) Polycrystalline grain showing crystal units with polyhedral outlines, smooth crystal-crystal boundaries and 120° interfacial angles at triple junctions of crystal boundaries.

a) and b) are typical of low to medium grade metamorphic rocks, c) of medium grade metamorphic rocks. Terminology from Young (1976).

All photographed under crossed polars: scale bars = 1mm.
Fig. 168. Detrital basic igneous rock fragments. Samples from Utopia quarry.

a) Microporphyritic basalt: groundmass completely replaced by haematite; plagioclase phenocrysts pseudomorphed by clay and calcite. Scale bar = 0.05 mm.

b) More coarsely porphyritic basalt; groundmass partially replaced by haematite; plagioclase phenocrysts, replaced by clay and carbonates, showing slight ophitic texture. Scale bar = 0.5 mm.

c) Coarsely porphyritic ?basalt; pseudomorphed phenocrysts including possible outlines of ferromagnesian grains. Scale bar = 1 mm.

All photographed in plane polarized light.
Fig. 169. Acid igneous rock fragments.

a) Detail of devitrified glass matrix, showing relict texture of welded glass shards, surrounding (base) an embayed quartz phenocryst. Sample from excavations at Silverdale New Mine, North Staffordshire. Plane polarized light. Scale bar = 1 mm

This sample compares closely with that described by Barrow (in Gibson 1905, p.131) from the same area.

b) Grain of devitrified tuff, showing relict glass shard texture. Sample from Highfield quarry, Aldridge. Plane polarized light. Scale bar = 1 mm.
Fig. 170. Tabular granule of foliated quartz rich schist. Sample from Silverdale New Mine. Plane polarized light. Scale bar = 1mm.
Fig. 171. Replacement textures in detrital lithic grains.

a) Lithic grains replaced by chloritic clay (greenish grains in upper right hand part of photograph) and microcrystalline quartz. Scale bar = 1mm.

b) Same field of view as in a) illustrating microcrystalline nature of replacive quartz. Crossed polars.

c) Lithic grain replaced by chloritic clay, and deformed to fill space between more competent grains. Sample from Silverdale New Mine. Plane polarized light. Scale bar = 1mm
Fig. 172. Grain replaced by chloritic clay, showing possible relict cleavage traces of original mafic mineral grain. Sample from Silverdale New Mine. Plane polarized light. Scale bar = 1mm
Fig. 173. Detrital ferruginized material.

a) Rounded clasts of indurated haematite. The form of these rounded clasts contrasts with the disseminated nature of haematite produced as an alteration product of lithic material, and thus may imply a detrital origin.

b) Silty mudstone grain with thick coating of haematite. The haematite has an irregular and penetrative boundary with the grain. Haematite is also present along relict bedding traces in the grain. This habit contrasts with the thin grain coatings produced by diagenetic processes (Fig. 175), and suggests prolonged alteration, probably in a latosol.

c) Silty mudstone grain with 'halo' of haematite running parallel to grain margin. Inferred origin as in b).

Sample a) and b) from Highfield quarry, Aldridge; c) from Utopia quarry, Aldridge.

Scale bars = 1 mm.
Fig. 174. Porous, botryoidal calcite filling empty pore space. This texture corresponds to the oolitic texture described by Williamson (1946), and is probably of recent vadose origin. Sample from Silverdale New Mine. Plane polarized light. Scale bar = 1mm.

Fig. 175. Poikilotopic calcite cement surrounding quartz grains with thin haematite grain coatings and small non syntaxial quartz overgrowths. Overgrowths are probably nucleated in areas where haematite coating is thin or absent. Order of precipitation: haematite first, quartz, carbonate last. Sample from Highfield quarry, Aldridge. Plane polarized light. Scale bar = 0.5mm.
Fig. 176. Poikilotopic calcite cement showing curved cleavage traces. See text for discussion. Sample from Highfield quarry, Aldridge. Crossed polars. Scale bar = 1 mm.

Fig. 177. Haematite replacing rhombohedral carbonate cement. Sample from Highfield quarry, Aldridge. Plane polarized light. Scale bar = 0.5 mm.
Fig. 178. Pore filling authigenic kaolinite. Sand grains in left hand part of photograph cemented by large authigenic quartz overgrowths. Sample from Highfield quarry, Aldridge. Plane polarized light. Scale bar = 0.5mm.

Fig. 179. Pore filling authigenic feldspar. Sample from Highfield quarry, Aldridge. Plane polarized light. Scale bar = 0.5mm.
Fig. 180. North Staffordshire depositional area: outcrop and location map.

Place names: N = Newcastle-under-Lyme
CH = Chesterton

Boreholes and colliery shafts:

1 - Parkhouse No.3 shaft 15 - Clayton B/H
2 - Holditch No. 2 shaft 16 - Stafford Colliery
3 - Wolstanton No. 3 shaft 17 - Radwood B/H
4 - Bowsey Wood B/H 18 - Whitmore B/H
5 - Silverdale Colliery 19 - Peacock's Lane B/H
6 - Redheath No.1 B/H 20 - Sidway Mill B/H
7 - Millbank Colliery 21 - Harley B/H
8 - Quarry Bank B/H 22 - Stabhill B/H
9 - Highway Lane B/H 23 - Groundslow B/H
10 - Barker's Wood B/H 24 - Meaford Hall No.1 B/H
11 - Pie Rough B/H 25 - Hobbergate B/H
12 - Werburgh B/H 26 - Holt's Barn B/H
13 - Hey Sprink B/H 27 - Kibblestone B/H
14 - Swallowcroft B/H 28 - Moddershall B/H

Legend: Trias - no ornament
Westphalian D (Keele and Newcastle Fm.) - dotted ornament
Etruria Formation - red
Productive Coal Measures - grey
Pre-Westphalian - diagonal lines

Triangular marks on fault lines indicate inferred direction of downthrow during the Carboniferous.
Fig. 181. North Staffordshire depositional area: correlation of borehole sections (1), showing interbedded and diachronous base of Etruria Formation. For location see Fig. 180.
Fig. 182. North Staffordshire depositional area: correlation of borehole sections (2), showing interbedded and diachronous base of Etruria Formation. For location see Fig. 180.
Fig. 183. North Staffordshire depositional area: correlation of borehole sections (3), showing interbedded and diachronous base of Etruria Formation. For location see Fig. 180.
Fig. 184. North Staffordshire depositional area: correlation of borehole sections (4), showing interbedded and diachronous base of Etruria Formation. For location see Fig. 180.
Fig. 185. Mid Staffordshire depositional area: outcrop and location map.

Place names:

C - Cannock
A - Aldridge
WL - Walsall

T - Tamworth
WV - Wolverhampton

Boreholes and colliery shafts:

1 - Enson B/H
2 - Sandon Bank B/H
3 - Allotment No.1 B/H
4 - Beacon B/H
5 - Blackheath B/H
6 - Hanyards B/H
7 - Parkhouse B/H
8 - Bricklawn B/H
9 - Brancote Gorse B/H
10 - Stoneford B/H
11 - Berryhill B/H
12 - Brocton B/H
13 - Devil's Dumble B/H
14 - Saredon Hill B/H
15 - Cannock Old Coppice Colliery
16 - Walsall Wood Colliery
17 - Aldridge Colliery

Legend: as for Fig. 180.
Fig. 186. Mid Staffordshire depositional area: regional correlation of boreholes and shafts in western part of area (Cannock Chase Horst). For location see Fig. 185.

Notes:

1) Littleton section based on Playground No.8 borehole and contour map of workings in Bottom Robins Coal.

2) Aldridge Colliery: Benches, 8 ft., and Park Coals from Walsall Wood Colliery No. 1 shaft. (These coals are not recorded in the scanty record of the Aldridge shaft).
Fig. 187. Mid Staffordshire depositional area: regional correlation of boreholes in eastern part of area. For location see Fig. 185.
Fig. 188. Mid Staffordshire depositional area: marked diachronism in the base of the Etruria Formation in boreholes to the north east of Stafford. For location see Fig. 185.
Fig. 189. Mid Staffordshire depositional area: marked diachronism in the base of the Etruria Formation in boreholes to the south west and south east of Stafford. For location see Fig. 185.
DEILS DUMBLE

ASHFLATS

BROCTON

BERRYHILL

BRICKLAWN

1.7 km

2.9 km

1.9 km

5 km

0 metres

100

200

300

entire interval up to base Trias may be Etruria Fm
Mid Staffordshire depositional area: stratigraphy of Etruria Formation in the area to the north of Wolverhampton, over the boundary between the Mid Staffordshire and Coalbrookdale area. (The seam sequence in Stretton borehole and possibly that in Gravelly Way borehole are typical of the Coalbrookdale area). For location see Fig. 185.
Fig. 191. Mid Staffordshire depositional area: diachronism in the base of the Etruria Formation near the eastern boundary of the area. For location see Fig. 185.
WHITTINGTON HEATH

1.5 km

BOWMAN'S BRIDGE

0

m

100

200

BOTTOM ROBINS

Aegirianum M.B.

BROOCH
Fig. 192. Leicestershire and South Derbyshire depositional area: outcrop and location map. Legend as for Fig. 180.
Fig. 193. Leicestershire and South Derbyshire depositional area: stratigraphy of Etruria Formation and Pottery Clay facies, and comparison with northern part of Warwickshire depositional area (Syerscote Barn borehole). For location see Fig. 192.
Cambriense M.B.
Shafton M.B.
Edmonia M.B.
Aegirianum M.B.
Maltby M.B.
Vanderbecki M.B.

HANGINGHILL FARM
GRANGE WOOD
CHURCH FLATS
SYERSCOTE BARN

5 km
1.1 km
8.8 km

not present

?
Fig. 194. Warwickshire depositional area: outcrop and location map.

Place names: T - Tamworth W - Wilnecote
D - Dosthill K - Kenilworth

Boreholes:

1 - Comberford Lane 8 - Berryfields Farm
2 - Syerscote Barn 9 - Blind Lane
3 - Coton Hall Farm 10 - Ram Hall
4 - Amington Hall 11 - Rough Close
5 - Kimberley's Grove 12 - Beanit Spinney
6 - Pickford Green 13 - Little Chase
7 - Parkhill Lane 14 - Wainbody Wood

Legend as in Fig. 180.
Fig. 195. Warwickshire depositional area: borehole and shaft correlation (1), showing probable diachronism of Etruria Formation in western part of area. For location see Fig. 194.
Fig. 196. Warwickshire depositional area: borehole correlation (2), showing diachronism of Etruria Formation in western part of area. For location see Fig. 194.
Fig. 197. Warwickshire depositional area: borehole correlation (3).

For location see Fig. 194.
Fig. 198. Warwickshire depositional area: borehole correlation (4), showing attenuation of Productive Coal Measure sequence to south. For location see Fig. 194.
Fig. 199. Warwickshire depositional area: isopachs of intervals in the Productive Coal Measures in the northern part of the area. From Mitchell 1942, Figs. 4, 5 and 6.
ISOPACHYTES IN FEET OF MEASURES BETWEEN BENCH AND SEVEN FEET COALS

ISOPACHYTES IN FEET OF MEASURES BETWEEN SEVEN FEET AND SLATE COALS

ISOPACHYTES IN FEET OF MEASURES(EXCLUDING COALS) BETWEEN SLATE AND THIN RIDER COALS
Fig. 200. South Staffordshire depositional area: outcrop and location map.

Place names:

D - Dudley Port  G - Gornalwood
O - Oldbury      N - Netherton
OH - Old Hill    A - Amblecote

Legend as for Fig. 180.
Fig. 201. South Staffordshire depositional area: stratigraphy of Productive Coal Measures and Etruria Formation, from Poole (1970). For location see Fig. 200.
Sequence of Productive Coal Measures and Etruria Formation encountered in Bogs Farm (= Beech Tree No. 1) borehole. Note division of thick coal into leaves and seat-earth dominated nature of P.C.M. sequence.
Base of Halesowen Formation

'Base' of Etruria Formation

Leaves of Thick Coal

TOP

BOTTOM
Fig. 203. Wyre Forest depositional area: outcrop and location map.

Place names: A - Alveley  UA - Upper Arley
Fig. 204. Wyre Forest depositional area: regional correlation with Clee Hills and South Staffordshire. All Wyre Forest boreholes were cored throughout this part of the sequence.

Note:

Claverley borehole. Section drawn is as recorded by Gibson, W. 1913. Trans. Instn. Min. Eng. 45, p.30. This section contains the following features which are anomalous when compared to adjoining sections, which all correlate reasonably well:

i) the Brooch/Highley Brooch Coal appears to be absent:
ii) two marine bands are recorded immediately below the base of the continuous Etruria Formation; iii) an anomalous coal is present immediately below these marine bands.

These anomalous features may be satisfactorily reconciled with the adjacent sections by suggesting that the core of part of this sequence was inadvertently inverted at the time of recovery. The lower of the marine bands would in this case be the Maltby (Sub-Brooch) Marine Band and the anomalous coal the Brooch Coal. The upper of the marine bands (presumably the Aegirianum band) and the Flying Reed Coal would be in situ. The length of the section affected (ca. 60 ft.) is the length of a standard core barrel.

If this interpretation is correct the correlation of the Aegirianum Marine Band shown here is incorrect.
Fig. 205. Wyre Forest depositional area: correlation of boreholes in southern part of area, containing dominantly red bed sequences. For locations see Fig. 203.

Borle Mill section recorded by D. Jones 1893; Kinlet section from Whitehead and Pocock 1947; Eymore Farm section from Poole 1966; Alton No. 1 section recorded by Johnson & Sons, 1910-11.
BCRL

E

IMILL KINLET

ET

1.4 km

5.5 km

3.4 km

Aegiricnum M. B.

HIGHLEY BROOCH

BORLE MILL

KINLET

EYMORE FARM

Nos. 2 & 14

ALTON

No. 1

0

metres

100

200

300
Fig. 206. Coalbrookdale depositional area: outcrop and location map.

Place names: L - Lilleshall

Legend as for Fig. 180.
Fig. 207A. Coalbrookdale depositional area: correlation of borehole and shaft sections (1).
Fig. 207B. Coalbrookdale depositional area: correlation of borehole sections (2).
GRANVILLE 7A

1.1 km

BRICKKILN PLANTATION

1.9 km

CHILD PIT LANE

0

m

100

200

Aegirianum M. B.

FUNGUS/MARQUIS Maltby M. B.

TOP

DOUBLE

Vanderbecki M. B.

NEW MINE
Fig. 208. North Shropshire and South Cheshire area: outcrop and location map.

Legend as for Fig. 180.
Fig. 209. North Wales: outcrop and location map.

Legend as for Fig. 180.
Fig. 210. North Wales: shaft correlations, Denbighshire coalfield, from Wedd et al., 1928, 1929.
Fig. 211. North Wales: borehole correlations, Chester area.
SHOTWICK

BLACON

CHURTON

300 m

Base of Coed-yr-Allt Fm. not recognised

Aegirianum M. B.

Maltby M. B.

Vanderbecki M. B.
Fig. 212. Yorkshire, Nottinghamshire and Lincolnshire: Westphalian outcrop and location map.
Fig. 213. Lincolnshire borehole sections: Nocton, Dunston and Stixwould sections from Lees and Taitt (1946).
Fig. 214. Summary of stratigraphy of Etruria Formation and Productive Coal Measures in central England.
Fig. 215. Palaeocurrent data collected from exposures in the Etruria Formation.
Current direction measured from cross bedding in major sand bodies

Estimated trends of channels

Arrow within circle = 1 observation
Fig. 216. Distinctive detrital components of Etruria Formation sandstones (italics), and inferred geology of sediment source areas. Very abundant components underlined, minor components in brackets.

Boreholes and localities:

1 - Prees - 1  
2 - Ternhill - 1  
3 - Stoke-on-Tern  
4 - Edgemond - 1  
5 - Kinley Farm  
6 - Hoo Hall  
7 - Leegomery House Farm  
8 - Lodge Farm  
9 - Wrekin Buildings  
10 - Coalport G2  
11 - Coton Hall Farm  
12 - Trickley Lodge  
13 - Rubery outcrop
NORTH STAFFORDSHIRE
Basic igneous (altered)
Polycrystalline metamorphic quartz
(Acid volcanic)
(Acid plutonic)

NORTH EAST SHROPSHIRE
Precambrian acid & basic
volcanics & plutons; gneiss,
low grade metasediments.
Lower Palaeozoic sediments.

TELFORD
Varied igneous & metamorphic
Vein quartz

CANNOCK & ALDRIDGE
Acid volcanic
 Quartzite
 Sandstone
 Basic igneous
 Shale

SOUTH STAFFORDSHIRE
Quartzite
Basic igneous (altered)
Sandstone
White mica
Acid volcanic

WEST WARWICKSHIRE
Precambrian acid volcanics,
Cambrian quartzites, shale,
basic intrusions.
Silurian sandstone.

WARWICKSHIRE
Quartzite
(Acid plutonic)

Outcropping pre-Carboniferous
Westphalian D on pre-Carboniferous
Borehole (see caption)
?Local sediment transport
?Regional sediment transport

Devonian sandstone & mudstone

?Metamorphic terrain sourcing
white mica (found only in
South Staffordshire)
Fig. 217. Types of coal seam split encountered in the Productive Coal Measures. Heavy arrow indicates dominant regional sediment supply from north; light arrow indicates minor local sediment supply from Wales-Brabant ridge.
Vegetation near edge of basin entraps sediment, protecting thick peat area from clastic influx.
Fig. 218. Legend for palaeogeographic maps (Figs. 219-225) and cross sections (Figs. 226-232).
Swamp - Facies Association I

Interdigitation of swamp and well drained floodplain - F. A. I & II

Well drained floodplain - F. A. II

Alluvial fan - F. A. III

Pre-Westphalian

Thick coals

Maximum extents of marine intercalations

Coals splitting into seat-earth dominated facies near basin margins

Intense local folding in late Westphalian C Etruria Fm. and Coal Measures denuded

Gentle regional folding in late Westph. C Local denudation of part of Etruria Fm.

Alkali basalt intrusions (and ?extrusions)

Namurian

Dinantian

Pre-Carboniferous

Coal seams

Marine bands

Swamp vegetation

Floodplain vegetation

? 'Upland' vegetation

Lateritic weathering mantle in source areas

Local sourcing of sediment

Regionally dominant sediment transport
Fig. 219. Palaeogeographic map of Central England during Westphalian A. For discussion see 10.2.2. and 10.2.3.
EARLY - MID WESTPHALIAN A (pre-Mealy Grey coal in Mid and South Staffs areas) & LATE WESTPHALIAN A (Vanderbecki marine incursion)
Fig. 220. Palaeogeographic map of Central England during early Westphalian B. For discussion see 10.2.4.
EARLY WESTPHALIAN B (Thick Coals)

CHESTER

WREXHAM

STAFFORD

SHREWSBURY

TEL FORD

STOKE

CANNOK

WOLVERHAMPTON

DUDLEY

BIRMINGHAM

TAMWORTH

NUNEATON

COVENTRY

WORCESTER

MANSFIELD

NOTTINGHAM

DERBY

LEICESTER

0 km 10 20 30
Fig. 221. Palaeogeographic map of Central England during mid Westphalian B. For discussion see 10.2.5.
MID WESTPHALIAN B (Maltby marine incursion; Brooch coal in Mid and South Staffs areas)

CHESTER

WREXHAM

SHREWSBURY

TELFORD

WOLVERHAMPTON

DUDLEY

BIRMINGHAM

COVENTRY

WORCESTER

STAFFORD

STOKE

CANNOCK

TAMWORTH

NUNEATON

MANSFIELD

NOTTINGHAM

DERBY

LEICESTER

W0RT

km 0 10 20 30
Fig. 222. Palaeogeographic map of Central England during late Westphalian B. For discussion see 10.2.6.
LATE WESTPHALIAN B (Aegirianum marine incursion and immediately preceding period)

[Map showing locations such as Chester, Wrexham, Stafford, Cannock, Wolverhampton, Dudley, Birmingham, Coventry, Dudley, etc.]

0 km 10 20 30
Fig. 223. Palaeogeographic map of Central England during early Westphalian C. For discussion see 10.2.7.
EARLY WESTPHALIAN C (immediately after Aegirianum marine incursion)
Fig. 224. Palaeogeographic map of Central England during mid Westphalian C. For discussion see 10.2.8.
MID WESTPHALIAN C (ca. Bottom Robins coal in Cannock/Mid Staffs. area. Cambriense marine incursion)
Fig. 225. Palaeogeographic map of Central England during late Westphalian C/earliest Westphalian D. For discussion see 10.2.9.
Fig. 226. Schematic cross section of Westphalian deposits in Staffordshire at the time of the Vanderbecki marine incursion. Section line for this and succeeding sections runs (approximately) from Rubery in South Staffordshire to Chartley borehole, east of Stafford, and thence into the North Staffordshire area. Legend in Fig. 218. For discussion see 10.2.2., 10.2.3., and 10.3.1.
Fig. 227. Schematic cross section of Westphalian deposits in Staffordshire at the time of formation of the Thick Coal. For discussion see 10.2.4. and 10.3.1.
Fig. 228. Schematic cross section of Westphalian deposits in Staffordshire at the time of the Aegirianum marine incursion. For discussion see 10.2.5., 10.2.6. and 10.3.1.
Fig. 229. Schematic cross section of Westphalian deposits in Staffordshire at the time of formation of the Winghay Coal in North Staffordshire. Coals above the Aegirianum Marine Band in Mid Staffordshire are Bottom Robins and Top Robins. For discussion see 10.2.7., 10.2.8. and 10.3.1.
Fig. 230. Schematic cross section of Westphalian deposits in Staffordshire at the time of formation of the Bassey Mine Coal in North Staffordshire. For discussion see 10.2.9. and 10.3.1.
Fig. 231. Schematic cross section of Westphalian deposits in Staffordshire during deposition of the main part of the Etruria Formation in the North Staffordshire type area. For discussion see 10.2.9. and 10.3.1.
Etruria Formation (of type area)
Bassey Mine
Great Row
Cambriense M.B.
Winghay
Bottom Robins/Rowhurst
Aegirianum M.B.
Broach/Moss
Thick Coal group
Vanderbecki M.B.
Subcrenatum M.B.
Fig. 232. Schematic cross section of Westphalian deposits in Staffordshire after deformation and peneplanation in late Westphalian C and early Westphalian D, and deposition of basal Halesowen Formation. For discussion see 10.2.9. and 10.3.1.
Fig. 233. Structures produced during late Westphalian C/early Westphalian D deformation in the Coalbrookdale area. Modified from Whitehead et al. 1928.
Fig. 234 Schematic palaeogeographical maps showing the evolution of north west Europe during the Westphalian. In part after Dvorak et al 1977, Bless et al 1977 and others.

It is likely that other areas were locally uplifted during the Westphalian C. Uplift of the Manx Askrigg area is based on the occurrence of an unconformity beneath Westphalian C/D red beds in the Ingleton outlier (Ramsbottom et al 1978). In other areas of Northern England and the North Sea and Ireland stratigraphical evidence has been removed by erosion.
Uplifted areas

Etruria Formation alluvium, locally derived from Wales - Brabant Massif

‘Pennant’ alluvium, regionally derived from Variscan front

BC  Bristol Channel landmass
LS  Lower Severn axis
MA  Manx - Askrigg high
MN  Mid Netherlands high
WBM Wales - Brabant massif

WESTPHALIAN A

WESTPHALIAN C

WESTPHALIAN D
Fig. 235  Schematic cross sections showing the evolution of the British area during the Westphalian.

Heavy arrows indicate important regional sediment sources. Light arrows indicate local sediment derivation.

Structural elements:

AA  -  Alston and Askrigg blocks  
BC  -  Bristol Channel 'landmass'  
LB  -  London Brabant 'massif'  
SH  -  Scottish Highlands  
SU  -  Southern Uplands

Depocentres:

C  -  Cornubian trough  
MV  -  Midland Valley, Scotland  
P  -  Pennine Basin  
SW/S  -  South Wales/Somerset Basin

In part after Leeder (1982)
WESTPHALIAN A

ETRURIA FORMATION

WESTPHALIAN C (late)

WESTPHALIAN D (mid-late)

'Sennant' alluvium, derived from Variscan front

Locally derived alluvium

Alluvium derived from Caledonian highs

Namurian and Viséan

Pre-Carboniferous

Pre-Carboniferous
APPENDIX 1

Measured sections of Etruria Formation exposures and cores; sources of borehole data

1. Measured sections

A brief description of all exposures and cores examined is given here, together with graphic logs of the larger and more important sections. Details are also given of access routes, ownership and condition of exposures.

NORTH STAFFORDSHIRE

Goldendale Quarry (SJ 850519)

This quarry exposes a small section of mudstones, fairly near the base of the Etruria Formation. The only feature of note is an evolved palaeosol which was (in 1977) fairly easily accessible on a sloping face near the top of the section (Figure 58).

The quarry is still worked.

Present owner: Mr. P.R. Powell, Bottom Farm, Peacock's Hay Road, Talke, Newcastle-under-Lyme.

Access: The quarry is situated to the east of the junction of Lowlands Road, Boathorse Road and Chatterley Road. The access gate is on Chatterley Road.

Platt's Tileworks

This tileworks contains two small exposures. The northern quarry (SJ 857508) exposes 10 m near the base of the Etruria Formation. The southern quarry (SJ 859507) exposures 17 m at a slightly higher level in the Formation.

Neither quarry is now worked and both are degraded.

Present owner: D. Platt Limited, Canal Lane, Brownhills, Tunstall.

Access is from Canal Lane, on the west side of Longport to Tunstall Road (Brownhills Road, A527).

Powell's Quarry (SJ 845509)

This is a small quarry, immediately to the west of the A500 (Potteries D road), exposing a monotonous section of ca 10 m of red mudstones and palaeosols in one vertical face.

The quarry is still worked.
Present owner: Mr. P.R. Powell.

The quarry is situated some 300 m north of Kimberley's quarry (q.v.). Access is from an unmetalled track which leads northwards from the end of Chemical Lane, Longport, passing under the D road near Kimberley's quarry.

Chatterley Quarry (SJ 848510)

This quarry adjoins the disused Chatterley tileworks, on the eastern side of the A500 (Potteries D road). It exposes ca. 18 m of Etruria Formation in several discontinuous degraded sections. The sections consist mainly of red mudstone. A sand body is patchily exposed in the adjoining D road cutting (Figures 72, 73).

The quarry is still intermittently worked, but is very degraded.

Present owner: Mr. P.R. Powell.

Access is as for Powell's quarry, an unmetalled track passing beneath the D road between the two quarries.

Kimberley's Quarry (SJ 847507)

This is a very small and degraded quarry immediately to the west of the A500, exposing ca. 5 m of red mudstone.

The quarry is still intermittently worked.

Present owner: not known.

Access: from unmetalled track leading from Chemical Lane, Longport.

Bentley Quarry (SJ 848505)

This quarry lies immediately to the west of the Potteries D road (A500) some 200 m to the south of Kimberley's quarry. Some 17 m are exposed at a horizon near the middle of the Etruria Formation. The section consists entirely of red mudstones and contains a polyphase palaeosol with a lower horizon containing calcareous concretions (cf. Palaeosol type 5) and a thin carbonaceous organic upper horizon.

The quarry has not been worked for many years and is considerably degraded. Plans exist to use it as a disposal site for toxic waste.


Access: by unmetalled track running southwards from Kimberley's quarry, parallel to the A500.
Rufus Quarry (SJ 843504)

This quarry forms a prominent scar on the western slope of Bradwell Wood. It exposes some tens of metres near the top of the Etruria Formation, at about the same horizon as the nearby Metallic Tileries quarry, but is at present very degraded.

The quarry has not been worked for some years, but is unlikely to be covered. Planning consent exists for the continued extraction of clay from this quarry and the area immediately to the south.


Access: via track leading westwards from Kimberley's quarry.

Metallic Tileries, Chesterton (SJ 840498)

This quarry contained a large exposure excavated in the north facing escarpment of Newcastle Formation. At the time of examination (1977) the top 33 m of the Etruria Formation were exposed in discontinuous sections in the southern face of the quarry (Figures A1, A2). Principal features of note were: i) type 3 palaeosol in sump section (Figure 41b); ii) reasonably well exposed sand bodies in main face (Figures 71, 79-81); and iii) nodular algal limestone horizon at boundary with Newcastle Formation (Pollard and Wiseman, 1971).

The quarry has now been infilled, leaving patchy exposures of the top few metres of the Etruria Formation, all in red mudstone, and an important although discontinuous section of the basal Newcastle Formation.

The quarry area is now occupied by an industrial development area, owned (probably) by the Newcastle-under-Lyme Borough Council. Access is from the A34 road (Talke Road).

Spoutfield Quarry (SJ 863464)

This small exposure is excavated in the east facing escarpment of the Newcastle Formation, ca. 800 m to the south of the original type section of the Etruria Formation at Etruria. In 1977 the top ca. 25 m of the Etruria Formation was very poorly exposed, together with the basal ca. 10 m of the Newcastle Formation. The boundary between the two was covered, and the Newcastle Fm. section inaccessible.

The Etruria Formation section consisted of monotonous red mudstones and poorly developed palaeosols, similar to those in the Metallic Tileries section. A composite laterally accreted sand body (Facies 13, 14) is present ca. 8 m below the top of the Formation, in which internal structures are particularly easily visible owing to the weathered nature of the exposure (Figures 85, 86). In the silt and mudstone unit immediately overlying this sand body two small crevasse channels (Facies 11) were found by excavation of the degraded section (Figure 40).
The quarry was being sporadically worked in 1977, but partial infilling had begun.

Present owner: J. Caddick Limited, Spoutfield Tilery, Brickkiln Lane, Cliff Vale, Stoke-on-Trent.

Access: from Brickkiln Lane.

Manor Quarry (SJ 885451)

This is the largest single exposure of the Etruria Formation in North Staffordshire, situated immediately to the east of Stoke-on-Trent railway station.

The quarry is traversed by a number of faults, known collectively as the Longton Hall Fault, whose throws probably exceed 30 m. Several distinct sections near the middle of the Etruria Formation are present.

Section 1 (Figures A3, A4). At the time the sections were measured (September 1978) it appeared that there were two faulted compartments forming the northern part of the east faces of the quarry. These two measured sections are here termed 1A and 1B. Subsequent excavation has shown that: a) the lower parts of both sections are identical; b) the intervals between 9 and 14 m in section 1B and above ca. 8 m in section 1A probably from one continuous section. It has not yet proved possible to measure an unambiguous section in this part of the quarry.

Main features of interest in these sections are: a) presence of palaeosols of type 3 and Facies 12 ironstones; b) a particularly thick polyphase palaeosol, with a very well developed organic phase (13.50 m - 14.50 m in section 1A); the sand body illustrated in Figure 74 (Facies 13, ?laterally accreted).

The palaeosols illustrated in Figures 41a, 45, 47, 49, 63, 70 were sampled and photographed after the sections were measured. They come from a horizon probably slightly below the bases of the sections illustrated in Figures A1 and A2.

Section 2 (Figure A5) This section formed the degraded northern faces of the quarry. The nature of its relationship to Sections 1 is not known.

Section 3 (Figure A6) This section formed the southern and south eastern faces of the quarry. Subsequent excavation has shown that part of the section between 1 m and 7 m is duplicated by faulting. The sand body has largely been removed since 1981.

The quarry is still working.

Present owner: Steetly Brick Limited.

Access: from City Road Fenton (A50) or from Old Mill Street, Stoke-on-Trent.
Springfield Quarries

Two quarries are present at the Springfield Tilery, one to the north of the works (North Quarry) and one to the east and south of the works (South Quarry).

North Quarry (SJ 861445)

This quarry exposes a small section near the middle of the Etruria Formation (Figure A7). The main exposure is in the northern face (Figure 96).

The upper part of this face contains a complex laterally accreted sand body, characterised by a high proportion of silt, and containing two well developed clay channel abandonment plugs (Figures 95, 96).

South Quarry (SJ 863442)

This quarry exposes a thicker sequence (Figure 108) at a stratigraphical horizon slightly lower than that seen in the North quarry. The succession is dominated by silty mudstones, and contains an example of a Facies II crevasse channel (Figure 38) at 21.5 m in the section.

In 1978 the northern quarry was unworked and the southern quarry was working. The quarries have since changed hands, and the associated tileworks is now largely disused. The present state of the exposures is not known.

Present owner: D. Platt Limited.

Access: from Newcastle Road (A34).

Lightwood Quarry (SJ 921409)

This quarry is situated in a valley to the south of Longton, the sides of which are formed by the escarpment of the Bunter Pebble Beds. The quarry exposes a section probably in the middle or upper part of the Etruria Formation (Figure A8). The basal 8 m of this section were measured in the northern area of the quarry: the remainder in the western faces of the main pit.

This quarry is still actively worked.

Present owner: D. Platt Limited.

Access: via an unmetalled track on the west side of Lightwood Road, leading through Copshurst Farm.

Chesterton Quarry (SJ 827493)

This extremely large exposure was visited before it was completely obliterated by tipping in 1977/78. Because of the high tectonic dip (ca. 30°) the quarry exposed a thick sequence (Enclosure 2) mainly in
the benches on its north eastern and south eastern faces. At the time of visiting the faces were extensively degraded.

Particularly interesting features present included: several thick evolved and stacked palaeosols; and two laterally accreted sand bodies showing more extensive lateral exposure than in any other site visited. (Sand bodies 1 and 4).

Knutton Quarry (SJ 828468)

This quarry exposes a section in the middle of the Etruria Formation (Figure A9). It was notable in 1977/78 for the presence of a typical polyphase palaeosol, of crevasse splay sheet sands with an associated crevasse channel fill, and of the best exposed example of a laterally accreted sand body.

The quarry is still actively worked, but is at present in a degraded state. The crevasse channel fill has been removed by excavation, and the laterally accreted sand body partially covered by the accumulation of talus.

Present owner: Steetley Brick Limited.

Access: from Church Lane, Knutton, through tile works.

Rosemary Hill Quarry (SJ 830460) also known as Walley's or Silverdale quarry.

At the time that field work was carried out for the present study, this quarry was nearly completely degraded, the only significant exposures being those of the sandbody exposed in the old access road cutting (Figure A10; see also Figures 89, 90). In 1977 a number of boreholes (Figure A10) were drilled to appraise clay reserves. The cores from these were examined, and from them a provisional section for the southern part of the quarry area has been made (Enclosure 8). However, core recovery was not complete, and much of the core was in poor condition and could not properly be examined. Clay extraction from the quarry has now resumed.

The section is at the base of the Etruria Formation starting ca. 50 m above the Blackbound Coal.

The access road section is presently being backfilled (1983).

Present owner: Steetley Brick Limited.

Access: from Cemetery Lane, Silverdale.

Silverdale Quarry (SJ 804462)

This quarry contains a very small, degraded and overgrown section at the base of the Etruria Formation. At present being filled in.

Present owner: Michelin Tyre Co. Limited, Stoke-on-Trent.
Access: from Hollywood Lane, an unmetalled track leading west from Pepper Street, Silverdale.

**Keele Quarry, Madeley Heath (SJ 788441)**

This large quarry is excavated in the escarpment of the Newcastle Formation. The top 43 m of the Etruria Formation (Enclosure 9) and the basal 18 m of the Newcastle Formation was exposed. At the base of the section an extremely thick evolved palaeosol is present (Figure 60). The sand body at 22 m in the section is exposed intermittently in the western and southern faces of the pit. It is obviously a complex, laterally accreted unit, but exposure is inadequate to draw up a detailed section showing the lateral variation.

The quarry is no longer worked, and is now very degraded.

Present owner: Steetley Brick Limited.

Access: through Keele brickworks, from Newcastle Road (A525).

**Kibblestone Borehole (SJ 911361)**

This borehole cored 96 m of the basal part of the Etruria Formation (Enclosure 3). The cores have not been preserved.

**CANNOCK AREA**

**Rosemary Quarry (SJ 975075)**

In this quarry a section of 24 m of Etruria Formation is exposed, ca. 70 m above the base of the Formation.

The sequence (Figure All) consists mainly of Facies Association II, with thick palaeosols and a major pebbly sandstone body, which forms the upper part of the north face of the quarry. The method of clay extraction — by box scrapers working on a sloping face — causes most of the section to be poorly exposed. It is thus not clear whether the sheet sand bodies at ca. 9 m are distal Facies Association III sheets (because of their coarse grain size) or might better be regarded as belonging to Facies Association II.

This quarry is still actively worked.


Access: through Rosemary works, on Coppice Lane, Cheslyn Hay.

**Redhurst Wood Quarries**

Two quarries are present in this area, on each side of Warstones Road, the A462 Cannock to Willenhall Road.
Redhurst Wood East Quarry (SJ 972052)

This is a small exposure, showing a mudstone dominated section (Figure 105).

The quarry is at present completely water filled.

Present owner: Hawkins Tiles Limited.

Access: from A462.

Redhurst Wood West Quarry (SJ 969052)

This very large exposure is of a horizon fairly high in the Etruria Formation. Two distinct stratigraphic units are present: the lower unit (Figures A12 and 106) consists of Facies Association II, while the overlying unit (Figure 148) consists of Facies Association III, containing examples of Facies 16, 17 and 18 which are discussed and illustrated in the text.

The western part of the quarry (mainly Facies Association II) is being actively worked. The eastern part (mainly Facies Association III) is at present being infilled.

Present owners: Hawkins Tiles Limited (western part); Adams Transport Limited (eastern part).

Access: from A462.

Essington Quarry (SJ 968044)

This quarry contains a small exposure, consisting mainly of mudstones with one conglomerate sheet of Facies Association III.

At the time of examination (1977) this quarry was not being worked and was degraded. Some extraction has been carried out more recently.

Present owner: Haunchwood Lewis Limited.

Access: via minor road leading westwards (towards Essington) from A462, opposite disused tileworks.

Allotment No. 1 borehole (SJ 947268)

A continuous section of the Etruria Formation was cored in this borehole (Enclosure 4). The Formation is here fairly thin, owing to erosion prior to the deposition of the Halesowen Formation. It consists entirely of Facies Association II sediments.

The core is at present (1983) stored by the National Coal Board (Western Area), but is likely to be destroyed.
Playground No. 8 borehole (SJ 972124)

A continuous section of the Etruria Formation was cored in this borehole (Enclosure 5). The Formation is here fairly thin, owing to erosion prior to the deposition of the Halesowen Formation. It consists entirely of Facies Association II sediments.

The core has been destroyed.

Streets Lane No. 1083 borehole (ca. SJ 972061)

In this borehole a 70 m section was cored continuously from the surface to the base of the Formation (Enclosure 6). The presence of two small faults, at 18 m and 85.5 m was inferred from slickensides and fracturing in the core. The lower part of the sequence consists of Facies Association II sediments: the upper part of Facies Association III.

The core is at present (1983) stored by the National Coal Board (Opencast Executive), Rumer Hill, Cannock.

ALDRIDGE AREA

Utopia Quarry (SK 046026)

This large working quarry exposes the top 22 m of the Etruria Formation, and the basal part of the Halesowen Formation. The latter has here been affected by Permo-Triassic reddening, but is sedimentologically and petrographically distinctive. There does not appear to be an unconformity between the two Formations, although a depositional hiatus is marked by the presence of a thick palaeosol in the top 4 m of the Etruria Formation.

The principal exposure is in the north face, where a number of Facies Association III sheet sand bodies are present (Figure 143, Figure A13 (Western end of face), Figure A14 (eastern end)).

This quarry is still actively worked.

Present owners: Ibstock Brick (Aldridge) Limited, Brickyard Road, Aldridge.

Access: from Walsall Wood, via Boatman's Lane.

Highfield Quarry (SK 043026)

This is an extensive shallow quarry immediately to the west of Utopia Quarry. The section exposed is at the same horizon, comprising the top 12 m of the Etruria Formation and the basal 8 m of the Halesowen Formation.
The quarry is at present not worked, and is extensively degraded. Planning consent has been granted for future working.

Present owners: Ibstock Brick (Aldridge) Limited.  
Access: via Boatman's Lane.

Empire Quarry (SK 043023)

This large quarry exposes in its northern face sediments of Facies Association III which immediately underlie those exposed in Highfield Quarry (Figure 141).

The extreme western part of the quarry is still worked. The central part of the quarry is currently not worked and has become degraded. The eastern part is being infilled, and exposures only remain high in the north wall. Access to much of the quarry was (in 1977) rendered inadvisable by the toxic nature of the material being tipped, and of its associate leachate.

Access: from Shelfield, by an unmetalled track leading eastwards from the junction of Spring Road and New Street.

Atlas Quarry (SK 044021)

This large quarry exposes the lowest horizons seen in the Etruria Formation in the Aldridge area (Enclosure 7). The lower part of the section consists of Facies Association II sediments, with one thick palaeosol stack. The upper part of the section contains two pebbly sand bodies. Of these the lower (at ca. 18 m) is probably a channel deposit, and the upper probably a sheet (Facies 18) of either channelised or unconfined origin.

The quarry is still actively worked. The working area, in the base of the quarry, exposes the basal ca. 8 m of the section. The remainder is exposed in the partly degraded northern and eastern faces.

Access: via Stubber's Green Road.

Tamworth Area

Wilnecote Quarry (SK 220000)

This quarry exposes a 28 m section (Figure A15) of the lower part of the Etruria Formation, starting ca. 10 m above the base of the Formation. The lower part of the section consists of Facies
Association II sediments including a thin coal seam. The upper part contains sheets and channels filled with shale clast conglomerate. (See Figure 142).

The quarry is actively worked.

Present owner: Wilnecote Brick Limited.

Access: through Wilnecote works, on south side of minor road leading eastwards from the north end of Dosthill village.

Stoneware Quarry (SP 222998)

The section in the eastern face of this quarry (Figure A16) forms a continuation of the section exposed in Wilnecote Quarry. The section consists mainly of Facies Association II mudstones, with one shale clast conglomerate sheet. The quarry is worked sporadically, but is extensively degraded.

Present owner: Stoneware Limited.

Access: by climbing from Wilnecote quarry, or from minor road leading eastwards from south end of Dosthill village.

Averill Quarry (SP 220998)

This quarry exposes shale clast conglomerates in the same group as those exposed in Wilnecote Quarry, which lies immediately to the north (see Figure 142). The quarry is disused, and is currently being infilled.

Present owner: Severn Trent Water Authority.

Kingsbury Quarry (SP 219989)

This quarry exposes the upper ca. 20 m of the Etruria Formation, which is here unconformably overlain by the Halesowen Formation. The sequence is similar in nature to the Facies Association III conglomerates and mudstones seen in Wilnecote Quarry, these sediments occurring probably at a slightly higher stratigraphic horizon than that seen in the section at Stoneware Quarry.

The lower part of the quarry is still worked, using box scrapers which render it impossible to measure a section. In the upper part of the quarry the east face contains very patchy and degraded exposures.

Present owner: Baggeridge Brick Co. Limited.

Access: through Kingsbury works, from minor road leading eastwards from south end of Dosthill village.
NUNEATON AREA

Bermuda Quarry (SP 351894)

This quarry contains the only significant section (Figure A17) of the Etruria Formation in this area. The section is measured from patchy exposures in the eastern, southern and western faces of the pit. It consists entirely of sediments of Facies Association II.

The quarry is still intermittently worked, but is fairly extensively degraded.

Present owner: Stanley Brothers Limited.

Access: via unmetalled road leading southwards from minor road at SP 354897.

Heath End Quarry (SP 348903)

This quarry is completely degraded and overgrown. The only remaining exposure consists of two isolated exposures of less than 1 m of a sand body, from which two palaeo-current readings were obtained (see Figure 213).

SOUTH STAFFORDSHIRE AREA

Ibstock Himley Quarry (SO 896902)

Two sections are present in this quarry: section 1 (Figure A18), in a deep trial pit at the south side of the quarry; and section 2 (Figure A19) measured in the northern face of the quarry. The two sections are separated by a gap of ca. 5 m.

Section 1 is the only section in which the interdigitation of red beds and coal measures at the base of the Etruria Formation is exposed. Section 2 consists of mudstones containing post depositionally oxidized seat earth palaeosols, interbedded with sandstone sheets which may be distal representatives of Facies 18.

The quarry is still actively worked.

Present owner: Ibstock Brick (Himley) Limited.

Access: through Himley brickworks, from B4175 Gornal to Kingswinford Road, at SO 900902.

Smithy Lane Quarry (SO 908898)

This quarry contains two sections, separated by a fault of indeterminate throw. The northern section exposes a few metres of
monotonous siltstones and mudstones. The southern section (Figure A20) contains 26 m of mudstones and sand bodies, in discontinuous, degraded exposures.

The southern section of the quarry is not at present worked. The northern section was being worked in 1978.

Present owner: Stourbridge Brick Co. Limited.

Access: on east side of Smithy Lane, Tansey Green.

Ketley Quarry (SO 898890)

The section exposed in the eastern faces of this quarry comprises 12 m. of Etruria Formation, overlain by the basal sand body of the Halesowen Formation. The Etruria Formation (Figure A21) consists entirely of sediments of Facies Association III, and is notable for the occurrence of well exposed channel fills (Facies 20) and laterally extensive sheet sandstones (Facies 18/19).

The quarry is still actively worked.

Present owner: Hinton, Perry & Davenhill Limited, Dreadnought Brickworks, Pensnett, Brierley Hill.

Access: along minor road leading south off A4101 Dudley to Kingswinford Road, running along western edge of quarry.

Himley Wood Quarry (SO 899911)

The north face of this extensive quarry exposes some 26 m near the middle of the Etruria Formation, comprising mudstones and palaeosols, some laterally persistent sheet sandstones, and, forming the top of the face, a laterally accreted sand body. Access to much of the section is difficult.

The quarry is actively worked.

Present owner: Baggeridge Brick Co. Limited.

Access: via a minor road leading southwards from B4176 Gornalwood to Himley road, signposted to the Crooked House public house.

WYRE FOREST AREA

Bayton Sawmill (SO 702753)

This site, formerly occupied by a brick and tile works, now houses a prefabricated buildings factory. A section of the Etruria Formation is poorly exposed along the eastern side of the factory buildings. The section, dominated by fluvial sand bodies is illustrated in Figure 112.
The section is likely to become degraded.

Present owner: London Brick Company (Gardens Division).

Access: by minor road leading southwards from A4117.

**Billingsley (SO 707850)**

About 1 m of red mudstone is poorly exposed at the site of a former brickworks, now occupied by a small holding.

This occurrence is of interest, being the only known exposure of red beds underlying the Productive Coal Measures.

In addition, several small natural exposures of pebbly sandstones and weathered red mudstones are present throughout the forest, notably in the valleys of Baveney Brook, Mad Brook, and Dowles Brook.

**TELFORD AREA**

**Blockley’s Quarry (SJ 683118)**

This is the largest and best exposure of Facies Association III sediments. Two sections are present:-

a) the main, southern face; and

b) degraded benches on the western and north western sides of the quarry.

The main face (Figures 144, 146, 147), giving excellent lateral sections of several sand and conglomerate bodies, is vertical and difficult to measure. Details of this section are shown in Figures 117, 118, 131, 132, 140, 145.

The vertical section of the western faces is illustrated in Figure 149.

The quarry is still actively worked.

Present owner: Blockley’s Limited, Hadley, Telford.

Access: by minor road leading north eastwards from Hadley to Oakengates road.

**Donnington Wood Quarry (SJ 710113)**

This quarry exposes a 14 m section in the Etruria Formation (Figure A23), consisting of mudstones and palaeosols, with two interbedded debris flow deposits (Facies 16).

The quarry is still worked, although the upper parts of the section are degraded. Only the west face is accessible.
Present owner: The Lilleshall Co. Limited.

Access: via minor road leading eastwards from A5266 Donnington to Oakengates Road, at SJ 705116.

2. Borehole Data

With a few exceptions, all borehole data used in the present study has been provided by the National Coal Board. Data are stored as follows:

Staffordshire, Shropshire, Cheshire, North Wales:
National Coal Board, Western Area Geological Services, Chatterley Whitfield, Tunstall, Stoke-on-Trent, Staffordshire.

Leicestershire, South Derbyshire, Warwickshire, Oxfordshire:
National Area Geological Services, Coleorton Hall, Ashby-de-la-Zouch, Leicestershire.

The following borehole data have been provided by the Institute of Geological Sciences:

Sidway Mill, Wrekin Buildings, Leegomery House Farm, Lodge Farm, Kinley Farm, Alton No. 1.

Data from the oil exploration wells Coole's Farm -1 and Netherton -1 are available from the Department of Energy Reference Library, Millbank, London, SW1.
SAND BODY 2
Figs. 79 - 81, 97

* correlates with top of sand body 1 at 7.50 m. in E. section (Fig. A2)

Sump section

METALLIC TILERIES
WESTERN SECTION, NORTH FACE, 1977

Fig. 41b
<table>
<thead>
<tr>
<th>Colour Facies</th>
<th>BASE OF NEWCASTLE FORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/9</td>
<td></td>
</tr>
<tr>
<td>?P5</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td></td>
</tr>
</tbody>
</table>

*correlation horizon

\[ \text{METALLIC TILERIES} \]

EASTERN SECTION, NORTH FACE, 1977

FIG. A2
Colour Facies

Sand body 2

Fig. 74

MANOR QUARRY
SECTION 1A  1978
FIG. A3
11111

Colour  Facies

R    9
V    P4
R    9,10
R    8
V    P4
R    8
V    P4
R    9
G    10
R    9
V    P4
R    9
G/V    P thin
R    8
V/GY    P3 stack

with F12 ironstone

MANOR QUARRY
SECTION 1B  1978
FIG. A4
Possibly silt dominated F13/14 channel deposit
<table>
<thead>
<tr>
<th>Colour</th>
<th>Facies</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>9</td>
</tr>
<tr>
<td>R/G</td>
<td>14,15</td>
</tr>
<tr>
<td>G</td>
<td>9</td>
</tr>
<tr>
<td>R</td>
<td>8</td>
</tr>
</tbody>
</table>

**Fig. 99**

**MANOR QUARRY**

**SECTION 3 1978**

**FIG. A6**
Springfield North Quarry
West Face, 1978
Figure A7
Colour Facies

G  14  Figs. 82, 88

R  8

GY/R  P3

R  8  Top of palaeosol eroded

V  P4  Fig. 52
stack

R  9

V  P4

R  9

LIGHTWOOD QUARRY
COMPOSITE SECTION, 1978

FIGURE A8
KNUTTON QUARRY
EAST & NORTH FACES, 1977
FIGURE A9

Colour Facies

20

R 9

G/R 14

V P4  
stack

R 8

V P4

R 9

V P4  
polyphase

Figs. 35 - 37

Figs. 48, 65

Figs. 75 - 77, 83, 84, 91, 92
<table>
<thead>
<tr>
<th>Colour</th>
<th>Facies</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>P4</td>
</tr>
<tr>
<td>R</td>
<td>9</td>
</tr>
<tr>
<td>V</td>
<td>P4</td>
</tr>
<tr>
<td>R</td>
<td>8</td>
</tr>
<tr>
<td>V</td>
<td>P4</td>
</tr>
<tr>
<td>R</td>
<td>8</td>
</tr>
<tr>
<td>R</td>
<td>9,10</td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 50
Fig. 44
Fig. 33
Fig. 34

UTOPIA QUARRY
SECTION 1, WEST PART
NORTH FACE

REDHURST WOOD
WEST QUARRY

SUM & WESTERN FACES
1977

FIG. A12
Fig. 130 (photo)

Fig. 143 (drawing)

Section laterally equivalent to Fig. A14

UTOPIA QUARRY

SECTION 1, WEST PART OF NORTH FACE, 1977
(see Fig. 143)

FIG. A13
BASE OF HALESWEN FM.

Fig. 143 (whole face)

Fig. 126 (this horizon, south side of quarry)

UTOPIA QUARRY

SECTION 5, EAST PART OF NORTH FACE, 1977
(see Fig. 143)

FIG. A14
Siderite present in red mudstone

Fig. 142 (whole face)

WILNECOTE QUARRY
COMPOSITE SECTION - MAIN (SOUTHERN) PART OF QUARRY - 1977

FIG. A15

Fig. 32
Conglomerate sheet thickens laterally to 1.10 m. and is cut by 2 m. deep conglomerate filled channel.
IBSTOCK HIMLEY QUARRY
SECTION 1 - DEEP
TRIAL PIT 1979
FIG. A18
Colour Facies

IBSTOCK HIMLEY QUARRY
SECTION 2 - MAIN WORKING AREA 1979
FIG. A19
**BASE OF HALESWEN FM.**

**Fig. 139**

**Fig. 138**

**KETLEY QUARRY**

**EAST FACE 1979**

**FIG. A21**
Fig. 93

HIMLEY WOOD QUARRY
NORTH FACE 1978
FIG. A22
Fig. 119

DONNINGTON WOOD QUARRY
WEST FACE 1979

FIG. A23
APPENDIX 2

Soil horizon nomenclature; processes of soil development

1. Soil horizon nomenclature

Two principal systems of nomenclature exist for soil horizons: the ABC system used for field description; and the more precise system, using precisely defined surface and subsurface horizons, introduced by the U.S. Department of Agriculture (Soil Survey Staff 1960).

In the latter system, the recognition of most horizons depends on laboratory determination or organic content, base saturation and/or exchangeable cation saturation. It is thus of limited use in field description and needs to be treated with the greatest reservation in the study of palaeosols, where such properties are readily altered during diagenesis. It has, however, been used in the description of palaeosols by Retallack (1977).

In the following list the nomenclature of both systems for more commonly occurring horizons. The list is largely after Birkeland (1974).

A horizon

Accumulation of organic matter and mineral fraction at surface. Divided into at least four surface horizons in USDA system; mollic and umbric horizons are dark coloured, contain more than 1% organic matter and have base saturations of greater than and less than 50% respectively; ochric horizons are lighter in colour and contain less organic material; histic horizons are peaty, containing more than 20% organic matter – these would be distinguished as O horizons.

E horizon, sometimes known as A2 horizon

Underlies A or O horizon, and is thus not a surface horizon; characterised by leached appearance due to removal of organic matter and/or sesquioxides and/or clays; also called an albic horizon. These horizons have a high preservation potential after burial.

B horizons

Argillic horizon: horizon containing more clay than the overlying A and underlying C horizons; clay enrichment may be by translocation from overlying horizons or by in-situ weathering, or both; also known as textural B horizon; fossil examples in sediments which are not excessively compacted may be recognised in thin section by the presence of cutans – field recognition may be ambiguous.

Spodic horizon: horizon occurring beneath an E (albic) horizon, characterised by concentration of organic matter and sesquioxides which have been translocated downwards from the E horizon.
Cambic horizon: a B horizon characterised by enough pedogenic alteration to eradicate most parent material structure, and/or intense oxidation; such horizons might be expected to occur commonly in palaeosols, but lack any distinctive preservable feature.

Oxic horizon: highly weathered subsurface (B) horizons characterised by the presence of hydrated iron and aluminium oxides and kaolinite (or other 1:1 lattice clay minerals); few primary rock forming minerals remain, except quartz, which is resistant to weathering; may contain concretions of hydrated iron oxides or haematite; these horizons should have fairly high preservation potential on burial.

Calcic horizon: horizon of enrichment in calcium carbonate, which if it reaches rock forming proportions, may be called a K horizon; very high preservation potential.

C horizon
A transitional horizon between soil and parent material, lacking properties of A and B horizons, but including weathering features and some modification of structure of parent material.

2. Some processes of profile development

Gleying is a process which occurs in waterlogged soils with low oxygen content. Iron and manganese compounds are reduced, giving rise to soil horizons with characteristic dark bluish grey colours, and allows considerable mobility of iron in solution. If there is fluctuation of the water table, alternation of oxidizing and reducing conditions can give rise to mottles of ferric ion pigment around roots and fissures. The mobility of the ferric is less than that of ferrous iron, with the result that the formation of such ferric mottles tends to be irreversible, and the mottles have a fairly high preservation potential. This process is known as hydromorphic gleying.

Gleying and hydromorphic mottling may be concentrated in the B horizon or affect the whole soil profile. They occur commonly in poorly developed soils in swampy alluvial areas, and are thus likely features of soils formed in depositional landforms.

Podsolization. This is a process in which iron, aluminium and organic matter are translocated downwards and concentrated in the B horizon of the soil. Transport takes place by eluviation and by the formation of organometallic complexes. In temperate regions soils thus produced are characterised by an albic A horizon and a spodic B horizon, which may become cemented to form an iron pan. In tropical areas, such soils contain less organic material, and iron oxides may accumulate as
haematite in the B horizon. In such soils silica is not transported downwards, and may become concentrated in the upper horizons of soil developed on quartz rich parent materials.

Latosols (Oxisols and Ultisols). Latosols are an informal group of soils (see Young 1976), used here to include all soils characterised by intense weathering and alteration involving the loss of all but the most insoluble soil materials, leaving a soil in which the majority of the material consists of kaolinite, haematite and quartz. As quartz is leached from the upper horizon of such soils, palaeosols of this type should be geochemically distinct from podzolic palaeosols.
Sand body 3

Complex laterally accreted sand body at this horizon in S face (very poor exposure)

Sand body 2

Sand body 1

Fig. 98

Fig. 39

Fig. 46

Figs. 55, 57

Fig. 59

Fig. 51

CHESTERTON QUARRY
COMPOSITE SECTION - EAST FACES 1977
ENCLOSURE 2
KIBLESTONE BOREHOLE
CORED SEQUENCE OF ETRURIA FORMATION
BASE c.20m ABOVE BASSEY MINE COAL

Depths in metres are as recorded by driller. The initial (hundreds) figure has been omitted.

ENCLOSURE 3
HALESOWEN FORMATION

BASE ETRURIA FORMATION

Fig. 110

ALLOTMENT No 1 BOREHOLE
CORED SEQUENCE OF COMPLETE ETRURIA FORMATION
For stratigraphy see Fig. 186
Depths as recorded by driller. The initial (hundreds) figure has been omitted.

ENCLOSURE 4
BASE OF HALESWEN FORMATION

PLAYGROUND No. 8 BOREHOLE
CORED SEQUENCE OF COMPLETE ETRURIA FORMATION
 Depths from surface

ENCLOSURE 5
Palaeosol developed on upper part of conglomerate body.

P3/4 stack

Fig. 54
BOREHOLE 10
4 - 18.80 m.

BOREHOLE 6
7.40 - 27 m.

BOREHOLE 3
7.50 - 34 m.

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ROSEMARY HILL QUARRY
COMPOSITE SECTION, SOUTHERN AREA,
FROM BOREHOLES NOS. 3, 6, & 10
ENCLOSURE 8
BASE OF NEWCASTLE FORMATION

KEELE QUARRY, MADELEY HEATH
COMPOSITE SECTION, 1976
ENCLOSURE 9