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OBSERVATIONS OF COAL CLEAT IN BRITISH COALFIELDS

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Introduction

This technical report presents the observations made during a study into cleat and joint directions, largely in the Pennine Basin. Field work was carried out under the BGS Research and Development programme in 1991-1992. Interpretation of these observations will be made elsewhere.

Cleat is the term widely in use to describe joints in coals. It is generally developed perpendicular to the bedding and there is normally one dominant set, known as the main cleat and a subsidiary, more or less perpendicular, set known as the back or butt cleat. Other sets may be developed in places, particularly in strongly faulted areas (see Figures 1, 2 and 3). Cleat is developed in all bright coals, including coalified allochthonous plant fragments and reworked clasts.

The study into coal cleat was formulated during the BGS regional mapping programme in the Yorkshire coalfield when the consistency of cleat azimuths was evident in several opencast coal sites. It is increasingly becoming clear that coal cleat development took place at an early stage of burial and diagenesis (see for example Gayer, 1992) whereas joints in adjacent strata formed later. Thus, variation between cleat and joint azimuths is potentially an important indicator of changes in palaeostress field.

The main area of interest for the study is the Yorkshire, Derbyshire and Nottinghamshire coalfield where 16 opencast sites, 4 collieries and one large exposure were visited. Observations were made also in four other areas: the Lancaster Fells area and Ingleton coalfield, where Namurian and Westphalian coals have recently been mapped by BGS in the survey of the Lancaster district (1:50 000 geological sheet 59) (Brandon, 1992; Ellison, 1991a; 1991b), and opencast coal sites in the North Staffordshire, Warwickshire and Cumbria coalfields. Coal cleat azimuths were recorded at all localities and at most of them joint azimuths in rocks adjacent to coal seams are recorded.

Each locality in this report has a reference number, and National Grid Reference for the central part of the locality. They are given below along with a list of horizons in which cleat and joints were measured. Joint azimuths are mainly shown on rose diagrams with 10° segments. At least 20 cleat fractures were measured in each seam; they are plotted as rose diagrams with the mean azimuth shown as a broad line extending beyond the rose.

The regional structure, drawn largely of the evidence of mine plans, and an indication of the stratigraphical position of coals is given for each site.

Cleat and Joint measurements

In most opencast coal sites cleat azimuths were measured on the top bedding surface of coal seams exposed prior to excavation of the coal. Surfaces of tens to hundreds of square metres were exposed allowing an excellent appreciation of local variation in cleat orientation and its relationship to joints and faults. In all cases it was found to be remarkably constant in direction in any one seam at a site. In view of this the number of measurements made was considered less important than gaining an indication of the range of direction in any one seam. Thus the cleat azimuth rose diagrams show the mean and range of cleat azimuths. Back cleat is illustrated where it is particularly well developed.

The azimuths of systematic joints in sandstones and siltstones are generally more variable in direction than cleat. They were measured as far as possible on two perpendicular quarry faces. Only the major, sub vertical, open, systematic joints are recorded and are plotted on rose diagrams with 10° segments..

The measurement of cleat underground was carried out by determining the angle between the cleat strike direction and a face line or heading centre line and then plotting the azimuth on a mine plan. The accuracy of these azimuths is likely to be +/-10° compared to compass bearings taken at surface outcrops.

Locality details

1. Skelton Opencast Coal Site (Figure 1)

The main structure at the locality is a 200m-wide graben in which the beds are gently folded into parallel periclines oblique to the graben, interpreted as having formed in response to sinistral shear along the graben bounding faults. There is evidence for compression in the form of tight chevron folds close against the northern boundary of the graben.

The dominant cleat trend is 135 to 140° but in the south-west of the site it trends at about 150°. Where both trends are present they result in an anastomosing pattern that leads to the coal fracturing into pencil-shaped pieces.

The Third Brown Metal Coal has a well-developed systematic joint set perpendicular to the cleat. It penetrates through the entire seam and into the measures above and below. A weak back cleat in a middle parting of bright coal has a consistent 045 to 055° trend and is much closer spaced than the joints.

2. Lawns Lane Opencast Coal Site (Figure 2)

The Stanley Main Coal is split into three leaves at this site, the lowest formerly mined by the pillar and stall method. Cleat azimuths were measured in the top of the top leaf.

3. Lofthouse Colliery Opencast Coal Site (Figure 2)

The site lies within 200m of the Morley Campsall fault belt. Cleat, in the Kent's Thick Coal is consistent at 140 to 142°. In the overlying siltstones and sandstones a conjugate joint set is developed. Its bisectrix, parallel to the maximum horizontal stress trajectory, lies at about 145°.

4. St John's Opencast Coal Site (Figure 3)

This site lies within the Morley Campsall fault belt, mostly in a NW-SE trending graben bounded on its northern side by a major, near vertical fault, the North Newlands Fault. It has a dip slip displacement of about 120 m down to the south. Close against this fault the Sharlston coals are almost vertical and are in places deformed in tight upright folds. The fault dip plane is near vertical and the fold axes orientation indicates that they formed during dextral transpression along the fault.

5. Ackton Opencast Coal Site (Figures 3 and 4)

The site lies south of the E-W trending North Featherstone Fault, a normal fault with an arcuate surface trace on the north side of the Morley Campsall fault belt. The structure of the Ackton area is particularly well known from mine plans in the Silkstone, Haigh Moor and Warren House Coals. The pattern of faults seen in the Opencast Coal Site is similar to that in the coals underground. This pattern is also observed on a smaller scale in association with a minor fault in the Sharlston Yard Coal (Figure 3). The general pattern of faulting can be accounted for by sinistral transtension along the North Featherstone Fault, resulting in the closely spaced normal faults at an acute angle to it. These NE-SW faults are near vertical and with a rapidly changing throw. Some are locally reverse faults, others pass into broad, open anticlinal flexures caused by dextral transcurrent motion along the North Featherstone Fault.

There is a variation of 16° anticlockwise between the main cleat azimuth of the Sharlston Yard and Sharlston Low coals, with an anticlockwise rotation from the older to younger coal. This is a significant variation when compared to the regional cleat orientation and may be caused by a change in direction of the maximum compressive stress during coalification.

6. Cornwall Opencast Coal Site (Figure 3)

This is a geologically simple site bounded on its eastern side by the NE trending Fairy Hill Fault with a normal throw down to the south. It is one of a dominant set developed in the northern part of the Yorkshire coalfield, largely to the north of the Don monocline. The coal cleat azimuth varies by 8°, rotating anticlockwise from the older Houghton Thin to younger Sharlston Yard coal.

8. Tinsley Opencast Coal Site (Figure 6)

This locality, along with localities 9 and 10, occupy similar structural situations. The beds dip at 3 to 9° on the west flank of a broad NW-SE syncline, and the Spa Fault cuts the axial plane trace. The cleat and joint directions at the three sites are closely similar.

Cleat in the Beamshaw Coal is unmineralised and generally has 2 to 3 mm spacing; a poor backcleat is developed. Cleat in the Winter and Meltonfield coals is colinear with the Beamshaw. An acute angle, up to 10°, between two cleat sets in all the coals results in pencil-shaped fragments of coal.

Systematic joints in the beds above the Winter Coal are rotated clockwise with respect to the cleat (mean 126.5°). The mudstone roof joints trend 140°, and in siltstones 5 m above the coal the joints trend 155°. A similar rotation is observed between the Beamshaw Coal and overlying strata: cleat 125°, mudstone roof 130°, overlying medium-grained sandstone 143°. The systematic joints in mudstone and sandstone are confined to individual beds and terminate abruptly at the bed boundaries.

9. Waverley East Opencast Coal Site (Figure 6)

The six coals examined at this site have cleat azimuths in the range 128° to 136° but there is no systematic variation. Joints in the sandstone above the First Thin Coal are arranged in two roughly perpendicular sets, a NW-SE trending set being oriented about 10° clockwise from the cleat in the underlying coal. In comparison, joints in the mudstone roof of the Winter Coal are dominated by a NE-SW set. The coal cleat terminates abruptly at the top of the Winter Coal and does not pass into the mudstone.

10. Pithouse Opencast Coal Site (Figure 6)

Systematic joints were measured in siltstone beds between the Barnsley and High Hazels coals exposed in a 10 m-deep cutting made for a drainage ditch. The dominant joint trend is 10 to 15° clockwise from the mean cleat of the High Hazels Coal. Another joint set in the sandstone, with dips between about 80° and 50°, strikes NNW-SSE.

Several tree stumps were observed protruding up to 0.1 m above the general bedding surface of the High Hazels Coal, their rims formed of coal and the former bole filled with siltstone. The cleat azimuth in their rims, formerly the tree bark, varies between 120° and 138°, and is generally divergent from that in the associated coal seam which is 127.5°. The cleat dip in the rim is near vertical where it is parallel to the cleat in the adjacent coal, but at points of greatest divergence from the regional azimuth the cleat in the rim dips about 80°. This deflection is interpreted as being caused by a NE-SW compression during coalification.

The Kilnhurst Coal in particular has a well developed back cleat whose azimuth is parallel to a small normal fault seen in the opencast site.

11. Slayey Opencast Coal Site (Figure 7)

Systematic joints and cleat occur in the Clowne Coal. The joint azimuth is rotated 10° clockwise from the main cleat. The joints continue through the coal and the overlying mudstone but the cleat terminates at the bed boundary. The joints have the same trend as minor normal faults in the coal and a larger fault with 20 m throw at the site boundary. This evidence indicates that the joints and faults post-date the cleat formation.

13. Dixon Opencast Coal Site (Figure 7)

There is a small variation in the cleat between coals in this site. The mean cleat azimuth range is 121.3° to 129.75° and the overall range of all cleat is 117 to 134° but there is no stratigraphical trend to the variation. Nevertheless it may indicate small shifts in the stress field between successive cycles of deposition. This is most likely to be related to movement associated with the contemporary Brimmington Anticline. There is no detailed evidence for the influence on sedimentation of this tectonic activity but Smith et al. (1967) reported regional thickness and/or facies changes related to the Brimmington structure, in particular in the Silkstone, Yard, Threequarters, Cockleshell, Piper and Deep Hard coals.

Joints in the Brampton High Coal and the overlying mudstone are more or less colinear with the cleat but none continues across the bed boundary.

The Mickley Cannel Coal does not have a cleat but there is a well developed joint set about 10° clockwise from the Mickley Thick Coal cleat.

14. Ryefield Opencast Coal Site (Figure 8)

The cleat in the Deep Hard and Piper coals and the systematic joints in the sandstone between the coals have significantly different orientations.

15. Godkin Opencast Coal Site (Figure 8)

There is an 8° clockwise rotation in cleat between the First Ell and Fourth Waterloo coals which are separated by only about 10 m of siltstones and sandstones (Frost and others, 1979). Joints in siltstone and sandstone beds are not in general colinear with the coal cleat. Those in a blocky siltstone between the Forth Waterloo and First Ell coals have a different trend to those in the succeeding cycle.

The cleat in a thin, dirty coal within a mudstone seatearth between the Forth Waterloo and Ell coals trends 110°, compared to 120 to 130° in the main seams. The difference may be accounted for by rotational movement along the numerous listric shear surfaces that are characteristic of seatearth palaeosols. This conclusion lends support to the idea that the cleat was established prior to the listric fractures that formed during preferential compaction between the clay minerals and the organic remains in the soil (for a review see Besley and Fielding, 1989).

17. Cossall Opencast Coal Site (Figure 9)

Directly overlying the Piper Coal is a hard, blocky, medium grey mudstone with well developed joints rotated 25° clockwise from the cleat in the Piper Coal. The joints pass into the coal where they are spaced at 0.3 m or more, compared to the cleat frequency of 10 mm or less.

20. Sudeley Opencast Coal Site (Figure 10)

The site is in the Warwickshire Coalfield. The most interesting observation here is the variation by 20° of the cleat between the Low Main Coal of early Westphalian B age, and the Lower Half Yard Coal, of late Westphalian B age. This variation, the greatest seen between coals within a site, is thought to be associated with contemporary tectonic activity (Fulton and Williams, 1988) which led to mild inversion in an area over the NNE-SSW trending Arley Fault (Bridge, 1992). The main evidence for tectonic activity is the line of seam splits in the Warwickshire Thick Coal, the removal by erosion of the Etruria Marl from a tract centred on the Arley Fault, and the regional thinning of the Westphalian A and B strata.

22. Chapeltown Opencast Coal Site (Figure 11)

The main seam exposed here is shown on the six-inches to one mile geological sheet as the Parkgate Coal. An allochthonous coal lens in the siltstones below the Parkgate Coal has cleat parallel to that in the main seam. There is a well developed orthogonal joint set in the siltstone and fine-grained sandstones above and below the coal.

23. Duckmanton Railway Cutting (Figure 7)

This section includes the type site of the Vanderbeckei Marine Band and the strata of Westphalian B (Duckmantian) age. The coal cleat in three seams is colinear but differs from the systematic joint azimuths in the associated sandstones and siltstones. The principal joint sets trend NW-SE and roughly E-W.

The mudstones overlying the Sitwell Coal show good examples of joints terminating at the boundary with overlying sandstone.

23a. Sharlston Colliery (Figures 3 and 5)

Cleat azimuths were taken in underground workings in the Stanley Main Coal south of the Morley Campsall fault belt. Additional measurements have been provided by British Coal Deep Mines. In combination with readings in the same coal south of the fault belt (see Locality 24), the influence of the fault on cleat development can be considered.

In the Stanley Main Coal the mean cleat reading is 151.2° (n = 42) and there is a variable backcleat with an azimuth at 90° to 60° to the main cleat.

24. Prince of Wales Colliery (Figures 3 and 5)

Workings in the Stanley Main Coal extend as far south as the Morley Campsall fault belt. Cleat measurements were taken as near to the fault belt as possible in order to assess its influence on cleat orientation.

The variation in cleat azimuth across the fault appears to be significant. The mean azimuth on the north side is 131.6° compared with 151.2° on the south side. A similar variation is seen between the Lofthouse Opencast Coal Site (Locality 3) and Lawns Lane Opencast Coal Site (Locality 2).

25. Riccall Colliery (Figure 12)

Riccall Colliery lies in the Selby Coalfield. Cleat azimuths were taken in several headings in the Barnsley Coal workings. Additional readings were provided by British Coal Deep Mines. Sub-horizontal to sub-vertical shears occur in the coal, many with sub-horizontal slickenslide fractures which in the more extreme cases give rise to a structure comparable to cone-in-cone.

An interesting feature is the rotation of cleat and the development of a conjugate set in certain areas. This is interpreted as the result of transpressive shear being concentrated along east-west fracture belts in the coalfield.

26. Askern Colliery (Figure 13)

Workings in the Warren House Coal close to the bottom of the shaft at the Colliery were examined and the readings combined with information from British Coal mine plans. Together, these sources give a geographical spread of data astride the Morley Campsall fault belt. Of significance is the more northerly trend of cleat to the south of the fault, a feature recognised in Wilcockson and Goossens (1958) at Askern and in the Hatfield-Thorne area.

Cleats close to a fault plane within the Morley Campsall fault belt are a conjugate pair of equal development, whereas elsewhere a more usual strong main cleat and only a relatively weak, orthogonal back cleat is developed. Transpressive shear along the faults during cleat development is though to be the cause. At the "Barnsley slit", close to the pit bottom, the seatearth underlying the Warren House Coal contains a 23 mm-thick lens of coal inclined at about 40° to the horizontal due to compactional shearing in the seatearth. The cleat in the coal is perpendicular to the contact with the surrounding seatearth, presumably having been rotated during the shearing event. This observation suggest that the cleat formation post-dates the shearing which in turn is generally regarded as taking place during compaction of the Coal Measures (see also observations at Locality 15).

27. Ingleton Area (Figure 14)

Coal cleat azimuths have been recorded during the recent survey of the Lancaster district. The coals are Namurian and Westphalian in age and lie in the Craven Basin which is bounded to the north by the Craven Fault. The most interesting aspect of the findings is that the cleat in the Westphalian coal nearest to the Craven Fault has a northerly trend, compared to the WSW regional trend. Although there are few data, it can be speculated that this is due to the proximity of the Craven Fault and its influence on the regional stress field during coalification, in a similar manner to the Morley Campsall fault belt in West Yorkshire.

The National Grid references and geological horizon of localities where cleat has been measured and the formation within which the coal occurs are listed below; the letters refer to the sites shown on Figure 14.

a)	Ward's Stone Sandstone	[SD 535 632]
b)	Ward's Stone Sandstone	[SD 576 669]
c)	Accerhill Sandstone (Clintsfield coals)	[SD 6260 7019]
d)	Accerhill Sandstone (Clintsfield coals)	[SD 6582 6515]
e)	Ward's Stone Sandstone	[SD 6213 6618]
f)	Four Feet Coal: Coal Measures	[SD 6712 7180]
g)	?Ten Feet Coal: Coal Measures	[SD 700 716]
h)	Accerhill Sandstone (Clintsfield coals)	[SD 6240 7209; SD 6264 7202]
i)	un-named coal: Coal Measures	[SD 6433 7206]
j)	?Blaeberry Coal: Coal Measures	[SD 6766 7130]
k)	un-named coal: Coal Measures	[SD 6810 7081]
l)	un-named coal: Coal Measures	[SD 6480 7167]

Acknowledgements

The co-operation of British Coal Opencast and British Coal Deep Mines is gratefully acknowledged, in particular Steve Graham, Sam Cochrane and Guy Wilson assisted the planning and execution of the field work. Figures 1 to 14 were prepared by Graham Tuggey.

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Index of localities and units with joints and/or coal cleat azimuths recorded

1 Skelton Opencast Coal Site [SE 350 305]
Second Brown Metal Coal
Third Brown Metal Coal
Middleton Little Coal
Joints in sandstone above Middleton Main Coal Middleton Main Coal
Middleton Main Coal

2 Lawns Lane Opencast Coal Site [SE 318 247]
Stanley Main Coal (Top leaf)

3 Lofthouse Opencast Coal Site [SE 324 253]
Kent's Thick Coal
Siltstone and Sandstone above Kent's Thick Coal

4 St Johns Opencast Coal Site [SE 370 218]
Sharlston Yard Coal
Sharlston Yard Coal close against the Newlands (Morley Campsall) Fault
Sharlston Low Coal

5 Ackton Opencast Coal Site [SE 418 216]
Sharlton Yard Coal
Sharlston Low Coal
Joints in the Glass Houghton Rock
Faults in Sharlston coals at surface
Faults in Silkstone Coal; from mine plans
Faults in Haigh Moor Coal; from mine plans

6 Cornwall Opencast Coal Site [SE 448 236]
Houghton Thin Coal
Sharlston Yard Coal (bottom leaf)

8 Tinsley Opencast Coal Site [SK 408 890]
Joints in fine-grained sandstone above Meltonfield Coal
Joints in siltstone above Meltonfield Coal
Main joint in mudstone roof of Winter Coal
Main joint in siltstone 5m above Winter Coal
Beamshaw Coal
Winter Coal
Meltonfield Coal

9 Waverley Opencast Coal Site [SK 418 876]

Joints in mudstone above Winter Coal
High Hazels Coal
Winter Coal (Bottom leaf)
Winter Coal (Top leaf)
Two Foot Coal
Meftonfield Coal
First Thin Coal
Joints in sandstone above First Thin Coal

10 Pithouse Opencast Coal Site [SK 457 840]
High Hazels Coal
Kilnhurst Coal
Joints in sandstone above High Hazels Coal
Joints in siltstone between Barnsiey and High Hazels coals

11 Slayley Opencast Coal Site [SK 480 760]
Clowne Coal
Joints in Clowne Coal

13 Dixon Opencast Coal Site [SK 402 7481
Joints in Mickley Cannel Coal
Mickley Thick Coal
Tupton Roof (Cockleshell) Coal
Brampton High Coal
Three Quarter Coal
Joints in silty mudstone overlying Brampton High Coal

14 Ryefield Opencast Coal Site [SK 390 470]
Deep Hard Coal
Piper Coal
Joints in sandstone underlying Deep Hard Coal

15 Godkin Opencast Coal Site [SK 430 480]
First Ell Coal
Third Waterloo Coal
Fourth Waterloo Coal
Joints in siltstone and fine-grained sandstone overlying Fourth Waterloo Coal
Joints in siltstone between Waterloo and First Ell coals
Un-named coal between Fourth Waterloo and First Ell coals

17 Cossall Opencast Coal Site [SK 475 427]
Piper Coal
Deep Hard Coal

Joints in sandstone overlying Piper Coal
Joints in Piper Coal

20 Sudeley Opencast Coal Site [SP 355 894]
Lower Main Coal
Lower Half Yard Coal
Joints in sandstone overlying Two Yard Coal
Joints in sandstone overlying Lower Half Yard Coal

22 Chapeltown Opencast Coal Site [SK 363 960]
Joints in siltstone underlying ?Parkgate Coal
?Parkgate Coal
Joints in siltstone and fine-grained sandstone overlying ?Parkgate Coal

23 Duckmanton railway cutting [SK 424 704]
Joints in mudstone overlying Sitwell Coal
Joints in fine-grained sandstone and siltstone underlying Sitwell Coal
Thin un-named coal overlying Vanderbeckei Marine Band
Chavery Coal
Sitwell Coal

23a Sharlston Colliery [SE 415 185]
Stanley Main Coal

24 Prince of Wales Colliery [SE 450 420]
Stanley Main Coal

25 Riccall Colliery [SE 630 370]
Barnsley Coal

26 Askern colliery [SE 558 139]
Barnsley Coal south of Morley Campsall Fault

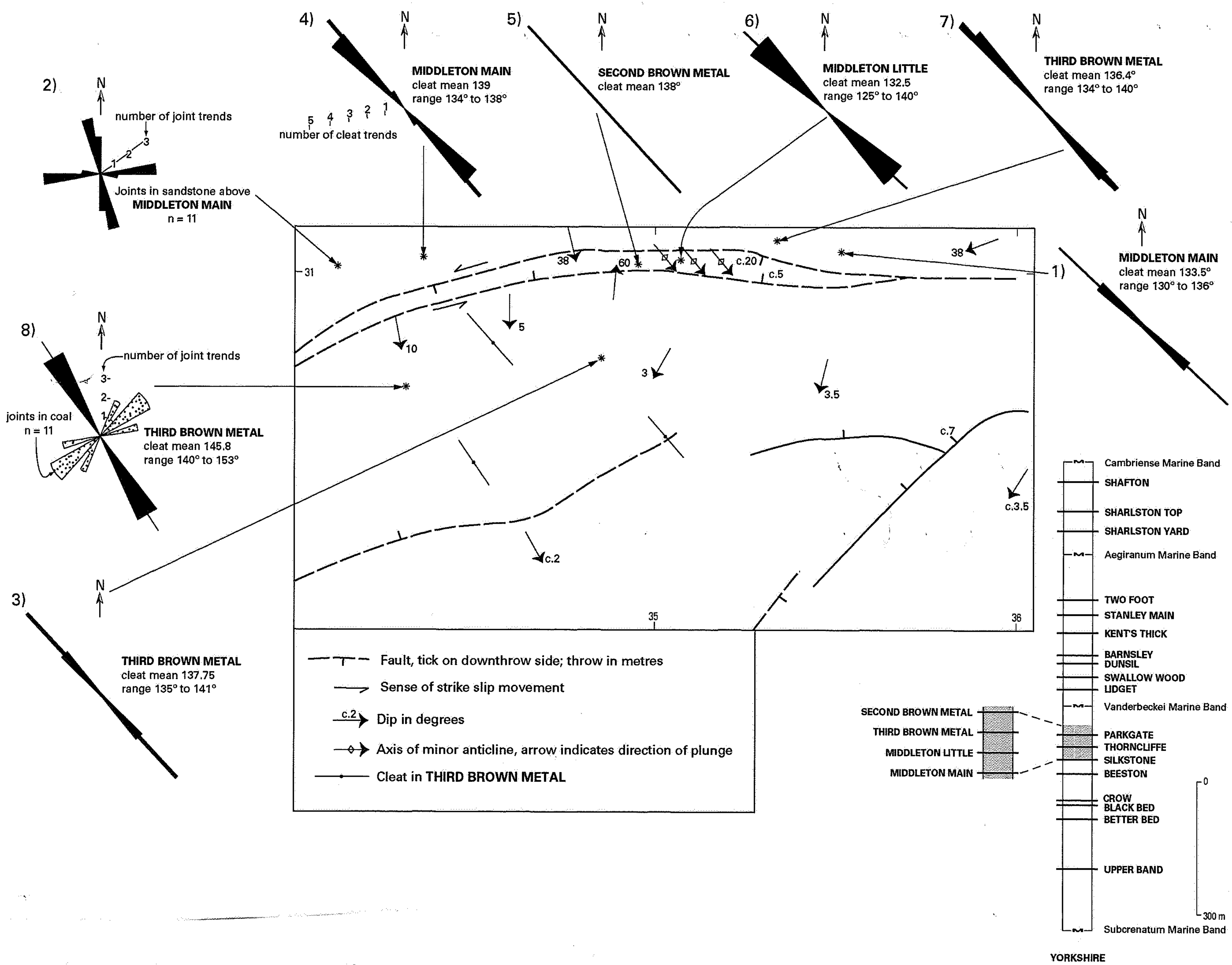


Figure 1 Skelton Opencast Site

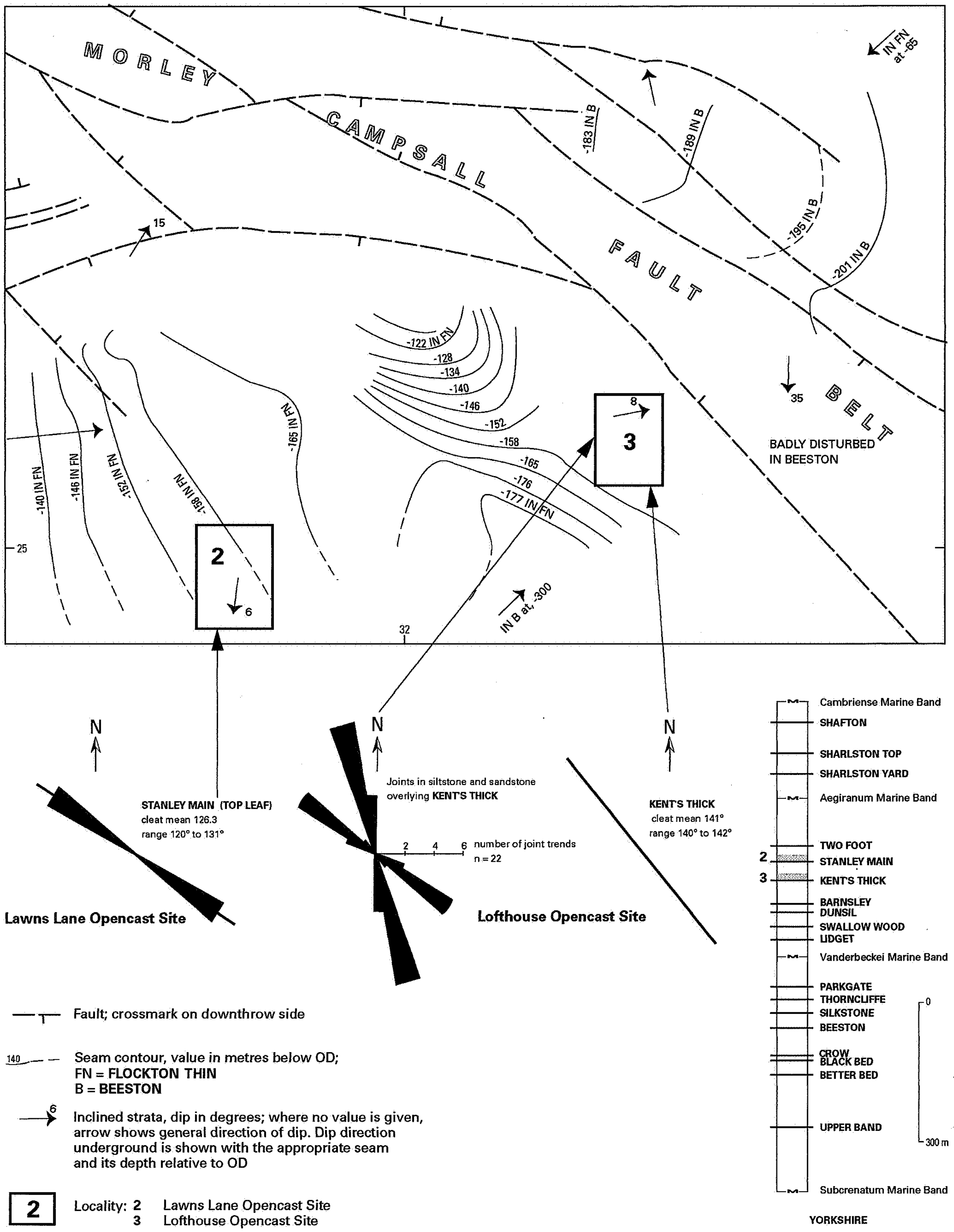


Figure 2 Lawns Lane and Lofthouse Opencast sites

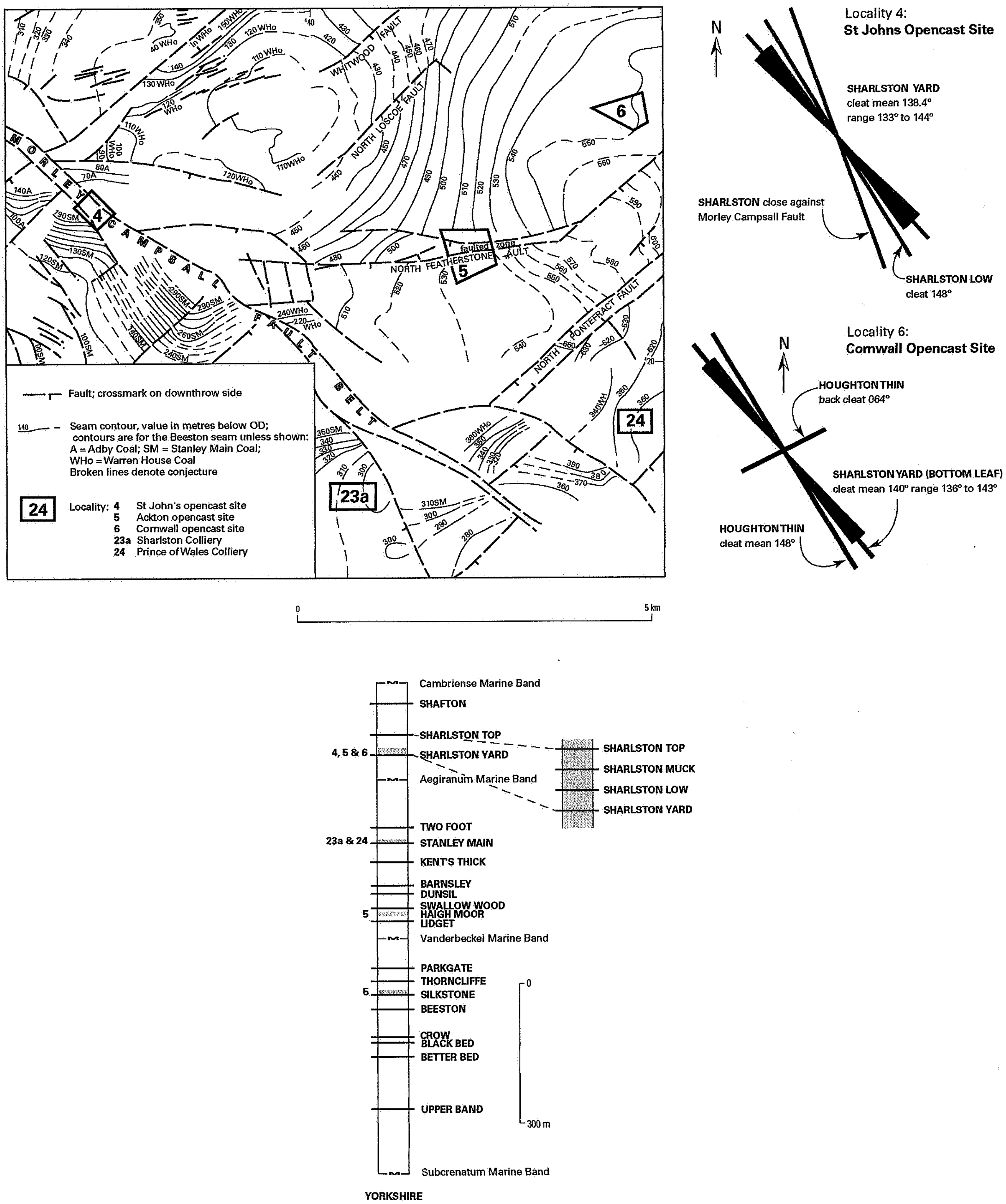
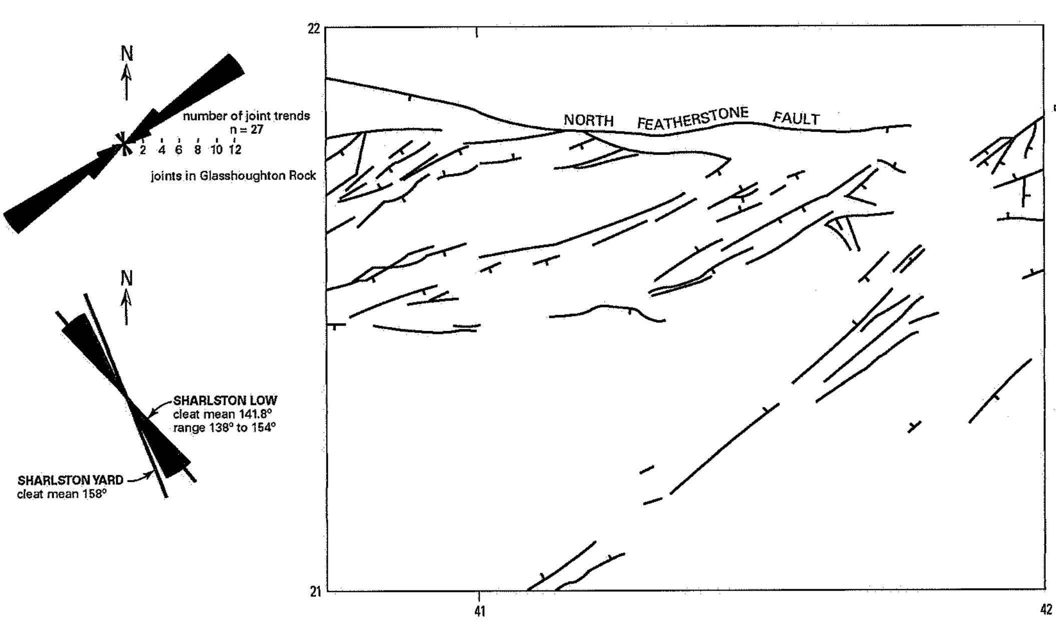
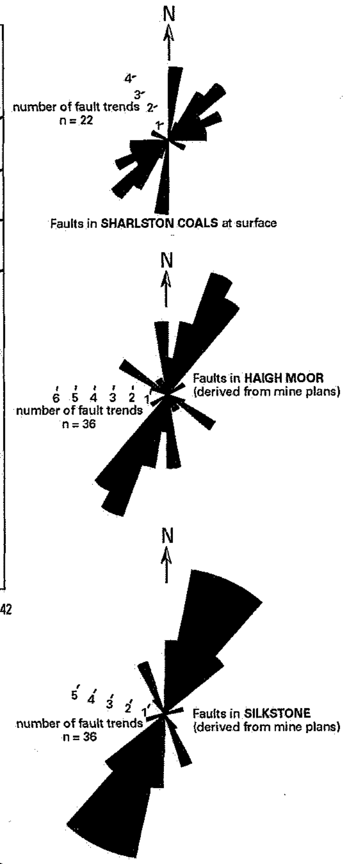
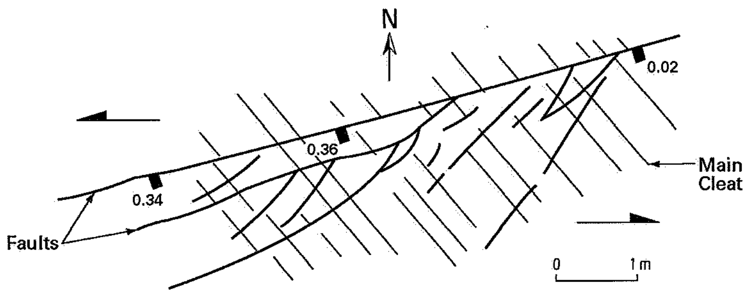


Figure 3 St John's, Ackton and Cornwall Opencast sites and Sharlston and Prince of Wales collieries





Fault pattern at the surface and at depth in the vicinity of the Ackton Opencast Site (locality 5)



Detail of a relationship of a fault to main cleat in Ackton Opencast Site; arrows indicate sense of transtensional movement along North Featherstone Fault; fault throw shown in metres

Figure 4 Detail at Ackton Opencast site

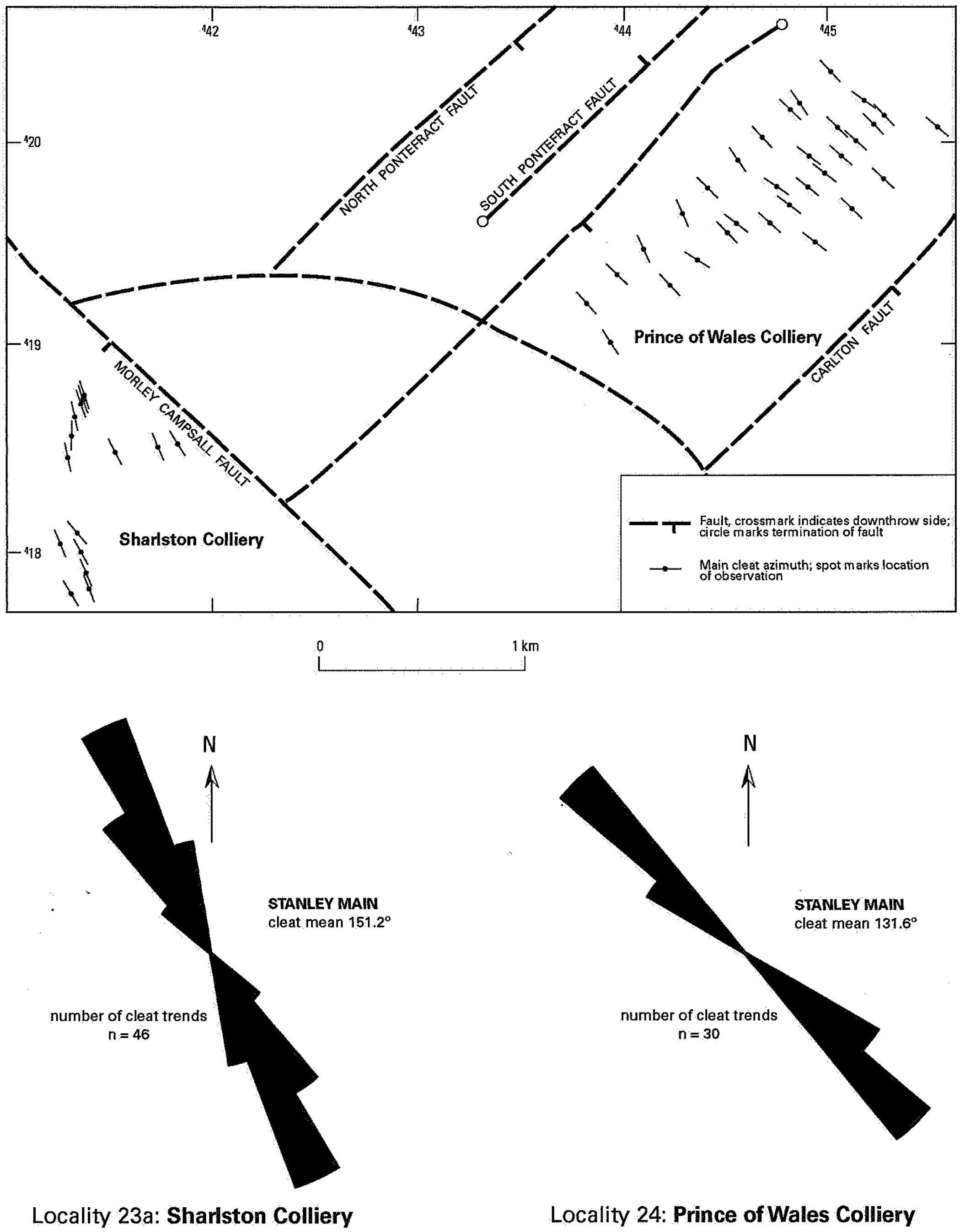


Figure 5 Comparison of cleat in the Stanley Main coal at Sharlston and Prince of Wales collieries

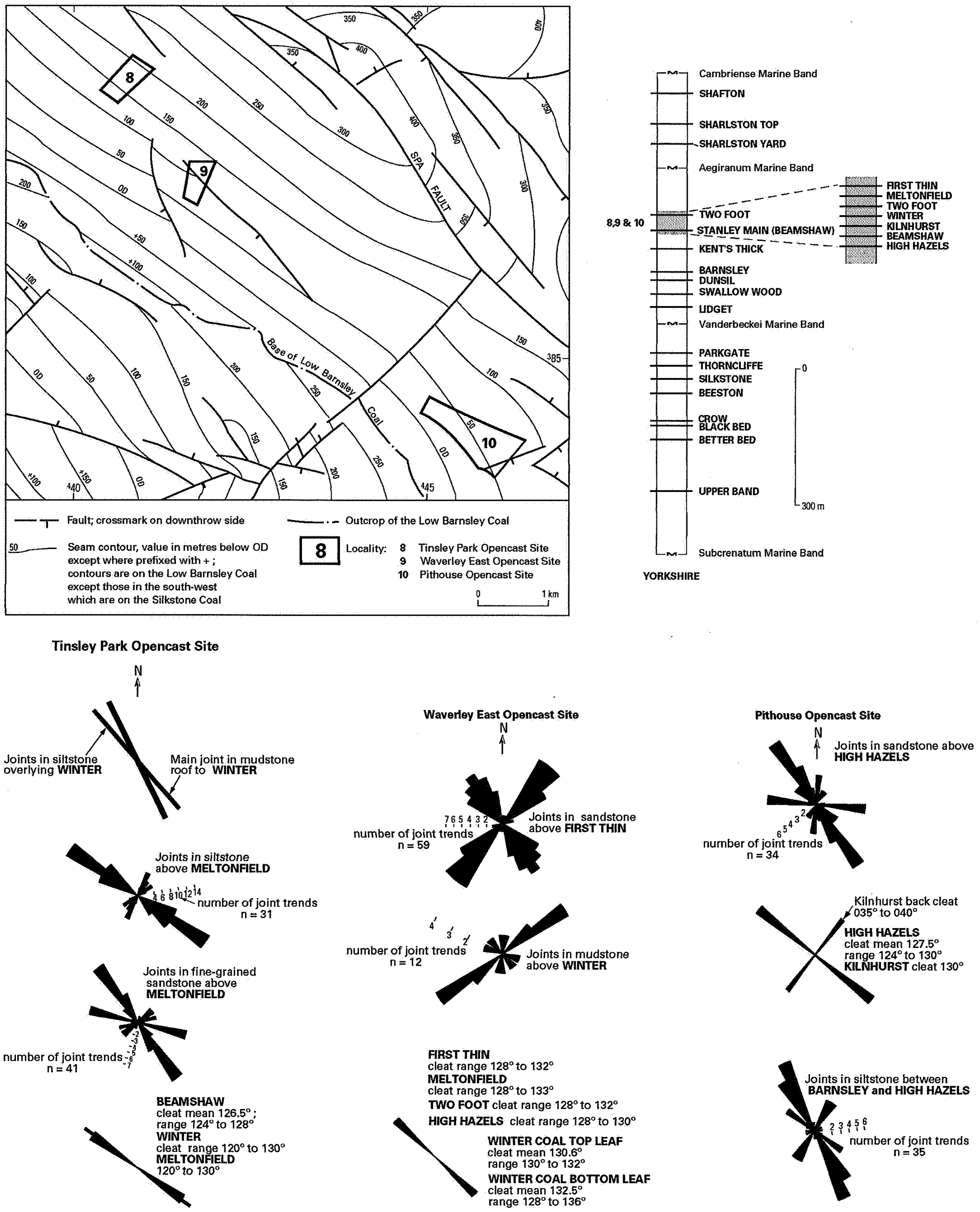


Figure 6 Tinsley Park, Waverley East and Pithouse Opencast sites

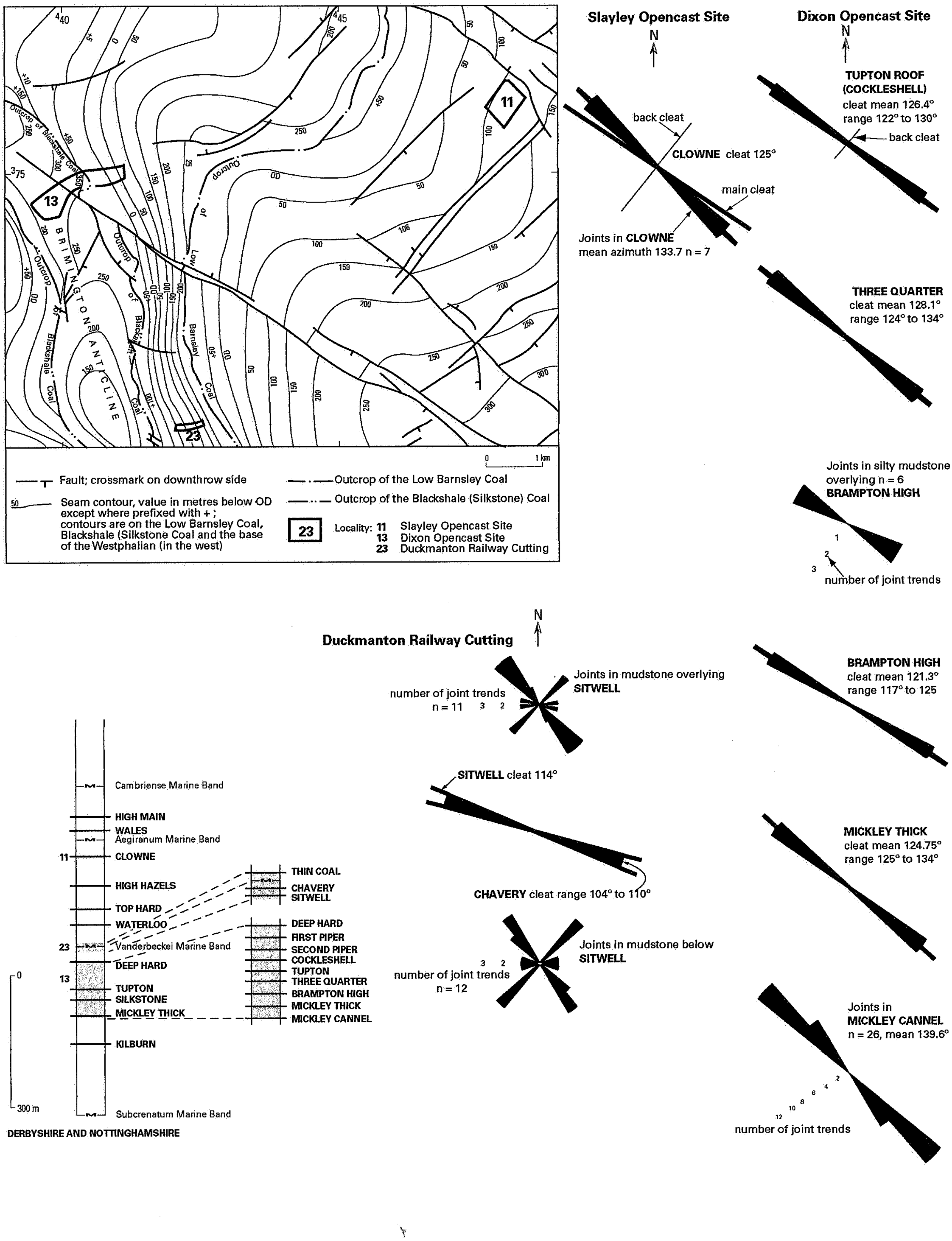


Figure 7 Slayley and Dixon Opencast sites and Duckmanton Railway Cutting

Fig 7 layout 3rd proof | Drawn by ...

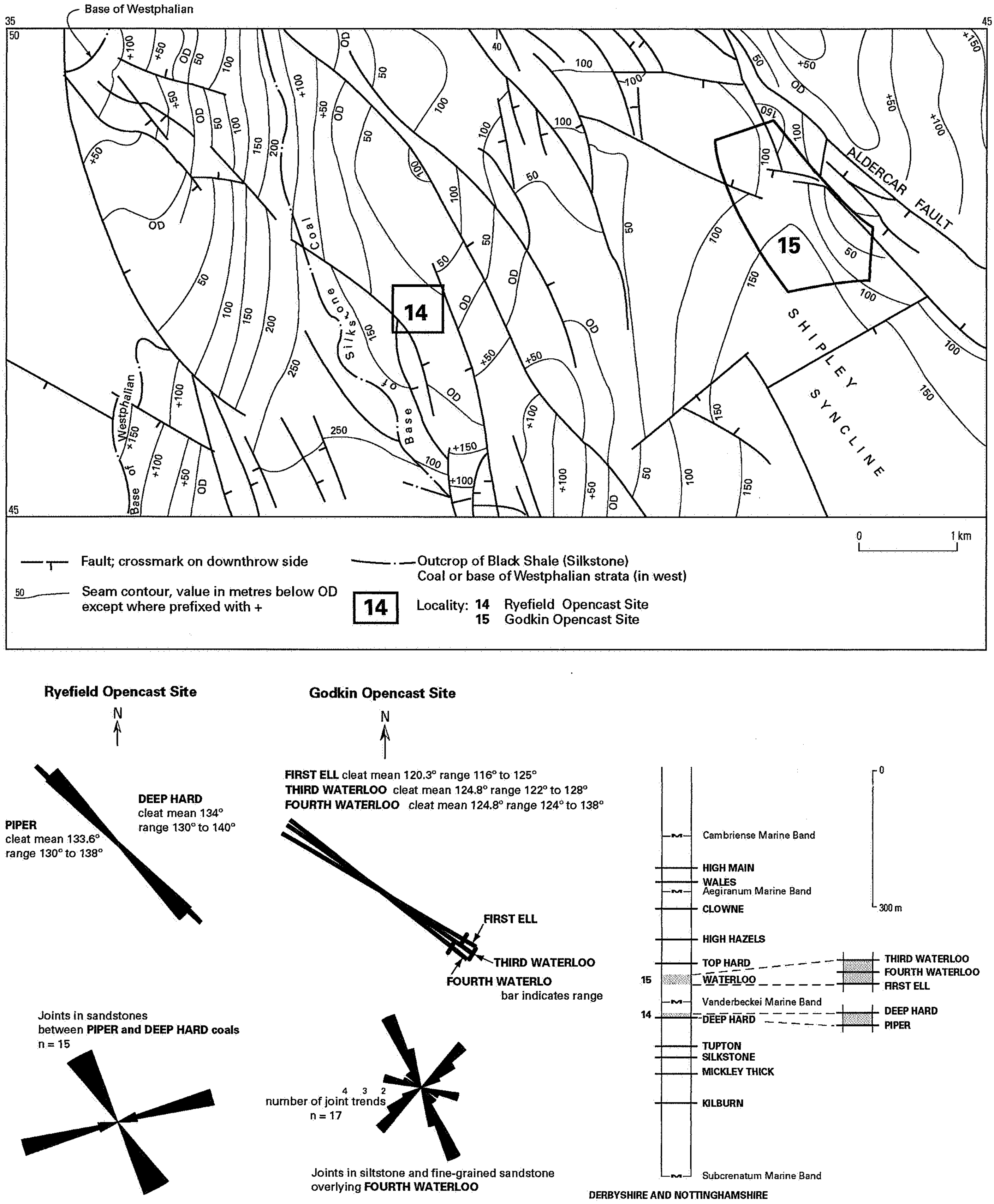
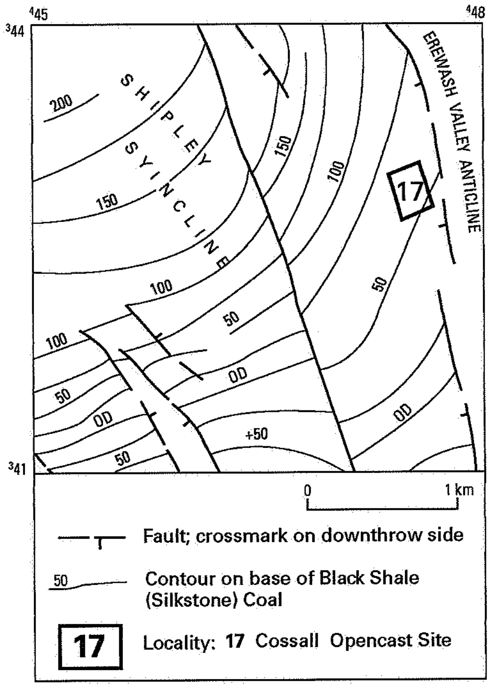
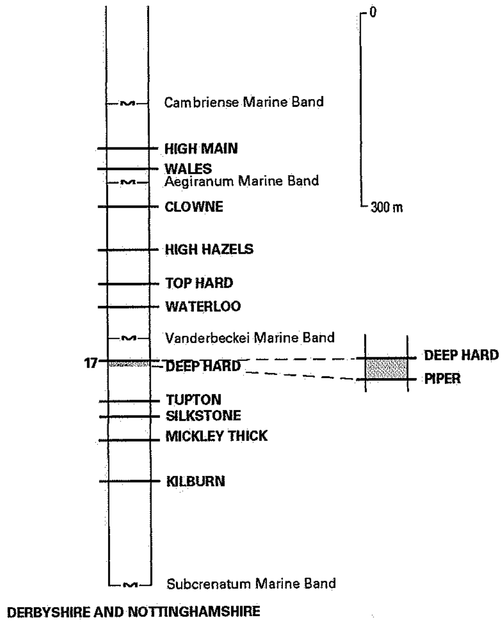


Figure 8 Ryefield and Godkin Opencast sites





Cossall Opencast Site

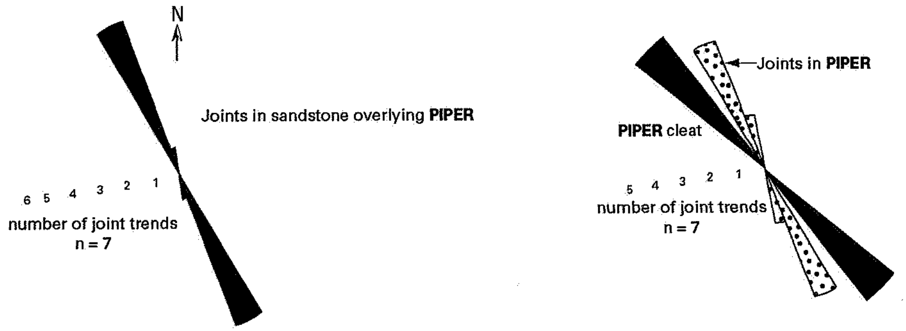


Figure 9 Cossall Opencast site

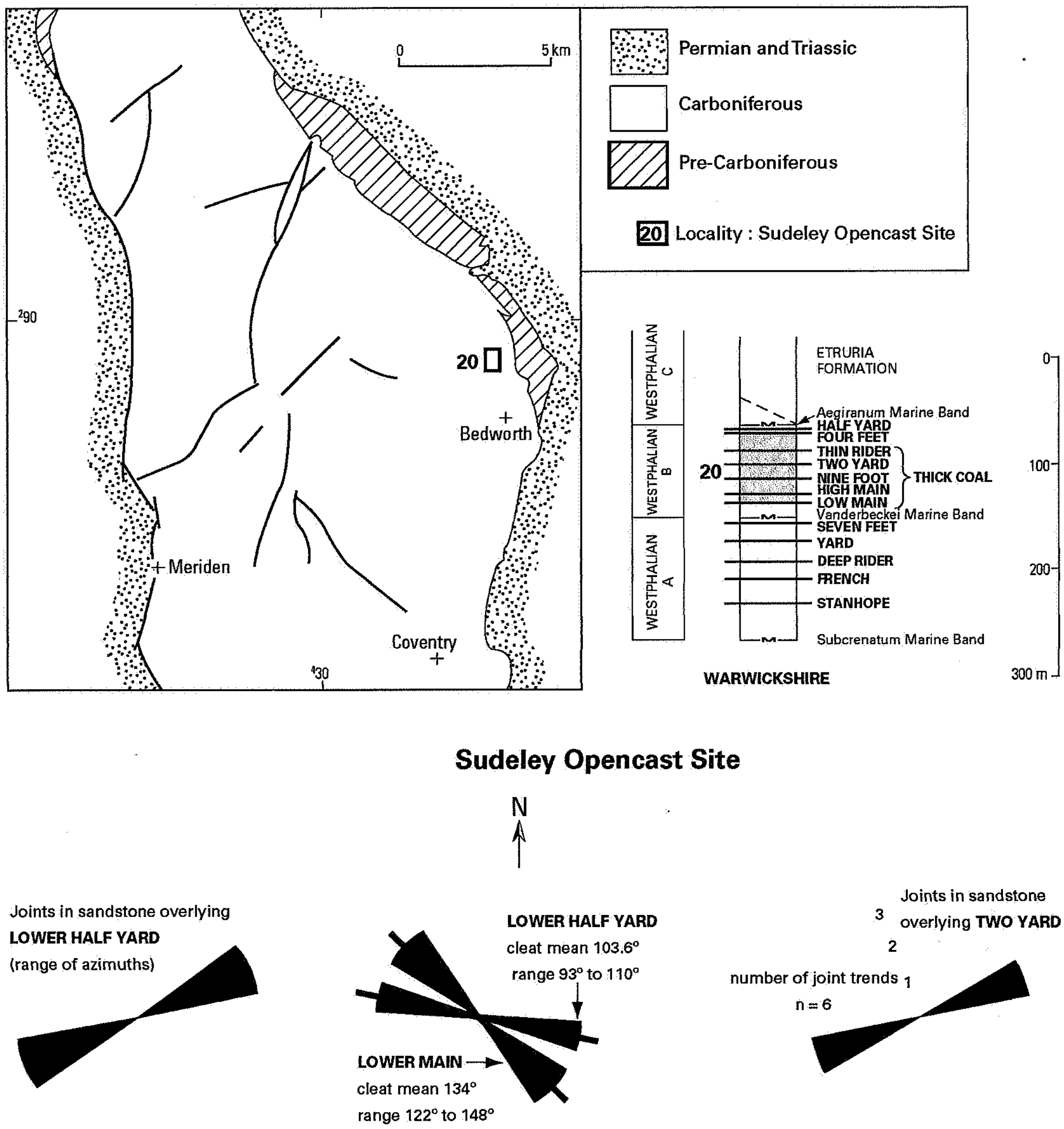


Figure 10 Sudeley Opencast site

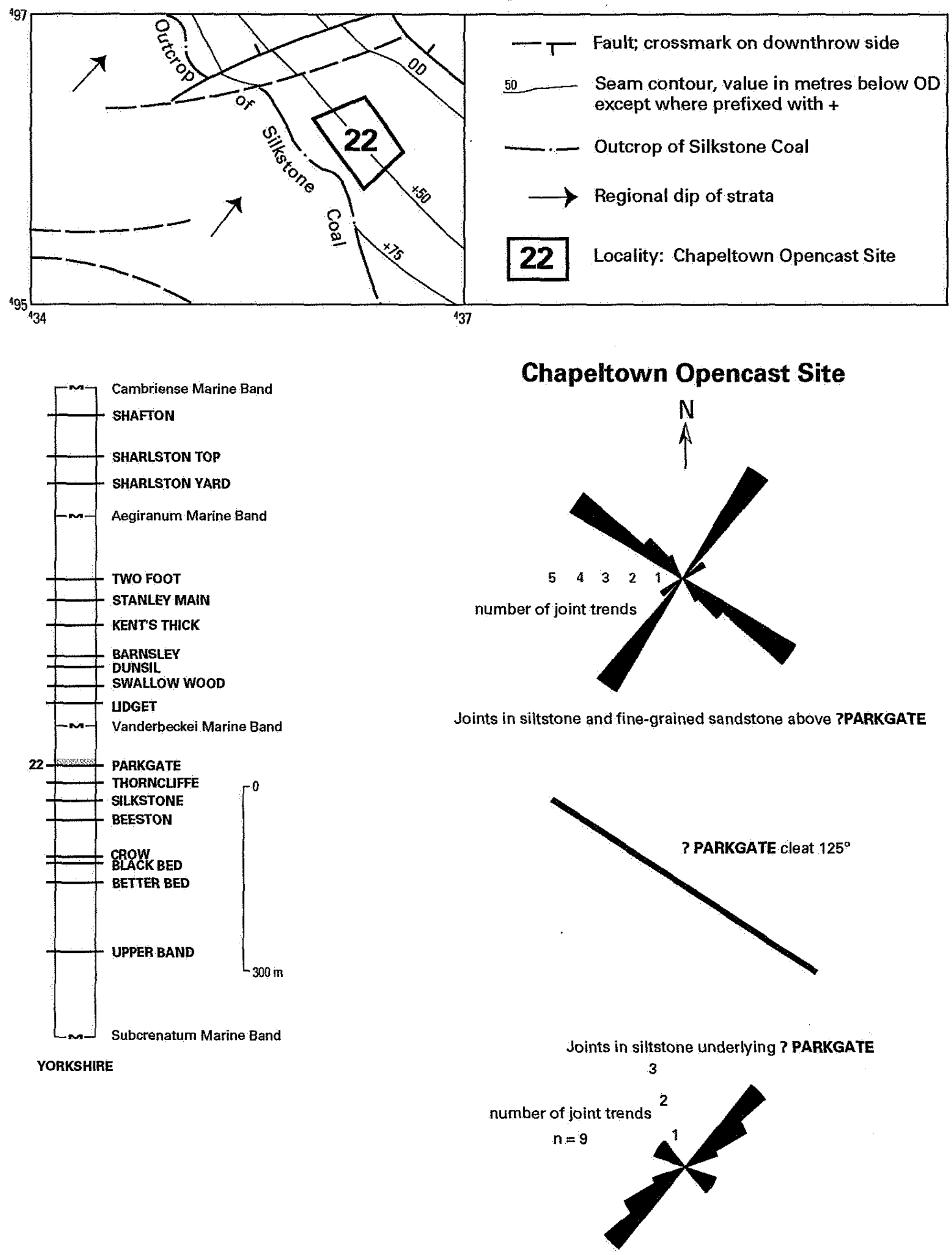


Figure 11 Chapeltown Opencast site

Fig 11 layout 3rd proof | Drawn by:G. J.Tuggey

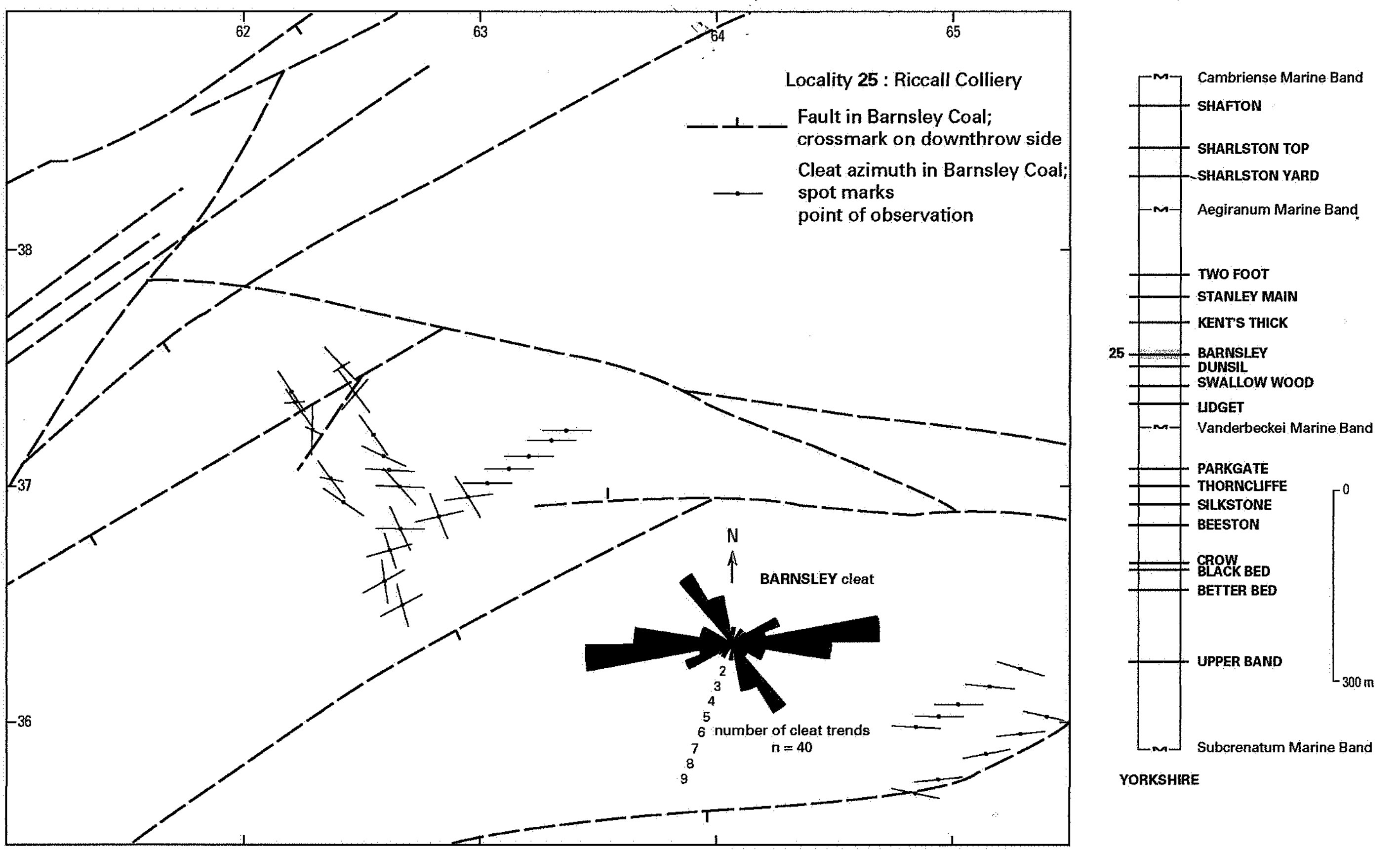


Figure 12 Riccall Colliery

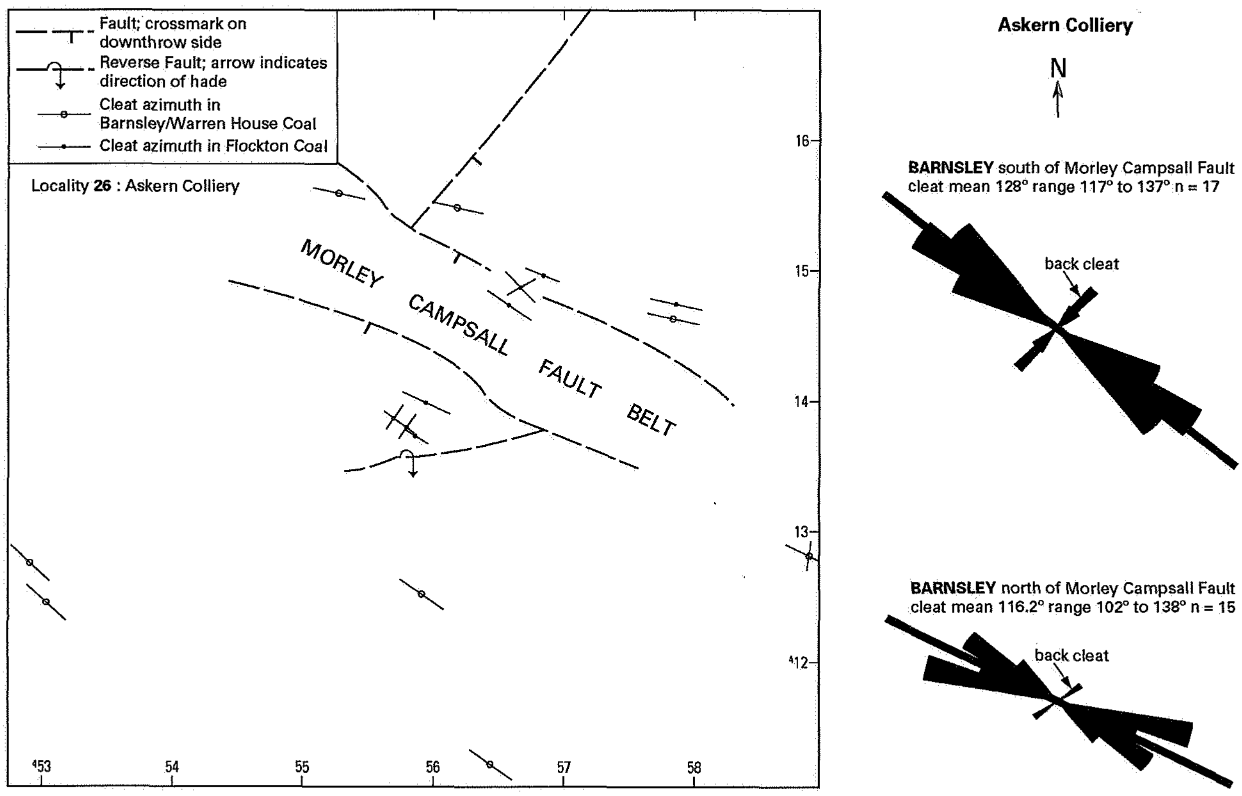


Figure 13 Askern Colliery

Lancaster Fells and Ingleton Coalfield

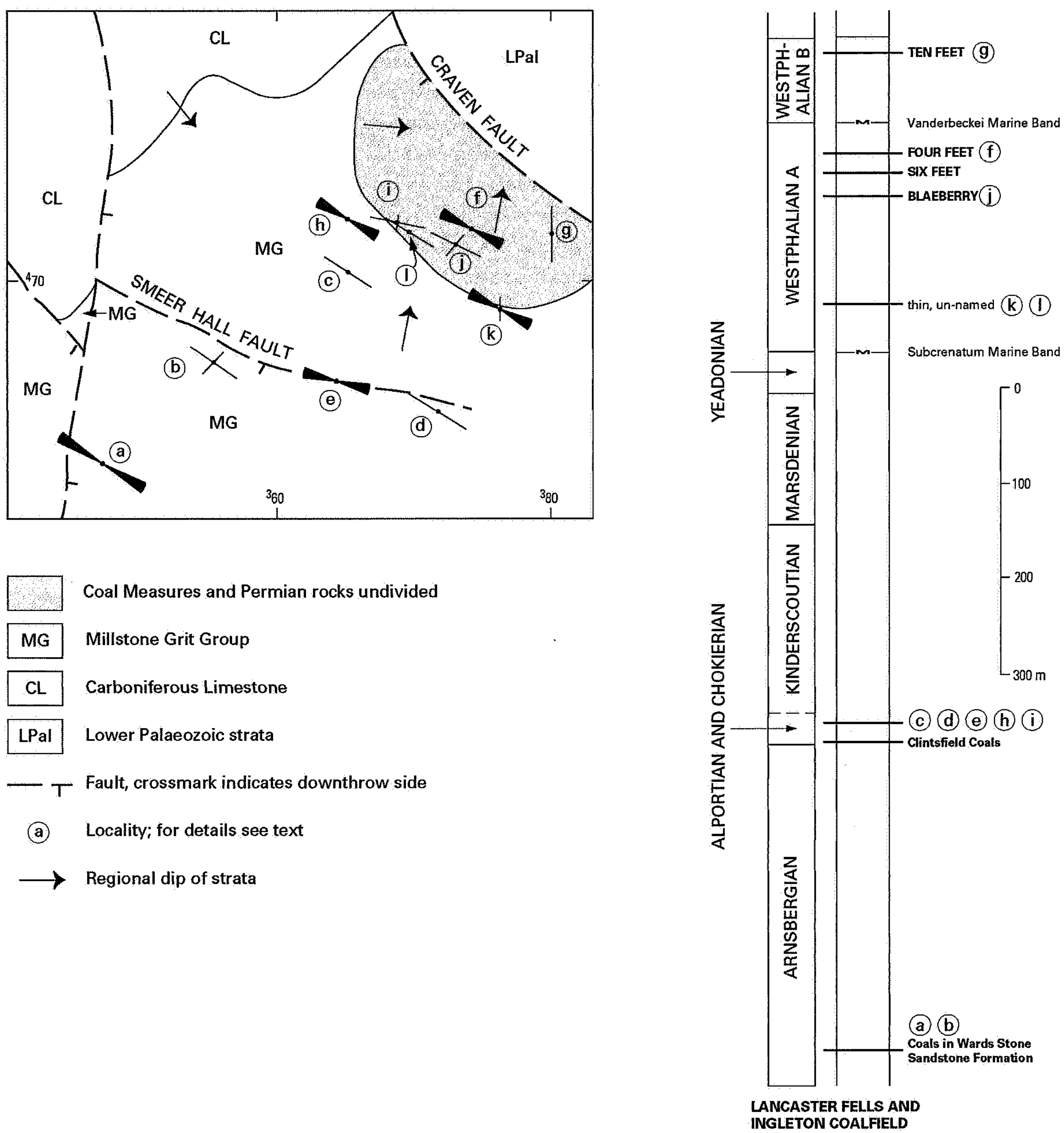


Figure 14 The Lancaster Fells and Ingleton Coalfield

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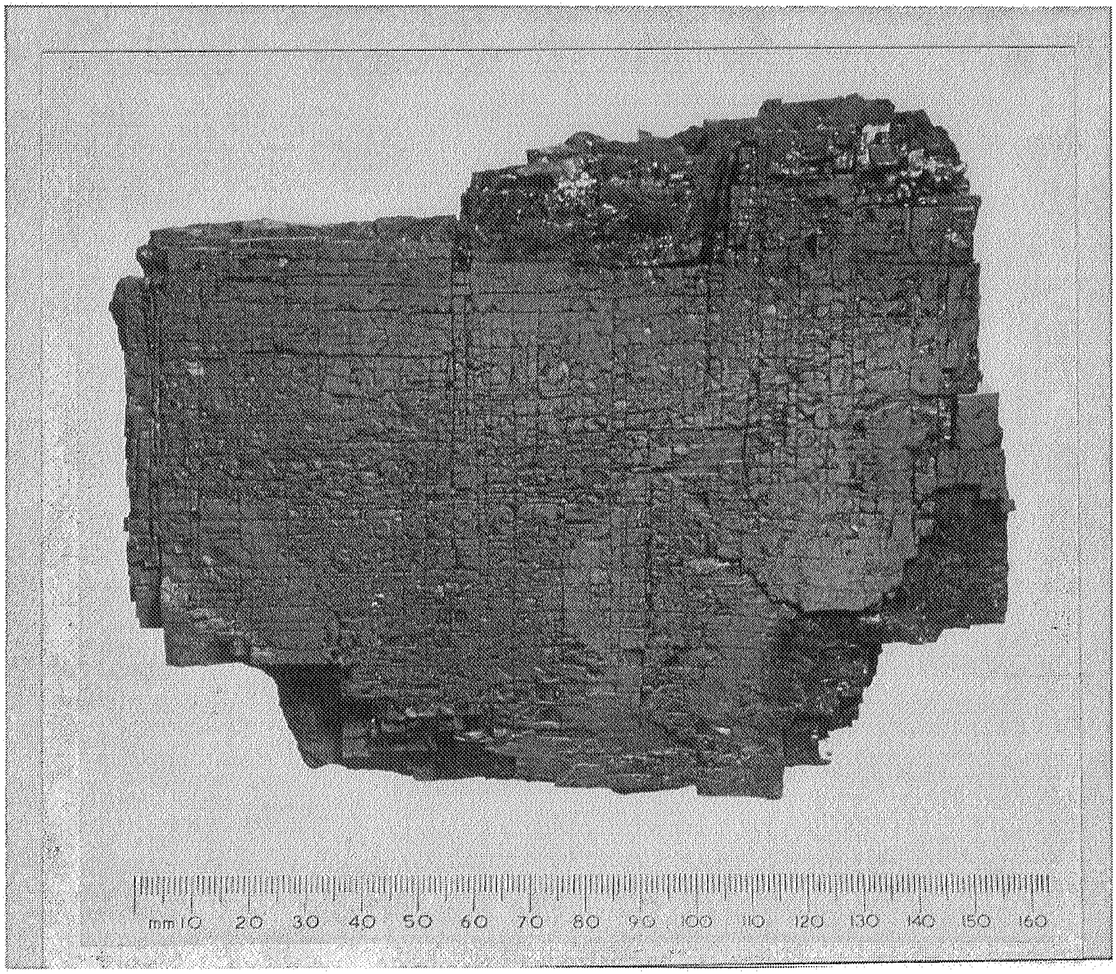

Figure 15. Meltonfield Coal from Tinsley Park Opencast site showing two orthogonal well developed cleat sets

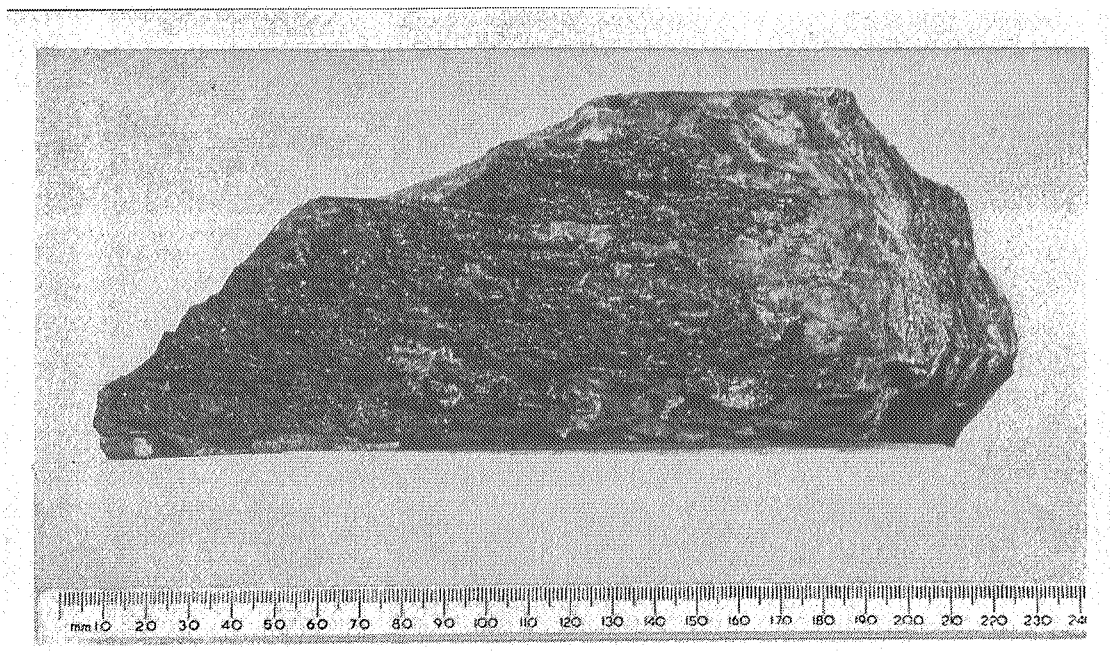

Figure 18. Dixon Opencast site: well developed cleat in the Mickley Thick Coal immediately overlying the Mickley Cannel Coal which has no cleat but joints (the edges of the sample) at an acute angle to the cleat

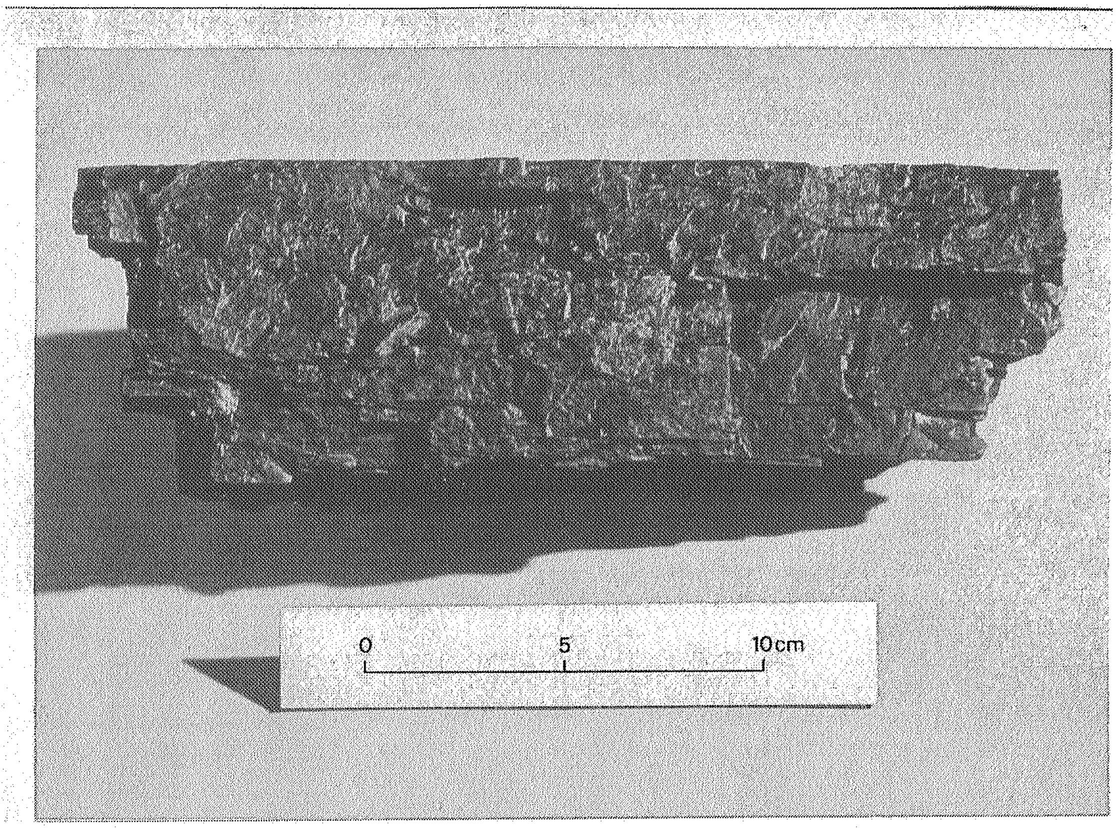

Figure 16. Two Foot Coal from Tinsley Park Opencast site showing one main cleat and a minor, orthogonal, back cleat

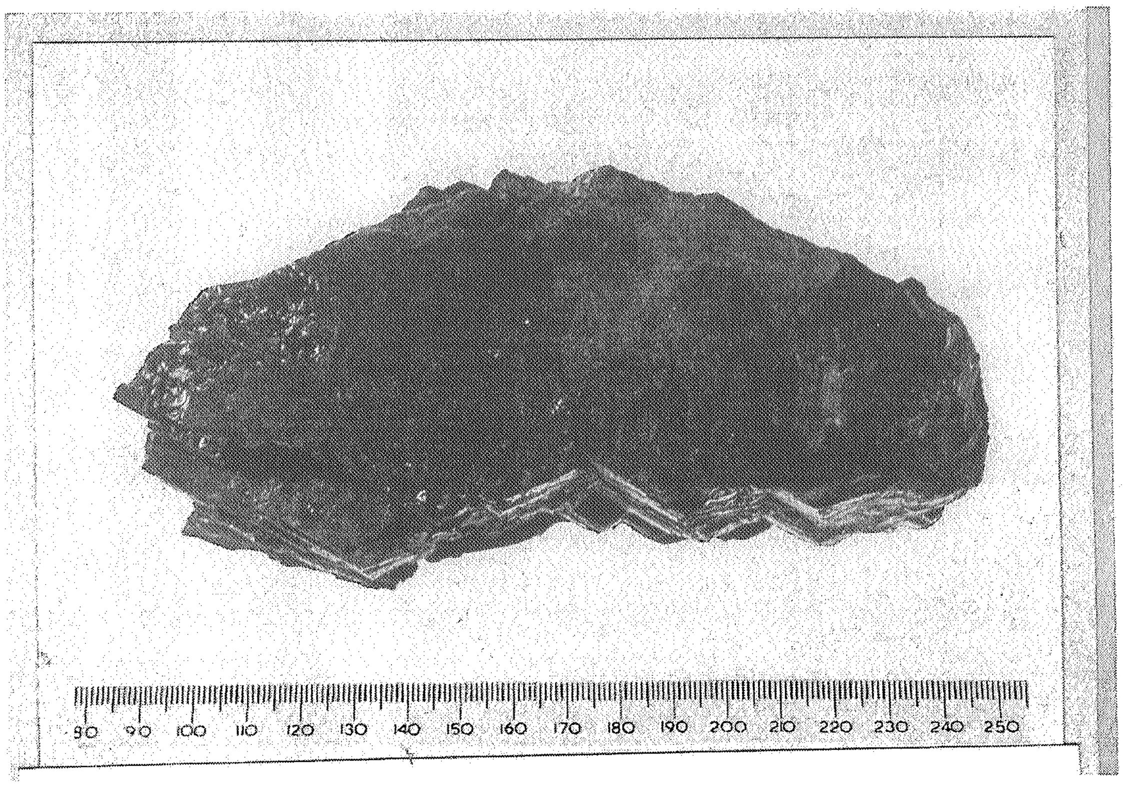

Figure 17. Deep Coal from the Ingleton Coalfield showing a two conjugate cleat sets

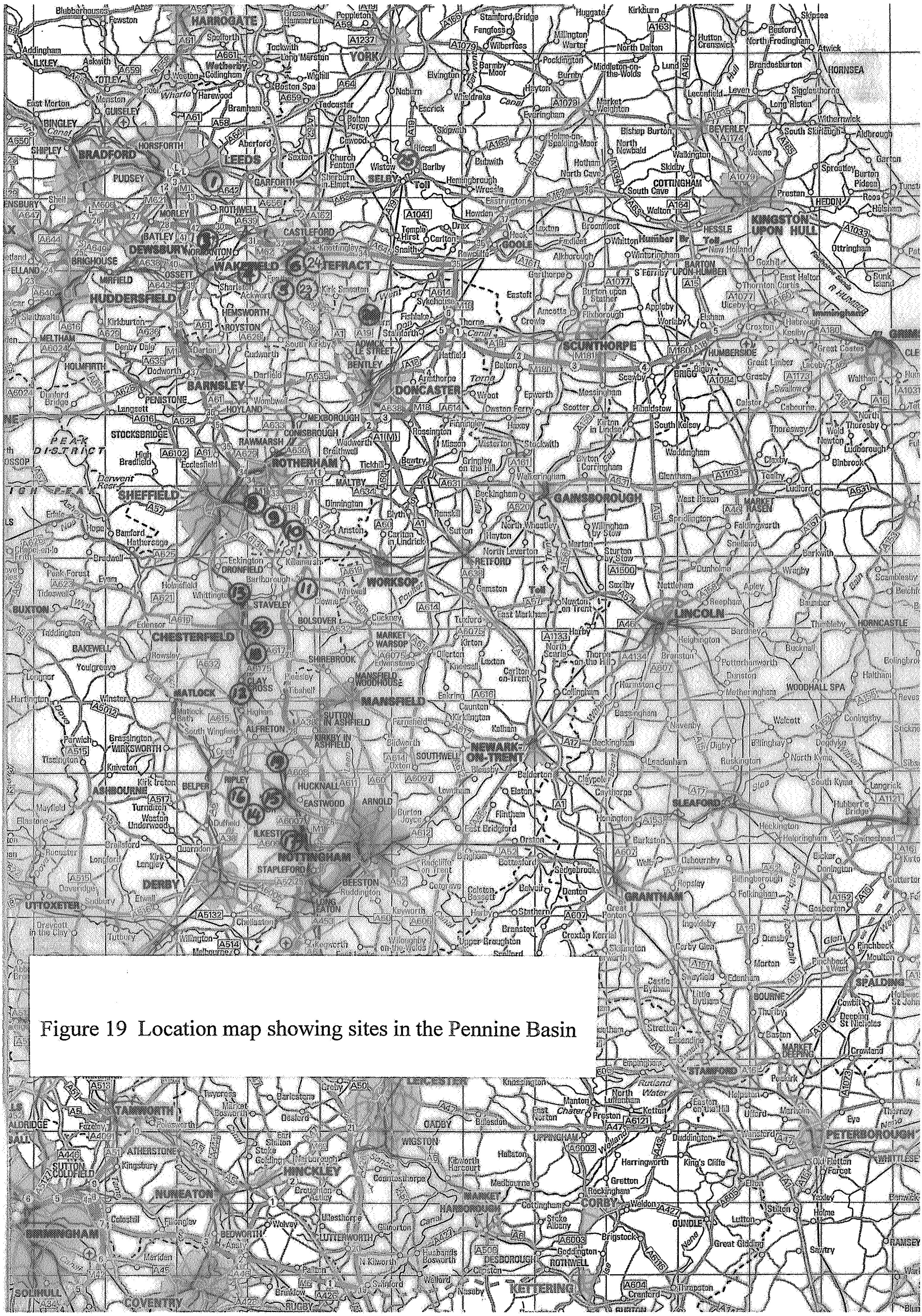

Figure 19 Location map showing sites in the Pennine Basin