British
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NATURAL ENVIRONMENT RESEARCH COUNCIL

Geology of the north Wirral district

Integrated Geoscience Surveys (Southern Britain)
Internal Report WA/98/66

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E Hough

Key words

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1 Introduction

This report describes the geology of 1:10 000 sheets SJ 28 NW (Hoylake), SJ 28 NE (Arrowe Park), SJ 29 SW (Meols), SJ 29 SE (Leasowe), SJ 38 NW (Tranmere) and SJ 39 SW (New Brighton) (Figure 1). This area (hereafter referred to as the 'north Wirral district') was first geologically surveyed on the 'old' county series by W W Smyth and E Hull in 1850-56, and revised by C De Rance in 1884-86. The district was subsequently remapped on the 'new' county series at the 1:10 560-scale by W C Simmons in 1912 and 1913. This survey was published on County Sheets Cheshire 6 SE, 7 (all sheets), 12 (all sheets) and 13 (all sheets). The one-inch Geological Sheet 96 (Liverpool) and the accompanying sheet memoir (Wedd *et al.*) were published in 1923. The area was resurveyed on the 1:10 000-scale by E Hough in 1998.

The north Wirral district is predominantly urbanized, with the town of Birkenhead the main centre of business. The suburban fringe of Birkenhead, which includes the small towns of Prenton, Greasby and Moreton, stretches inland from the Mersey to Arrowe Park; the expanding urban area of Wallasey lies at the north-east of the Wirral Peninsula. The west of the district covers the commuter towns of Hoylake and West Kirby, as well as small patches of arable farmland and public parkland.

The seaward-limits of the north Wirral district are delineated by the Dee Estuary to the west, the Mersey Estuary to the east and southern part of Liverpool bay to the north. The area described within this report is bounded to the south by OS National Grid northing $^{3}85$, which is from Caldy on the Dee Estuary, through Landican to New Ferry on the Mersey.

The low-lying areas of the district are for the most part covered by a variable thickness of till of late Devensian age. During the Holocene, wide spreads of Tidal Flat Deposits were laid down, associated with the proto-Fender and Birket water courses. More recently, Blown Sand in the form of sheets and dunes has accumulated on the coastal fringes at Hoylake, Leasowe and New Brighton. Drift-free terrain within the north Wirral district is essentially restricted to high ground, including Thurstaston and Caldy Hills in the west, Arrowe Hill in the central part, and Prenton Hill, Bidston Hill and parts of New Brighton in the east.

The north Wirral district is underlain at rockhead by ?Permian to Triassic strata of the Sherwood Sandstone and Mercia Mudstone Groups. Generally, strata dip gently to the east-north-east. Parts of the sequence are repeated by a series of normal faults which trend broadly north-south through the central and western parts of the Wirral Peninsula.

Several important deep boreholes prove full or partial sequences of the Permo-Triassic formations, and are referred to throughout this report. Their locations are shown in Figure 2, with details of the main boreholes given in Appendix 1, and graphic logs in Appendix 2.

Logged sections of the main outcrops referred to in the text are given in Appendix 3.

All National Grid references in this report lie within 100 km quadrant SJ. They are given as eight figure numbers within square brackets. All borehole depths are given in metres below ground level.

Surface sections are described from base to top; graphic logs are right-way-up. Those prefixed by '⊙' are provings from borehole records; only selected borehole provings are given.

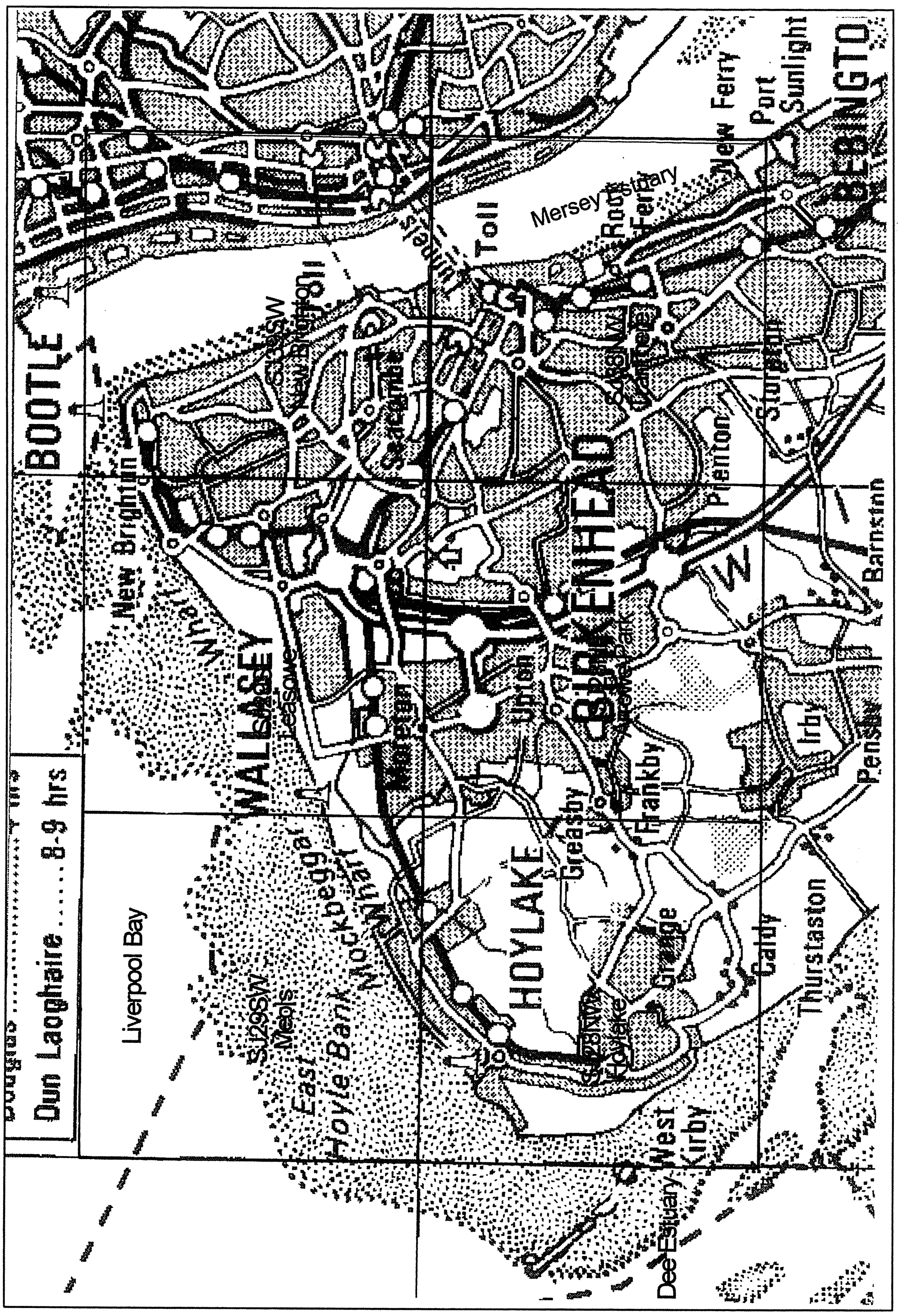


Figure 1: Map of the north Wirral district showing component 1:10 000 National Grid sheets.

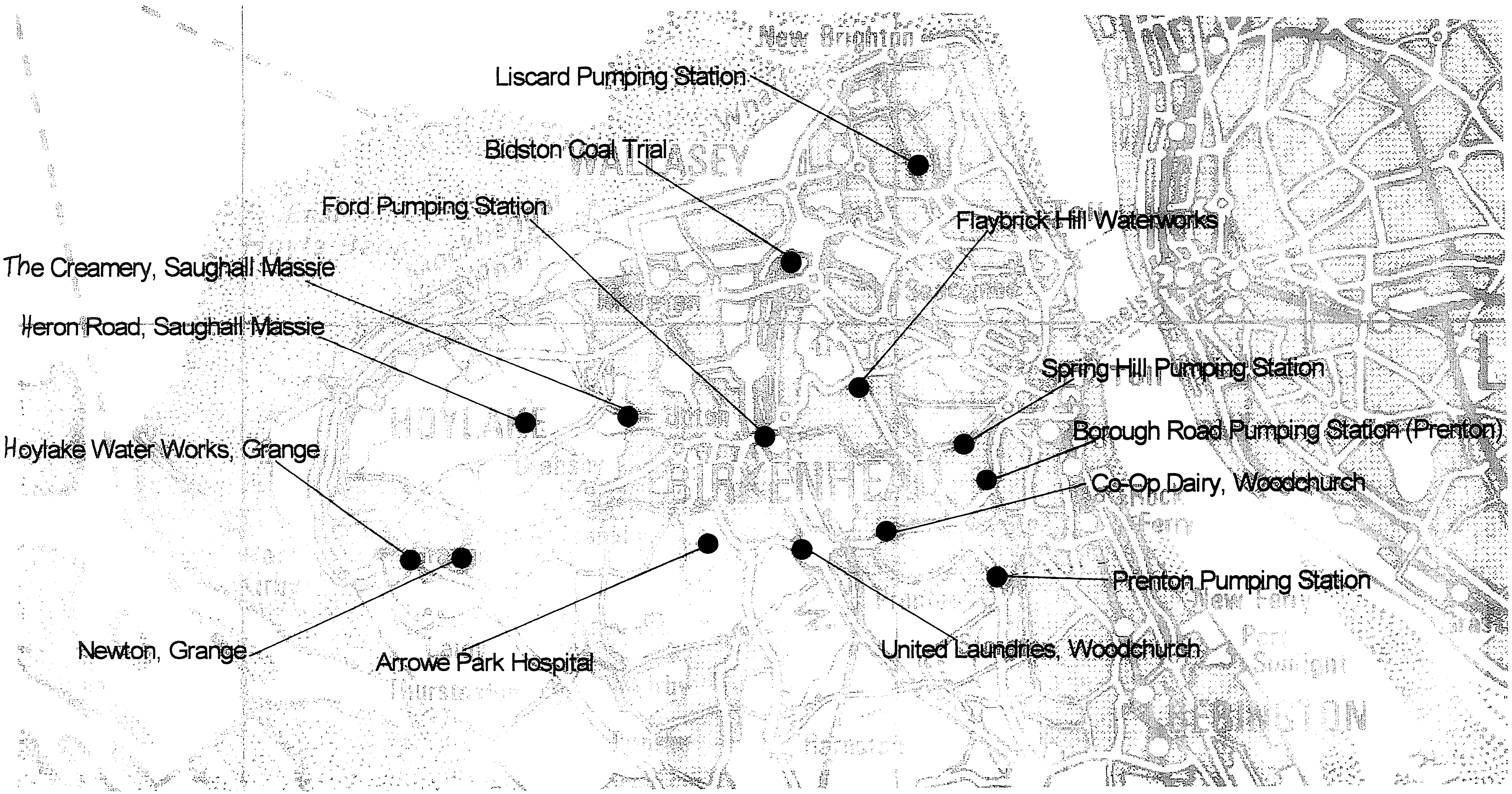


Figure 2: Map of the north Wirral district showing locations of the main boreholes referred to in the report.

2 Geological sequence proved in the north Wirral district

Quaternary (not necessarily in order of superposition)

- Blown Sand

- Salt Marsh deposits

- Alluvium

- Marine and Coastal Zone Deposits (undifferentiated)

- Tidal Flat Deposits and Peat

- Till

- Glacio-fluvial Sand and Gravel

Triassic

- Mercia Mudstone Group
    - Eldersfield Mudstone Formation
    - Tarporley Siltstone Formation

- Sherwood Sandstone Group
    - Helsby Sandstone Formation
        - Frodsham Sandstone Member
        - Delamere Sandstone Member
    - Wilmslow Sandstone Formation
        - Thurstaston Sandstone Member
    - Chester Pebble Beds Formation

?Permian - Triassic

- Kinnerton Sandstone Formation

Strata below the middle part of the Chester Pebble Beds Formation are inferred from deep borehole data within the district.

Due to the lithological continuity of the Sherwood Sandstone Group and lower part of the Mercia Mudstone Group with the Cheshire Basin, nomenclature for all formations up to and including the Tarporley Siltstone Formation is derived from that basin.

The north Wirral district is underlain at rockhead by strata of ?Permian to Triassic age. Based on Warrington *et al.,* (1980), these strata are grouped within either the Sherwood Sandstone Group, or the overlying Mercia Mudstone Group. The colour of the Permo-Trias is extremely variable, from dark reddish-brown 'bleached' to yellow and pale buff-grey. Thompson (1969) suggests this bleaching is due in part to mineralisation subsequent to deposition. Interaction between porewater, meteoric waters, modern groundwater and unstable minerals, altering the redox-chemistry of the sandstone, was suggested by Burley (1984). In general, the colour of the bedrock in the north Wirral district cannot be used as a reliable indicator of stratigraphic position.

3 Sherwood Sandstone Group

3.1 KINNERTON SANDSTONE FORMATION (FORMERLY 'LOWER MOTTLED SANDSTONE') ?LATE PERMIAN - SCYTHIAN

The Kinnerton Sandstone Formation is the oldest unit proved in the north Wirral district. Although previously considered Triassic (Edwards and Trotter, 1954), the formation has been assigned to the upper Permian (Holloway, 1985) in the north Cheshire basin based on its stratigraphic position, which is possibly equivalent to, or above, the Manchester Marl Formation (also upper Permian) and below the Chester Pebble Beds, which are Triassic. Warrington *et al.* (1980) note that the formation probably spans the Permo-Triassic system boundary. In the southern part of the Cheshire Basin, Rees and Wilson (1998) place the base of the Triassic system at the base of the Kinnerton Sandstone. Age diagnostic fossils have not been recorded from the Kinnerton Sandstone.

The presence of the Kinnerton Sandstone Formation beneath the district has been inferred from records of the Bidston Coal Trial Borehole, which was drilled in 1892 in the hope of proving economically viable Productive Coal Measures under the northern part of the Wirral. The boring penetrated 176.74 m of sandstone, which was pebble-free and 'coarse' in places; one mudstone parting at a depth of 792.07 m was noted. These strata, lying below 410.31 m of sandstone with sporadic pebbles (Chester Pebble Beds), were assigned to the Kinnerton Sandstone Formation (Lower Mottled Sandstone) by C E De Rance.

Borehole proving

SJ29SE (Leasowe)

⊙ Bidston Coal Trial Borehole (SJ29SW/6); see Appendix 2

> 176.74 m sandstone, dark red, coarse and fine-grained; one marl parting noted; base not proved

Correlation with adjacent districts

The old name 'Lower Mottled Sandstone' has been used in two senses. In the area where the Manchester Marl Formation is identifiable, it was applied to the sandstone-dominated unit between the Manchester Marl Formation and the Chester Pebble Beds. Where the Manchester

Marl Formation cannot be identified, it included all Permo-Triassic strata between the Carboniferous and the Chester Pebble Beds. As the Bidston Coal Trial Borehole does not prove the Manchester Marl Formation, the 176.74 m of sandstone below the Chester Pebble Beds in this borehole was assigned to the Lower Mottled Sandstone, now included in the Kinnerton Sandstone Formation.

The Kinnerton Sandstone Formation is about 305 m thick in the adjacent Flint district (Earp and Taylor, 1986). In central parts of the Cheshire Basin the formation is up to 210 m thick (Rees and Wilson, 1998). Within the offshore East Irish Sea Basin, the Kinnerton Sandstone Formation is equivalent to the Freshfield Member of the Manchester Marl Formation.

Sedimentology

Regionally, Jackson *et al.* (1987) consider the unit to be dominantly aeolian. Within the Cheshire Basin, Wild (1987) interpreted accumulation by wind-ripple, grainflow and grainfall processes on dune complexes and on dry interdune areas in an aeolian environment.

3.2 CHESTER PEBBLE BEDS FORMATION (FORMERLY 'BUNTER PEBBLE BEDS') SCYTHIAN, INDUAN - OLENEKIAN

The Chester Pebble Beds lie above the Kinnerton Sandstone Formation and beneath the Wilmslow Sandstone Formation. Within the north Wirral district, the Chester Pebble Beds are on the whole non-pebbly. This has previously led to misidentification of the formation at outcrop and in borehole sections. Both the basal and upper junctions of the formation are lithologically transitional, with both pebbly and non-pebbly sandstone assigned to the Chester Pebble Beds, and exclusively pebble-free strata assigned to either the younger or older formations.

The Chester Pebble Beds at outcrop are typically reddish brown, medium-grained with extremely rare pebbles. Where pebble-free, the formation is distinguished from adjacent formations by being more strongly cemented and micaceous, with more angular grains, and poor sorting. Examination of the Perch Rock [3111 9437] exposure yielded a solitary rounded sandstone pebble, 0.5 cm in diameter; at Prenton Dell [3015 8572] the formation is pebble-free throughout. The sandstone is on the whole trough and planar cross-bedded, and linguoid ripple form sets are preserved at Perch Rock. Soft sediment deformation structures are preserved at Prenton Dell, where the sandstone contains common, well-rounded, reworked aeolian grains.

The base of the formation has been proved in the Bidston Coal Trial Borehole, where it was placed at 691.94 m by C De Rance. The top was picked at 281.63 m, making the complete formation 410.31 m thick. The exact positions of both junctions are, however, difficult to place with accuracy, due partly to the poor quality of the written log. The depth and thickness values given above should therefore be taken as a 'best estimate' based on the data available.

The upper part of the formation has been proved in a further two boreholes. The Mount Road Pumping Station Borehole (Prenton Pumping Station) proved 73.3 m of micaceous sandstone with sporadic quartz pebbles to a depth of 259.08 m. The presence of Chester Pebble Beds below 109.11 m in the Co-Op Dairy Borehole, Woodchurch, has been based on the better cemented fabric of the sandstone compared with the less well-cemented Wilmslow Sandstone Formation.

Main Section Details and selected provings from boreholes

SJ28NW (Hoylake)

⊙ Newton No. 1 Borehole (SJ28NW/6)

146.34 m sandstone, 'in places hard', with subordinate red shale and mudstone beds; base not proved

SJ29SE (Leasowe)

⊙ Bidston Coal Trial Borehole (SJ29SE/2)

410.31 m sandstone, pebbly sandstone, red, with subordinate blue and red marl partings. Sandstone is commonly micaceous.

SJ28NE (Upton)

⊙ Co-Op Dairy, Woodchurch (SJ28NE/8)

121.01 m 'hard red and white sandstone'; base not proved

SJ38NW (Tranmere)

Prenton Dell [3015 8572]

Roadside exposure: 1.42 m sandstone, reddish-brown, fine-grained, poorly-sorted. High-angle cross-bedded, in part deformed by soft-sediment processes; rare preferentially-cemented nodules. Rests on 1.9 m sandstone, reddish-brown, fine-grained, well-sorted, feldspathic, silty. Some reworked aeolian grains. Low-angle cross-laminated; foresets indicate northerly palaeoflow.

Balls Road East, Birkenhead [3125 8811] (exposure along alley way)

1.27 m red and yellow mottled, fine-grained, moderately-well sorted sandstone with planar cross-bedded sets up to 0.5 m, and rounded mudclasts up to 15 mm diameter. (?indeterminate stratigraphy).

⊙ Mount Road (Prenton) Pumping Station (SJ38NW/5)

73.3 m sandstone, red and grey, coarse-grained; sporadic quartz pebbles

SJ39SW (New Brighton)

Perch Rock [3100 9445]

Foreshore exposures; sandstone, dark reddish-brown, fine- to medium-grained, poorly sorted, consisting one well-rounded, sub-spherical pebble to south-east of the Fort at Perch Rock. Low angle cross-stratified bedforms preserved; linguoid ripples and bedforms indicative of ?lateral accretion.

Correlation with adjacent districts

The thickness of the Chester Pebble Beds proved by the Bidston Coal Trial Borehole at 410.31 m, is well over double that for the formation in the Chester area, where at Mouldsworth it is 171 m (Earp and Taylor, 1986). It is significantly greater than the thickness proved in the southern part of the Cheshire Basin (c. 220 m; Rees and Wilson, 1998). Within the offshore East Irish Sea Basin, the equivalent to the Chester Pebble Beds is the Rottington Sandstone Member of the St Bees Sandstone Formation. This thickens north-westwards, where it is in the region of 550 m thick (Jackson *et al.*, 1997).

Sedimentology

Within the Cheshire Basin, the sandstone has been attributed to a 'flood gravel' regime (Earp and Taylor, 1986) within a low- to medium-sinuosity braided river setting. Earp and Taylor (1986) suggest a general northwards flow direction for the river system, accounting for the more distal 'pebble-free' facies on the Wirral compared to the more pebbly facies of south Cheshire. Within the north Wirral district, the Chester Pebble Beds Formation show some erosionally-based channelised sandstone units which exhibit poorly developed upwards-fining cycles. In many places, however, there is little evidence of this, and the sandstone channels are more or less homogeneous, composed of fine-to medium-grained reddish-brown sandstone, and are pebble-free. The scarcity of pebbles in the formation on the Wirral, size of pebbles (at New Brighton reaching a maximum of only 5 mm), and the fairly silty nature of the formation indicates a further reduction in flow velocity than in locations further south.

3.3 WILMSLOW SANDSTONE FORMATION (FORMERLY 'UPPER MOTTLED SANDSTONE') SCYTHIAN, INDUAN - OLENEKIAN

The Wilmslow Sandstone Formation gives rise to a gently undulating, low-lying topography. For the most part, the formation is covered by drift; exposures are essentially restricted to the scarp-slopes immediately beneath the overlying Helsby Sandstone Formation.

The base of the formation is taken in boreholes at a point where either:

1. sandstone becomes pebble-free above the 'pebbly' Chester Pebble Beds, or

2. sandstone in written logs is described as 'soft' when compared to the underlying 'hard' lithology of the Chester Pebble Beds.

In practice, the base of the formation is difficult to place. Borehole sections proving the complete formation have not been drilled within the north Wirral district.

East of the Thurstaston Fault: Wilmslow Sandstone Formation (undifferentiated)

The Bidston Coal Trial Borehole was spudded approximately 15 m below the top of the Wilmslow Sandstone Formation, giving an the estimated total thickness for the formation of 289 m. A previous interpretation of the Spring Hill, Borough Road and Liscard Pumping Station boreholes indicated that they may have bottomed out in Chester Pebble Beds (Wedd *et al.*, 1923). These assumptions cannot be relied upon due to the poor nature of the written logs; indeed, doubt was cast upon these interpretations in Wedd *et al.* (1923); until conclusive evidence is presented, it is assumed that these boreholes do not prove the Chester Pebble Beds.

Borehole records indicate that the formation is composed mostly of red, grey and white 'soft' sandstone with sporadic 'marl' or 'loam' partings (probably sandstone units with high proportions of clay and silt). At exposure in the north Wirral district, the formation is a distinctive 'foxy' red colour, commonly leached pale brownish-yellow. Leached sandstone is best exposed at Lower Flaybrick Road, Bidston [2926 8985], and Red and Yellow Noses at Wallasey [2996 9407]. The lower part of the formation is pebble-free at crop, and typically fine- to medium-grained and well-sorted. The sandstone is commonly flat, high- and low-angle cross bedded; massive units are rare. Extensively developed soft-sediment deformation, including slumping and oversteepened bedding is preserved at crop (for example, the lower part of the Boundary Road section at Bidston Hill). Cataclastic fractures are common throughout the formation. Generally, there has been no measurable displacement across individual fractures. Preferential cementation along fracture planes by barite and calcite has subsequently taken place. The fractures appear to be associated with faulting, and are best seen at Thermoplaye Bidston Court Gardens at [2853 8884].

West of the Thurstaston Fault: Thurstaston Sandstone Member and Wilmslow Sandstone Formation (undifferentiated)

The Wilmslow Sandstone Formation is divisible into two units within the part of the district west of the Thurstaston Fault. The lower unit is undifferentiated Wilmslow Sandstone Formation, and is lithologically similar to the Wilmslow Sandstone Formation east of the Thurstaston Fault. The upper unit, the 'Thurstaston Sandstone Member', was originally defined by Thompson (1970a) as the lowermost member of the overlying Helsby Sandstone Formation (see discussion below).

Approximately 58 m below the base of the Helsby Sandstone formation is a well-cemented pebbly sandstone bed, which is mappable in the Thurstaston Common and Caldy-Grange areas. It is also proved in several boreholes west of the Thurstaston Fault (e.g. Hoylake Waterworks No. 1 and 2 boreholes). This bed was named the Thurstaston Hard Sandstone Bed by Thompson (1970a), and was shown on the previous BGS survey (IGS, 1975) as a 'thin inconsistent bed of hard sandstone' within the Wilmslow Sandstone Formation. The Thurstaston Hard Sandstone Bed at Thurstaston Common is typically a duller grey-brown colour than beds above and below, which are bright reddish-orange, brown and yellow. It is medium- to coarse-grained and moderately well-sorted. Pebbles include red mudclasts that are rounded and tabular, and vein quartz. The bed is very well-cemented, and commonly weathers proud from the less well-cemented Wilmslow Sandstone Formation below and Thurstaston Sandstone Member above; consequentially, the bed is feature forming, and fairly easy to map out in the Caldy and Thurstaston areas. The bed is c. 1.1 m thick on Thurstaston Common and 1.52 m thick in Hoylake Water Works No. 1 Borehole.

The base of the Thurstaston Hard Sandstone Bed defines the base of the Thurstaston Sandstone Member. Strata above the Hard Bed exhibit common soft sediment deformation structures (best exposed along the Thurstaston road cutting [2444 8462]), and the lithological characteristics are similar to the remainder of the Wilmslow Sandstone Formation. A road cutting at Grange [2194 8693] exposes the lower 3 m of the member, consisting of cross-bedded sandstone with minor soft-sediment deformation in the upper part of the section. The junction with the overlying Helsby Sandstone Formation is exposed at the eastern end of the section. Set bounding surfaces are typically low angle, and the section below the Helsby Sandstone Formation can be divided into four main co-sets. Wind ripples and ichnofossils have been described by Øxnevad (1991).

Cataclastic fracture zones are well-developed in both the upper part of the Wilmslow Sandstone Formation and within the Thurstaston Sandstone Member on the western flanks of Caldy Hill. The member is between 57.92 and 62.5 m thick in the Hoylake Water Works boreholes, and is well exposed on Thurstaston Common and Caldy Hill.

The Thurstaston Sandstone Member is here re-defined and included in the Wilmslow Sandstone Formation rather than within the Helsby Sandstone Formation (Thompson 1970a). The three main reasons for this are:

1. The Thurstaston Hard Sandstone Bed is laterally discontinuous. Where it is absent, there is no mappable marker to differentiate the Thurstaston Sandstone Member from the underlying strata in the Wilmslow Sandstone Formation.
2. In the Heswall district, more than one well-cemented pebbly sandstone bed has been identified within the upper part of the Wilmslow Sandstone Formation (Lawley, in prep.). Which of these beds correlate with the Thurstaston Hard Bed is uncertain.
3. The Delamere Sandstone Member (of the Helsby Sandstone Formation) is a regionally mappable lithological unit. It is identifiable not only over the north Wirral district, both east and west of the Thurstaston Fault, but also throughout most of the Cheshire Basin. The Thurstaston Hard Sandstone Bed is not present to the east of the Thurstaston Fault in the district.

Main Section Details and selected provings from boreholes

Wilmslow Sandstone Formation

SJ28NW (Hoylake)

⊙Hoylake Water Works No. 2 Borehole (SJ28NW/5); see Appendix 2

c. 111.29 m below the Thurstaston Hard Bed; basal contact is faulted.

⊙Hoylake Water Works No. 1 Borehole (SJ28NW/4); see Appendix 2

60.98 m below the Thurstaston Hard Bed; basal contact is not proved.

⊙Newton No.1 Borehole (SJ28NW/6); see Appendix 2

82.93 m sandstone with subordinate shale and marl beds; upper boundary is not proved

Grange Road Cutting (A540) [2194 8693]

c. 12 m section of aeolian dune form-sets and partial form-sets. Upper part disturbed by soft-sediment processes; see log for location SJ28NW-6 in Appendix 3 for graphic log and interpretation.

SJ28NE (Upton)

Lower Flaybrick Road, Bidston [2926 8985] General dip 7/039

c. 8.5 m section of dominantly cross and planar bedded sandstone; see log for location SJ28NE-1 in Appendix 3 for graphic log and interpretation.

Howbeck Road, Claughton [2983 8852] dip 14/018

c. 3.3 m yellow-orange fine-grained moderately-sorted sandstone with sporadic medium-grained frosted quartz grains. Lower 1.6 m and upper 1 m are thinly-bedded, low angle cross-stratified. Intervening 0.7 m is thickly bedded and essentially massive.

Hill Road, Claughton [2940 8909] main surfaces 7/020; foresets 11/289

section 1.82 m high and c. 62 m long. Yellow, medium-grained sandstone with erosionally-based low angle cross-sets. Some foresets have distinctive ‘olgive’ (‘S’) shape.

Bidston Court Gardens and Thermoplaye Pass, Bidston, around [286 887] general dip 6/281 (variable)

numerous exposures of pebble-free, highly fractured yellow-orange sandstone with both planar and cross bedding. At [2853 8885], part of a 3.15 m section (also shown in a line drawing from photographs, in Figure 3) shows the following sandstone section (from top-down):

0.32	planar parallel bedded (grades into cross-bedded at top)
1.17	low angle cross-bedded in sets c. 0.5 m thick
0.30	planar parallel bedded
0.37	low angle cross-bedded

The sandstone is very well sorted, fine-grained with sporadic medium-grained frosted quartz grains. The exposure is faulted, with a c. 3.5 m wide shear zone. The fault dips 68/003, strikes 298, and throws to the north-east.

Quarry, 150 m north-east of The Farm, Landican [2826 8517]

> 2.96 m sandstone, pebble-free, 'soft', with typical aeolian dune and interdune structures. Foreset dips variable, but generally north-westerly. Lithology: sandstone, yellow and ocherous. Pebble-free, mica-free. Well sorted, medium-grained with rare coarser grains. Slightly silty. Well rounded grains.
>
> Top-down:
>
> 1.14 sandstone, parallel-bedded
>
> 0.36 sandstone, planar bedded; medium bedded
>
> 0.09 sandstone, planar bedded, medium- to thinly-bedded
>
> 0.09 sandstone, massive
>
> 0.59 sandstone, low and high angle cross-bedded
>
> 0.69 sandstone, high angle cross-bedded

SJ29SE (Leasowe)

Red Noses, New Brighton [2980 9393] General dip 5-6/117.

> c. 3.3 m section of dominantly cross and planar bedded sandstone; see logs for location SJ29SE-1 and location SJ28NE-2 in Appendix 3 for graphic logs and interpretations.

Warren Road, New Brighton [2990 9379]. General dip 3-4 towards NE.

> 1.64 m buff yellow and ocherous cross bedded (and minor massive) sandstone with asymptotic forestes. Sporadic granule lags and bimodal sorting; pebble free. Fractures dominantly 82/019
>
> 0.5 m thinly bedded silty sandstone with wavy parallel and non-parallel lamination.

Boundary Road, Bidston [2861 9027]. Dips vary

> c. 12.6 m section of dominantly cross and planar bedded sandstone, exhibiting soft sediment deformation; see log for location SJ28SE-4 in Appendix 3 for graphic log and interpretation.

Lodge, West Poulton [2994 9133]. Major surface dips 12/217

> c. 3 m yellow-brown and orange medium grained moderately well-sorted sandstone with low angle planar cross-bedding. With spherical, sub-rounded grains; pebble free. Faulted against similar lithology, the fault having a 2 m wide shear zone with dips of 63/033 and 86/216; striking broadly 130-310.

St Hilary's Brow, Wallasey [2962 9196 - 2967 9194]. Foreset dips 15/248

> 2.45 m cream-buff brown fine- to medium-grained slightly silty sandstone with asymptotic planar cross-bedded sets; pebble free.

'Cliff Point', Cliff Road, Wallasey [2985 9148] major surface dips 4/106

> 1.5 m yellow, medium- to fine-grained, poorly sorted cross-bedded sandstone; pebble free.

Lennox Lane, Bidston Village [2844 9037] foresets 29/353

> 0.7 m yellow, very well-sorted, fine-to medium-grained sandstone with high angle planar cross-bedding. Many well-rounded, spherical, frosted quartz grains; pebble free.

Bidston Village Road, Bidston Village [2850 9024] foresets 20/307; major surfaces 7/002

> 1.47 m yellow, fine-grained, moderately well-sorted slightly silty sandstone with thinly-bedded planar cross-stratification. Pebble free, with some preferentially cemented (calcite or barite) nodules. Few frosted quartz grains.

Bidston Village Road-Boundary Road junction, Bidston Village [2857 9027] foresets 29/356; major surfaces 4/069

> 1.94 m fine-grained, well-sorted pale yellow sandstone with planar and wavy-planar high angle asymptotic cross-bedding. Pebble free, with preferentially-cemented (?barite) nodules; cataclastic fractures common, also preferentially cemented.

Bidston Village Road, opposite primary school [2863 9031] foresets 12/286; major surfaces 6/056

> 2.8 m fine and sporadically medium-grained, moderately well-sorted sandstone with planar and low-angle cross bedding. Pebble free; many frosted quartz grains; cataclastic fractures.

⊙ Bidston Coal Trial Borehole (SJ29SE/2)

> 274.62 m sandstone, red and yellow, with sporadic marl partings; base at 281.63 m.

SJ38NW (Tranmere)

Brough Road, Birkenhead [3138 8793] main surfaces 6/014; foresets to 190

> 1.4 m yellow-buff very well sorted sandstone, pebble-free, with planar and low angle cross-bedding. Grains are rounded and spherical; section is fractured.

⊙ Mount Road (Prenton) Pumping Station (SJ38NW/5)

> 185.78 m sandstone, yellow and red, no pebbles noted; top of formation not proved.

⊙ Spring Hill, Oxton (SJ38NW/10)

> 254.61 m sandstone, red, grey and white; base of formation not proved.

SJ39SW (New Brighton)

Yellow Noses, New Brighton [3011 9408].dip 2/214

> c. 5 m section comprising buff yellow, fine- to medium-grained, moderately-well sorted (some bimodal grainsize lamination) silty sandstone. A high proportion of very low angle cross and planar laminated sandstone, with some wind ripple lamination; pebble free.

Hamilton Road, New Brighton [3038 9368]. Dip 3/092; fractures 85/031; 72/207

> 1.85 m yellow-orange, very fine- to medium-grained, moderately sorted, pebble-free sandstone with large-scale cross bedding, sporadic wavy bedding and bimodal grainsize lamination; pebble free.

⊙ Liscard Pumping Station (SJ39SW/55)

> 215.2 m sandstone, fine- to coarse-grained, no pebbles noted; base of formation not proved.

Thurstaston Sandstone Member

SJ28NW (Hoylake)

Royden Park [2407 8571]

> 2.84 m sandstone. Aeolian grain-types (both feldspar and quartz present), high- and low angle cross-bedded. 'Scoop-shaped' based laterally-inpersistent co-sets.

Thurstaston Common [2433 8500]

> 'Hard Bed': 0.96 m medium-to coarse-grained, moderately well-sorted, rare quartz pebbles. Two units present within the Hard Bed: a lower 0.69 m pale greyish-brown sandstone with sporadic mudclasts and coarse stringers and an upper 0.37 m sandstone,

reddish-brown, trough cross-bedded with minor slumping. This rests on reddish-brown pebble-free sandstone with low angle cross- and planar and planar-wavy-bedding.

Hairpin bend, King's Drive, Caldy [2237 8545]

'Hard Bed': 0.45 m sandstone, grey, hard, with mudclasts, overlain by 0.36 m sandstone, red, soft, planar laminated, and c. 1.5 m sandstone, grey, hard, with mudclasts, erosionally based.

King's Drive North, Caldy [2302 8574]

2.2 m sandstone, red, very well-sorted. Mostly planar bedded. Faulted- fault plane slickensided; throws to the north-east, dips 84/074.

Caldy Road [2262 8522]

1.85 m sandstone, red, pebble-free, fine-grained, with rare medium- to coarse-grains. Faulted; fault strikes 358, throws to the east. Rare cataclastic fractures; weakly cemented. Low angle cross-bedded.

Quarry north of King's Drive, Caldy [2266 8573]

c. 3.5 m sandstone, reddish-brown, rare small pebbles; coarse-grained.

⊙Hoylake Water Works No. 2 Borehole (SJ28NW/5); see Appendix 2

Proves the Hard Bed at c. 67.07 m depth, overlain by c. 56 m of the Thurstaston Sandstone Member (Member is 57.92 m thick).

⊙Hoylake Water Works No. 1 Borehole (SJ28NW/4); see Appendix 2

Proves the Thurstaston Hard Bed from 65.54-64.02 m (1.52 m thick), overlain by 60.98 m of the Thurstaston Soft Sandstone Member.

Correlation with adjacent districts

Within the Cheshire Basin, the thickness of the Wilmslow Sandstone is variable, ranging up to about 900 m in the central part of the Cheshire Basin (Rees and Wilson, 1998); in the Chester area it is only 305 m (Earp and Taylor, 1986). The equivalent Calder Sandstone Member of the East Irish Sea Basin is up to 730 m thick (Jackson *et al.*, 1997).

Sedimentology

Planar and low angle cross bedding are the most common sedimentary structures within the Wilmslow Sandstone Formation, making up well over 90% of strata exposed in north Wirral; the remainder are either wavy-bedded or massive. Features typical of aeolian deposition are commonly present. These include bimodal grainsize lamination (after Hunter, 1977), well-rounded, well-sorted quartz grains with frosted surfaces (so-called 'millet seed' grains), and low angle first order set bounding surfaces. The absence of large pebbles, mudclasts or mudstone beds also suggest a predominantly non-aqueous palaeoenvironment of deposition. Individually, these features do not define an aeolian deposit, but when several features are present, the evidence for an aeolian origin is compelling. Macchi (1990) ascribes a mixed fluvial-aeolian origin to the Thurstaston Sandstone Member, based on observations from the Thurstaston road cutting [2444 8462], just to the south of the district.

Foreset dips increasing up-section indicate dune development from interdune or sandsheet to mature dune. These relationships are well displayed at the western part of the Lower Flaybrick Road section. The Grange Road section exposes four main dunes. Dunes are preserved advancing up the lee slope or climbing down the stoss slope of older dunes. Ichnofossils, interpreted as burrows and ?dinosaur footprints have been described from this section (Øxnevad, 1991); no other fossils have been identified from the formation in the north Wirral district. The exposure at Red Noses shows several partially-preserved aeolian dunes, with a typical preserved co-set thickness in the region of 0.3-0.4 m. Planar parallel units are interpreted as inter-dune, or 'dry sandsheet' deposits; these can also be clearly be seen at Bidston Court Gardens, where the ratio of preserved interdune to preserved aeolian dune is approximately 1: 2.5 (Figure 3).

Adhesion structures, formed within a 'damp sandsheet' environment have been identified in part of the Red Noses exposure (4th unit from the base of the section on the composite log for location SJ29SE-2; see Appendix 3). Slumps and convolute bedding have been identified in the lower part of the Boundary Road section. Soft sediment deformation is initiated once sediment becomes saturated below the water table. The angle of repose for sediment under water is less than in air. Once below the water table, the sediment re-adjusts to the new conditions by slumping down foreset slopes (Macchi, 1991).

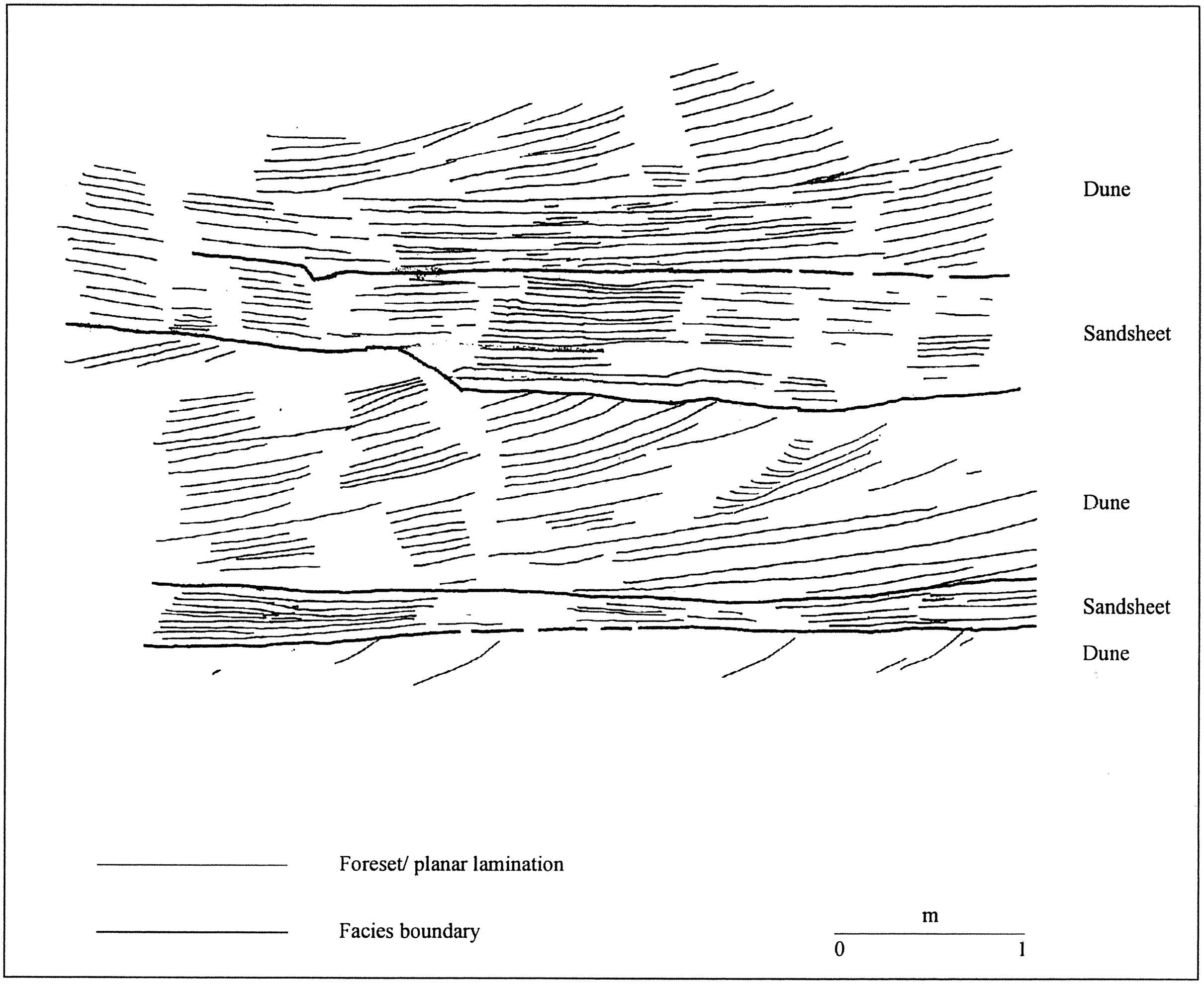


Figure 3. Bidston Court Gardens. Section of the Wilmslow Sandstone Formation, showing inter-bedding of facies: top, middle and bottom are low- to high-angle aeolian dune facies; note foreset dip increases up-dip, as is expected in Aeolian dune development. Dune facies are separated by planar-parrallel sandsheet or interdune facies.

Both major bounding and foreset surfaces have been plotted on stereograms (see Appendix 4). Corrections for regional (structural) dip have not been applied to the data sets as the effects of a c. 6° dip on the measurements would have a negligible effect on final results (Collinson and

Thompson, 1982). Foreset data is seen to have a distinct trend when compared to major bounding surface data. Foreset azimuths are broadly to the south west, and major surfaces are to the north west. This indicates that the prevailing palaeowind direction was towards the north-west. Dune migration was to the south-west, *transverse* to the prevailing wind.

The Hard Bed was thought by Shackleton (1953) to represent a silicreted land surface. Thompson (1997) disputed this, and suggested the Hard Bed is the product of a deep fluvial channel. The form and lithology of the Thurstaston Hard Bed indicates a fluvial origin. It is poorly sorted and pebbly; the basal contact is erosional, and was eroded into partly cohesive (damp) sediment (Macchi, 1991) of the Wilmslow Sandstone Formation. The preferential cementation of the bed was due to epigenetic solutions, although why only the fluvial unit was preferentially cemented is unclear (Thompson, 1970a). The dimensions of the Hard Bed indicate it was formed by unconfined sheet-flood processes which planed off the sandstone beneath. Foreset azimuths are variable, but indicate general northwards and westwards palaeoflow.

3.4 HELSBY SANDSTONE FORMATION (FORMERLY 'LOWER KEUPER SANDSTONE') MIDDLE - UPPER SCYTHIAN, ANISIAN

The Helsby Sandstone Formation occupies much of the high ground of the north Wirral district. The formation was divided into three members by Thompson (1969; 1970a), the Thurstaston, the Delamere and the Frodsham Sandstone Members. For reasons explained in the previous chapter, the Thurstaston Member is now considered part of the Wilmslow Sandstone Formation. The Delamere Sandstone Member is composed of pebbly and pebble-free sandstone with subordinate mudstone beds. This is overlain by the Frodsham Member, a pebble-free sandstone unit similar in lithology to the Wilmslow Sandstone Formation. The Delamere and Frodsham Sandstone Members were defined from exposures in the northern part of Cheshire, to the south-east of the Liverpool Geological Sheet (96) area. In North Wirral, the members are only identifiable separately at depth west of the Woodchurch Fault and at surface west of the Frankby Fault. East of the Woodchurch Fault, the Frodsham Sandstone Member is absent. Thompson (1970a) suggests that this is due to lateral passage into Delamere Sandstone type-facies.

East of the Woodchurch Fault

The Helsby Sandstone Formation in this area is approximately 120 m thick, and consists of both pebbly and non-pebbly sandstone with subordinate mudstone beds. The most representative exposures are those at The Arno [3048 8730] and The Breck [2980 9170] quarries, St. Hilary's Brow roadside section [2973 9195], and Bidston Hill [2880 8970]. The lithology of the Helsby Sandstone Formation is typically moderately-sorted and fine- to medium-grained. Grains are mostly quartz; rarer are mica and volcanics. Grains are typically not as well rounded as those from the Wilmslow Sandstone Formation, although reworked well-rounded grains (probably from the Wilmslow Sandstone Formation) are fairly common at some levels. The colour of the sandstone is variable, including ocherous yellow, reddish brown and greenish-brown. Pebbles include both intraformational rounded and tabular rip-up clasts of mudstone and sandstone, and a varied suite of exotic clasts including Lower Carboniferous limestone, volcanic rock and quartz from north Wales. Pebbles are commonly concentrated as lags at the base of foresets, but are also scattered throughout some beds, often aligned along foresets.

West of the Woodchurch Fault: Delamere Sandstone Member

The most representative exposures of the Delamere Sandstone Member are those at Irby Hill Quarry 2515 8595] and in small quarries on Grange Hill [2257 8606] and Caldy Hill [2246 8548]. The member displays both large and small-scale trough and planar cross-stratification. Massive beds occur in places. Pebble free units are common at Irby Hill. Mudstone units are only present at Hilbre Point and Irby Hill Quarry; there are rare thin beds of siltstone and sitly sandstone in many of the other exposures. The sections exposed at the war memorial at Grange Hill show large-scale trough cross-bedded sandstone which is overlain by smaller-scale trough cross-bedding, which is topped by flat-bedded sandstone with primary current lineation.

The Saughall Massie Borehole proved the upper 12.17 m of the member, which consists of very fine-grained sandstone with scarce medium-grained, well-rounded quartz grains. Bedding structures are rare, although some discontinuous wavy non-parallel lamination and silty drapes were noted in the upper part.

The stratigraphy of the exposures at Hilbre Point and Red Rocks islands has been a matter of considerable debate since the first geological survey of the Wirral in 1850. The history behind the problem is discussed in detail by Thompson (1998). The previous BGS survey of the area (IGS, 1975), placed Hilbre Point (and Hilbre Islands) within the Chester Pebble Beds Formation. Jackson and Mulholland (1993), The East Irish Sea solid map (BGS, 1994) and Jackson *et al.*, (1995), consider the rocks to be part of the East Irish Sea Basin, and have assigned nomenclature correspondingly. They place Hilbre Point within the St Bees Sandstone Formation (equivalent to the Chester Pebble Beds) and the Hilbre Islands within the Ormskirk Formation (equivalent to the Helsby Sandstone). More recently, Thompson (1997, 1998) considered both exposures to be from the middle-to upper-part of the Delamere Sandstone Member of the Helsby Sandstone Formation. If the strata were from the Chester Pebble Beds, a large easterly-throwing fault would be needed between Hilbre Point and Grange Hill; seismic reflection profiles show no evidence of this. Lithologically, there is no reason to place the Hilbre Point exposures within the Chester Pebble Beds (in fact, compared with the Chester Pebble Beds elsewhere on the Wirral, the Hilbre Point exposure would be remarkably pebbly indeed). The interpretation of Thompson (1997, 1998), that Hilbre Point and Red Rocks are part of the Delamere Sandstone Member of the Helsby Sandstone Formation, is therefore supported here.

West of the Woodchurch Fault: Frodsham Sandstone Member

The base of the member is taken at the base of the pebble-free sandstone sequence overlying the Delamere Sandstone Member. The member is between 20 and 55 m thick in the Cheshire Basin (Thompson, 1969), and the type area is at Frodsham in north Cheshire.

The formation has been proved in the Saughall Massie and Ford Pumping Station boreholes, where it is 21.1 m thick in the former and about 30 m thick in the latter. Compositionally, the member is similar to the Wilmslow Sandstone Formation, being essentially pebble- and mudstone-free. The member was examined at Frankby [2448 8662]. Here, the sandstone is composed of >95% quartz grains, the remainder made up of feldspar and rare dark volcanic clasts. The sandstone is reddish-brown in colour, and fine- to medium-grained. Overall, the grains are very well sorted, and well-rounded grains with frosted surfaces prodominate. The grains are weakly cemented by a resinous (possibly barite) cement. The lowermost 1 m at this section is high-angle cross-bedded; this is overlain by 1 m of planar laminated sandstone which passes upwards to low-angle cross-bedded sandstone. Cataclastic fractures occur sporadically throughout the exposure; these are preferentially cemented by barite and weather proud of the section.

In the Saughall Massie borehole, the Frodsham Sandstone Member is reddish-orange in colour, medium grained, and moderately-well sorted. High-angle cross-bedding structures are predominant in the lower part, with wavy bedding common in the upper 6.91 m of the member. One intraformational red, angular mudclast, 7 mm x 1 mm was noted 1.21 m above the base of the member.

Main Section Details and selected provings from boreholes

Helsby Sandstone Formation

SJ28NE (Upton)

Vyner Road, Bidston [2854 8908 - 2892 8958]

> Roadside section showing trough cross-bedded sequence of sandstone with sporadic pebbles. Medium-grained and poorly-sorted on the whole, and with many frosted well rounded quartz grains, muscovite flakes and pink (?volcanic) grains. Sets are m-scale with erosional bases; ripple laminated with rare post depositional slumps or loads.

Bidston Hill, Bidston (centred on [2880 3980]

> Essentially a dipslope exposure of brown, grey and buff sandstone with sporadic pebbles. Although good sections are not present, fairly good form sets are preserved 185 m north of the windmill (see sedimentological discussion, below).

SJ29SE (Leasowe)

St Hilary Brow, Wallasey [2966 9199]

> 2.7 m yellow-buff fine- to coarse-grained poorly sorted pebbly sandstone with trough and subordinate low-angle planar cross-bedding. Pebbles to 14 mm. Erosionally-based sets up to 7 cm occur within erosionally based cosets 1-2 m thick. See log for location SJ29SE-3 in Appendix 3 for graphic log and interpretation.

The Breck, Wallasey [2890 9170]

> Up to c. 9 m exposed sections in disused quarry. Dominantly trough- and planar cross-bedded pebbly sandstone; see log for location SJ29SE-5 in Appendix 3 for graphic log and interpretation.

Boundary Road, Bidston [2861 9027 - 2875 9023]

> c. 2.5 m poorly exposed pebbly sandstone resting on the Wilmslow Sandstone Formation; see log for location SJ28SE-4 in Appendix 3 for graphic log and interpretation.

SJ38NW (Tranmere)

Willan Road, Oxton [3062 8769]

> c. 0.4 m very fine- to fine-grained, moderately sorted pebble-free sandstone (indeterminate stratigraphy).

The Arno Quarry, Prenton [3048 8730]

> Up to c. 5 m sections in disused quarry. Dominantly cross-bedded sandstone with rare pebbles; see log for location SJ38NW-1 in Appendix 3 for graphic log and interpretation.

Prenton Road East, Prenton [3188 8703]

> 0.6 m reddish-brown and light-brown fine- to medium-grained moderately sorted pebbly sandstone with low angle trough cross-bedding. Grains: muscovite, pale ?igneous, angular and subordinate (reworked) rounded quartz.

SJ39SW (New Brighton)

Quarry Park, Sutton Road, Liscard [3080 9334]

> Northern wall: 2.08 m fine- to medium-grained, micaceous, pebbly sandstone, with trough and planar cross-bedding. Pebbles are up to 30 mm; quartz and sporadic mudstone flakes.
>
> Southern wall: the strata are generally more silty, with some ripple-lamination preserved.

⊙Vernons Flour Mills, Birkenhead Docks (SJ39SW/61)

> 213.41 m sequence of sandstone, pebbly sandstone and 'sandy marl', probably completely within the Helsby Sandstone Formation. The poor details in the log preclude subdivision into members, and the possibility that the borehole penetrates the Wilmslow Sandstone Formation is not discounted.

Delamere Sandstone Member

SJ28NW (Hoylake)

Hilbre Point (Land-locked 'Red Rocks') [2030 8850]

> c.10.5 m pebbly sandstone and subordinate mudstone succession; see log for location SJ28NW-1 in Appendix 3 for graphic log and interpretation.

Red Rocks Island, off Hilbre Point [8870 2010]

> c. 5 m cross-bedded pebbly sandstone; see log for location SJ28NW-2 in Appendix 3 for graphic log and interpretation.

Grange Road, opposite Monk's Way [2208 8689]

> 1.55 m sandstone and pebbly sandstone; see log for location SJ28NW-5 in Appendix 3 for graphic log and interpretation.

Grange Hill Quarry, Long Lane [2193 8728]

> c. 8.3 m pebbly sandstone, trough cross-bedded. One 0.3 m thick micaceous sandy siltstone bed.

Grange Hill, south-west side of cemetery [2211 8713]

> Up to 2.5 m reddish-brown and cream sandstone and pebbly sandstone. Mostly trough cross-bedded. Structures indicate transverse downstream accretion processes in a fluvial setting.

Caldy Hill Quarry [2257 8608]

> c. 4 m sandstone and pebbly sandstone; see log for location SJ28NW-3 in Appendix 3 for graphic log and interpretation.

Caldy Hill [2246 8548 - 2248 8558]

> c. 8 m sandstone, pebbly sandstone and mudstone section; see log for location SJ28NW-4 in Appendix 3 for graphic log and interpretation.

Grammar School, Column Road [2264 8622]

> 0.1 m sandstone, pebble-free (channel fill) on 0.6 m pebbly sandstone.

Column Road, Caldy [2304 8602]

> 1.03 - 1.62 m pebble-free sandstone, bright reddish-orange. High-angle cross-bedded. Fine-grained, moderately- to moderately-well-sorted, with rare feldspar grains; cataclastic fractures.

Memorial, Grange Hill [2189 8714]

> Sandstone and pebbly sandstone; two main upwards fining cycles; lower one wedges out laterally. Cycles c. 1.1 m thick.

⊙Hoylake Water Works No. 1 Borehole (SJ28NW/4); see Appendix 2

> 3.04 m of the basal part of the Delamere Sandstone Member.

⊙Hoylake Water Works No. 2 Borehole (SJ28NW/5); see Appendix 2

> 9.15 m from the basal part of the Delamere Sandstone Member.

⊙SJ28NW/7

> 0.2 m sandstone, dark reddish-brown, very fine-grained. Slightly micaceous. Vugs to 5 mm diameter; calcite-lined.

⊙SJ28NW/8

> 0.2 m sandstone, dark reddish-brown, very fine-grained, micaceous. Some well rounded polished grains.

⊙Saughall Massie Borehole (SJ28NW/22); see Appendix 2

> Basal 11.5 m proved is in the Delamere Sandstone Member, overlain by 21.1 m attributed to the Frodsham Soft Sandstone Member.

SJ28NE (Upton)

Irby Hill Quarry [2515 8590]

> Large quarry with many sections of sparsely-pebbly sandstone and subordinate sandy mudstone beds; see logs for locations SJ28NE-3 and 4 in Appendix 3 for graphic logs and interpretation.

⊙Ford Pumping Station (SJ28NE/3); see Appendix 2

> Proves c. 40 m Delamere Sandstone member (base faulted) overlain by c. 35 m of pebble-free strata attributed to the Frodsham Sandstone member.

⊙The Creamery Borehole, Saughall Massie (SJ28NE/9)

> Proves the upper 22.41 m of the Frodsham Sandstone Member, recorded as 'grey fine-grained hard sandstone, very faintly laminated'.

Irby Hill Quarry, Irby Hill centred on [2515 8592]

> Overall, the quarry shows the lateral facies changes within the Helsby Sandstone Formation, and that some apparently large fractures have no displacement, and some faults with narrow shear zones have potentially great displacement. Lithofacies E (Table 1) is present on the northern face of the quarry

Frodsham Sandstone Member

SJ28NW (Hoylake)

Poplar Farm, Frankby road section [2488 8662]

> 2.5 m sandstone, bright reddish-brown. Fine- to medium-grained. Very well sorted, many aeolian grains; resinous (?barite) cement. Planar and low and high-angle cross bedding structures. Rare cataclastic fractures. Frodsham Sandstone Member.

⊙Saughall Massie Borehole (SJ28NW/22)

> 21.1 m (complete member proved): sandstone, red, rounded grains, 'soft'. High-angle cross-bedding predominates; cataclastic fractures noted.

⊙ SJ28NW/23.

91 m sandstone; no further details. The upper part of this may be tentatively correlated with the Frodsham Sandstone Member.

Correlation with adjacent districts

The formation as a whole ranges from 85 to 120 m thick within the north Wirral district. Within the East Irish Sea Basin, the equivalent Ormskirk Sandstone Formation averages 250 m in thickness (Jackson *et al.* 1987). The Delamere Sandstone Member reaches approximately 80 m and the Frodsham Member 20-30 m in the Chester area (Earp and Taylor, 1986).

Sedimentology: Helsby Sandstone Formation

Six lithofacies were identified within the pebbly units of Helsby Sandstone Formation by Thompson (1970b) (Table 1). Thompson (1970b) suggests a dominantly fluvial origin for the formation, with some of the pebble-free units being interpreted as aeolian in origin. The majority of sections in the north Wirral district show on the whole, fluvial characteristics, and are typically composed of lithofacies B, C and D as defined by Thompson (1970b). The sections at the Arno and Breck quarries, and St Hilary's Brow have been interpreted mainly as stacked sheetflood or fluvial channel events (dominantly lithofacies B). A reduction in water level is suggested by preserved ripple-lamination at Arno Quarry (lithofacies C). A waning of flow is suggested by one ponding event, represented by a mudstone bed that is preserved at St Hilary's Brow (lithofacies F). The pebbly fluvial sandstone facies appears to make up the majority of the formation east of the Woodchurch Fault. The ratio of fluvial to aeolian facies is greater than 9:1 or higher. Stacked fluvial channel associations up to c. 9 m thick are exposed in The Breck Quarry, and thinner, partial sequences are common elsewhere. A low- to high- sinuosity braided environment was suggested by Thompson (1970b), with the sinuosity of depositional rivers, and hence clay and silt content, increasing up-sequence. There is, however, no evidence to prove this from boreholes or exposures in the north Wirral district.

Table 1: Lithofacies identified within the Helsby Sandstone Formation, and their interpretation (from Thompson, 1970b).

Lithofacies	**Characteristics**	*Interpretation*
A	Pebble and cobble conglomerate, breccia or gravel	Channel floor and bar deposits
B	Coarse-grained pebbly sandstone	Channel bars; large-scale ripples
C	Fine- to medium-grained sandstone with a few pebbles	Large-scale ripples of lower flow velocity channels than B, at a lower stage and discharge
D	Fine-to medium-grained sandstone interbedded with shale	Riverplain top-stratum and rarely levee
E	As lithofacies D, but with sandstone units interjecting the shale	as D; sandstone units coarser
F	Shale and mudstone	Bar swales and abandoned cut-off channels

Macchi (1990) suggests that the formation evolved through three phases:

1. Sandstone, coarse-grained, dominated by channel-structures. Extrabasinal quartzose pebbles are abundant.
2. As above, but with far less extrabasinal pebbles and many intrabasinal mudstone clasts
3. Variable sandstone facies- interpreted as mixed fluvial-aeolian (a channel-sandflat environment is suggested)

Clemmensen *et al.* (1994) suggest a mixed fluvial-aeolian origin for the Helsby Sandstone Formation based on observations at Helsby Hill, the type section of the formation, which is 20 km to the south-east of the north Wirral district. They suggest the formation was deposited by up to three main river systems which flowed northwards into the Cheshire Basin. They envisage a series of upward-drying sediment packages composed of two phases, a lower humid phase dominated by fluvial facies (pebbly, trough-cross-bedded sandstone) overlain by an upper arid phase dominated by aeolian dune and sandsheet facies (pebble-free planar- and cross-bedded sandstone). The arid phase largely reworked the upper part of the humid phase. The base of the fluvial phase is characterised by an erosional flood surface. A sand-drift surface terminates the fluvial phase and marks the base of the aeolian phase (see Figure 4). The cycle is repeated throughout the Helsby Sandstone sequence.

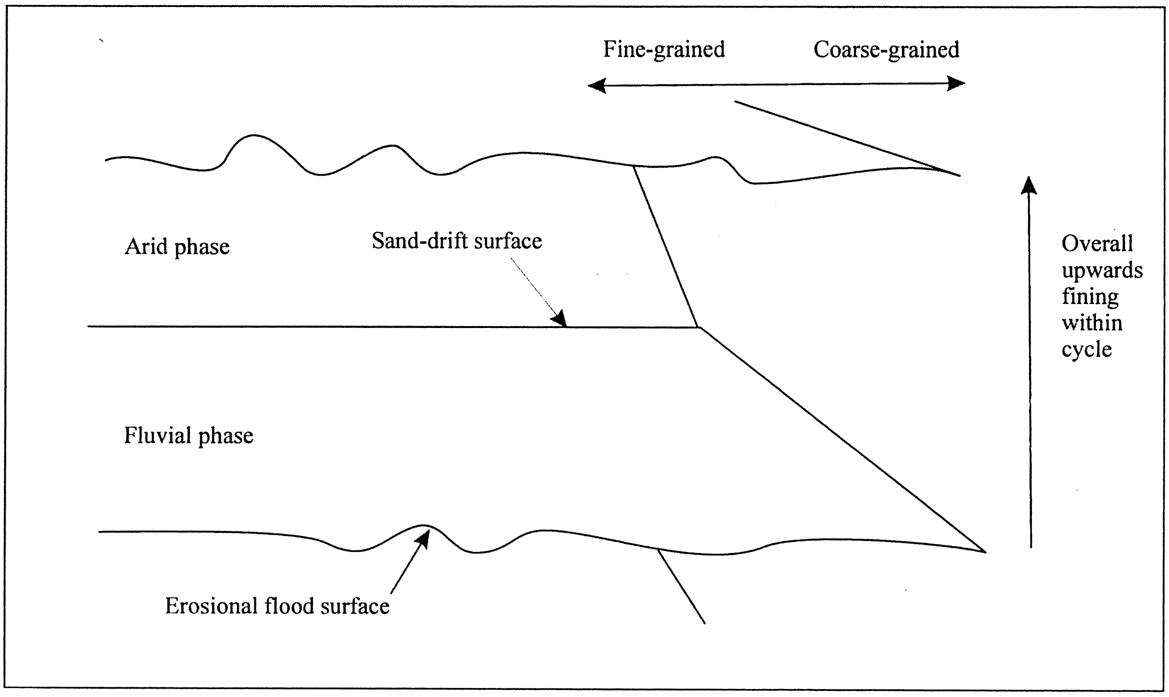


Figure 4: A complete upward-drying cycle within the Helsby Sandstone Formation, as described by Clemensen *et al.* (1994).

Upward-drying cycles are exposed at the Vyner Road North section. Such small-scale (i.e. less than 10 m) cycles have further been interpreted as a result of palaeomonsoonal climatic variations, which have been related to Milankovitch-type driving forces (Clemmensen *et al.*, 1994).

Both major bounding and foreset surfaces have been plotted on stereograms (see Appendix 4). Corrections for regional (structural) dip have not been applied to the data sets, as the correction factor for c. 6^0 dip is negligible (Collinson and Thompson, 1982). Foreset azimuth data are diverse, but broadly trend southwards, and major surfaces azimuths are to the north-north west (see Appendix 4). These data may be interpreted as representing bar sets migrating transverse to the predominant flow direction. These features are preserved on the eastern dipslope of Bidston Hill, where diagonal bar form sets are preserved. These show the crests of in-channel bars trending obliquely to major surfaces, and a model of bars migrating downstream with crests at an angle to the main flow direction is proposed.

Sedimentology: Delamere Sandstone Member

Within the north Wirral district, lithofacies B of Thompson (1970b) makes up most of the member. The remainder of the member is composed of lithofacies C, D and E. Lithofacies F has not been identified. Structures within units interpreted as fluvial are consistent with a braided (low sinuosity) fluvial environment, first suggested by Thompson (1970b).

Structures exposed at Hilbre Point may be interpreted as a series of stacked sheetflood events, with mudstone units representing ponding of water within abandoned channels, which allowed a finer sediment to settle out i.e., lithofacies B, C and F of Thompson (1970b). The presence of mudclast lags and horizons suggest these mudstone units were often reworked by renewed fluvial activity. The upper part of the Hilbre Point exposure represents a possible minor aeolian event, although fluvial re-working of aeolian deposits may show similar facies characteristics. Annelid tracks, described by Morton (1897) from Hilbre Point (but not identified during the current resurvey), indicate temporary subaerial exposure.

Sections at Irby Hill Quarry expose upward-fining co-sets with rare mudstone drapes/plugs. These are interpreted as multi-story sheetflood and channelised events. A small quarry on Caldy Hill exposed upward-fining sandstone and mudstone units up to 4.6 m thick. Similar upward-fining cycles at Grange Hill are also typically fluvial; primary current lineation structures show the depositional current was fairly strong and unimodal. Ripple-laminated sandstone units have been assigned a bar-top origin.

Sedimentology: Frodsham Sandstone Member

The Frodsham Sandstone Member has been interpreted as aeolian (Thompson, 1969; Macchi, 1991). The term 'Frodsham Sandstone Member' was defined by Thompson (1969) to apply to the unit of sandstone above the Delamere Sandstone Member in which structures indicative of 'dome-shaped aeolian dunes' and 'transverse dunes' are present, the former being dominant. Dome-shaped (or 'star') dunes are believed to evolve from transverse dunes (McKee, 1966). Although structures relating to dome-shaped dunes have not been identified within the north Wirral district, the lithology is comparable to that in the type section at Frodsham. Thompson (1969) suggests that sediment was sourced from dried-up river beds to the east of the region.

Facies within the Saughall Massie Borehole are dominated by high-angle cross- lamination, consistent with the upper part of an aeolian dune. The mudclast 1.21 m above the base of the member may have been reworked from the Delamere Sandstone Member, or could be a remnant of an intra-Frodsham Member fluvial event. Low angle major surfaces at the Frankby exposure are consistent with an aeolian system. The up-dip increase in foreset dip in the upper unit is also typical of aeolian dune development, the lower foreset dips representing interdune or the lower part of a dune, with higher dips in the upper part of a dune. Minor facies in the Saughall Massie Borehole include wavy bedded slightly silty sandstone. This is interpreted as an interdune deposit region (dune-slack). Interdune regions are commonly fairly moist, and windblown 'fines' adhere to their surfaces, resulting in a slightly siltier facies than aeolian dune facies.

4 MERCIA MUDSTONE GROUP

4.1 TARPORLEY SILTSTONE FORMATION (FORMERLY 'WATERSTONES') MIDDLE - UPPER SCYTHIAN, ANISIAN

The Tarporley Siltstone Formation is equivalent to the 'Waterstones' unit of previous terminology (Warrington *et al.*, 1980; Nutt and Lowe, 1986). The base of the formation, as defined by Thompson (1970a), is taken above the Frodsham Sandstone Member of the Helsby Sandstone Formation, at the base of a thick sequence of interbedded fine-grained sandstone, siltstone and mudstone. In borehole sections, this boundary has been taken at the upward transition where mudstone becomes dominant over sandstone. The top of the formation, again defined by Thompson (1970a), is taken at the top of the highest sandstone unit over 0.5 m thick, which is succeeded by 10 m or more of interbedded siltstone, shale or mudstone.

Complete sections through the formation are proved by the Arrowe Park Hospital, Creamery, Saughall Massie and Ford Pumping Station boreholes. The Arrowe Park Hospital Borehole proved about 41 m of undivided mudstone resting on reddish-brown sandstone of the Helsby Sandstone Formation. The Saughall Massie Borehole proved about 30.4 m of interbedded sandstone, fine-grained, siltstone and subordinate claystone. Stratification within the formation is diverse in type. Lamination is commonly wavy and non-parallel; climbing ripple-lamination is evident. Desiccation structures are common throughout the finer-grained units and are usually filled by coarser sediment. Brecciation through desiccation is apparent 17 and 20 m above the base of the formation. Deformation by loading is common in the basal 10 m. Sandstone units commonly contain mudclast lags and rounded mudclast pebbles; the coarser-grained units may be grey in colour as well as reddish-brown. The formation becomes siltier upwards, where it grades into the overlying Eldersfield Mudstone Formation. Palynological analysis on samples from the Tarporley Siltstone Formation from the Saughall Massie Borehole yielded spore and pollen broadly indicative of an Early to Middle Triassic (Anisian) age (Warrington, 1999).

The Ford Pumping Station Borehole proved 32.01 m of 'fine hard sandstone' interbedded with 'micaceous grey shale' and 'marly sandstone'. The Creamery Borehole, Saughall Massie proved a 43.13 m interbedded sandstone and shale sequence, the upper part of which may represent the lower beds of the Eldersfield Mudstone Formation, beneath 25.9 m thick Quaternary till. These thicknesses are similar to the previously mapped 'Waterstones', recorded as 38.1- 45.7 m thick (Wedd *et al.,* 1923).

The formation crops out in the central part of the district. It is exposed along Arrowe Brook, both north and south of Arrowe Brook Road. Although the stream-sections are weathered and poorly exposed, ripple-lamination is well-displayed in places. Ripple crests are mainly sinuous in-phase; some are bifurcated. Ripple crest wavelengths vary between 2 and 8 cm. Sandstone units contain rare rounded mudclasts along some foreset bases.

Main Section Details and selected provings from boreholes

SJ28NE (Upton)

Arrowe Brook, Greasby [2649 8712]

> c. 2.7 m mudstone and sandstone sequence; see log for location SJ28NE-5 in Appendix 3 for graphic log and interpretation.

Arrowe Brook, Arrowe Park [2616 8578 - 2662 8610]

c. 21 m partially exposed, faulted mudstone and sandstone sequence; see log for location SJ28NE-2 in Appendix 3 for graphic log and interpretation.

⊙Ford Pumping Station (SJ28NE/3)

42.38 m sandstone, micaceous, with shale.

⊙Creamery, Saughall Massie (SJ28NE/9)

43.13 m marl, red, sandy. Upper part is probably from the Eldersfield Mudstone Formation.

⊙Arrowe Park Hospital (SJ28NE/131)

c. 41 m; no lithological details available.

SJ28NW (Hoylake)

⊙ SJ28NW/ 10.

1 m sandstone, reddish-brown, very fine-grained, micaceous (current rippled?), with reddish-brown mudstone pebbles. Some 1 mm wide voids, possibly after halite.

⊙ SJ28NW/11.

0.1m sandstone, greenish-grey, micaceous, cross-laminated, with subordinate siltstone, greenish-grey, with a mudstone pebble.

⊙ SJ28NW/12.

0.2 m sandstone, greenish-grey, very fine-grained, micaceous, thinly-bedded. Pseudomorph (hopper) after halite on 1 mm thick mudstone parting; rare current ripple-lamination.

⊙ SJ28NW/13.

0.1 m sandstone, brown, very fine-grained, micaceous, thinly-bedded, cross-laminated, with reddish-brown mudstone pebbles. Voids, 1 mm wide, possibly after halite.

⊙ SJ28NW/14.

0.25 m sandstone, dark reddish-brown, fine-grained, micaceous with scattered reddish-brown mudstone.

⊙ Saughall Massie Borehole (SJ28NW/22)

c. 40 m silty sandstone interbedded with mudstone; complete sequence proved.

Correlation with adjacent districts

The Tarporley Siltstone Formation was formally defined within the Cheshire Basin (Warrington *et al.*, 1980), where it is up to 152 m thick (Earp and Taylor, 1986; Rees and Wilson, 1998). The Tarporley Siltstones pass northwards and north-westwards into the Hambleton Mudstones of west Lancashire and Merseyside, in the onshore part of the East Irish Sea Basin (Wilson and Evans, 1990); these equivalent beds are 30-37 m thick. Warrington (1999) notes that the miospore assemblages obtained from the formation in the Saughall Massie Borehole are similar in composition to those recovered from the Hambleton Mudstone Formation in the Blackpool area.

Sedimentology

Ireland *et al.* (1978), identified five distinct lithofacies within the Tarporley Siltstone Formation, based on observations from the northern part of the Cheshire Basin. The exposure in Arrowe Brook, Greasby, 200 m north of Arrowe Brook Road [2649 8712] shows structures similar to lithofacies B (low-mid intertidal sandflat) and E (high intertidal sandflat) of Ireland *et al.*, (1978) (see Table 2).

The presence of desiccation cracks shows some degree of aerial exposure; these are interpreted as forming within an ephemeral ponded water setting. Small-scale interbedding and interlamination would result from seasonal fluctuations in sediment-type. Similar facies are interpreted from Arrowe Brook in Arrowe Park [2616 8578 - 2662 8610], and from the Saughall Massie Borehole.

Table 2: Interpretation of structures within the Tarporley Siltstone Formation, Arrowe Brook, Greasby.

Structures-Lithology	**Interpretation**	**Lithofacies (after Ireland *et al*, 1978)**
Sandstone	Sandflat	B (low-mid intertidal sandflat)
Siltstone- claystone; parallel interlaminae, desiccated	Ephemeral lake	B (low-mid intertidal sandflat)
Siltstone- claystone; parallel interlaminae, current rippled	Perennial lake with sporadic sheetflood events across lake-bottom	B (low-mid intertidal sandflat)
Silty sandstone; parallel laminated	Perennial 'sandy' lake	B (low-mid intertidal sandflat)
Mudstone, massive	Perennial 'muddy' lake	E (high intertidal sandflat)

4.2 ELDERSFIELD MUDSTONE FORMATION (FORMERLY 'RED MARL') MIDDLE - UPPER SCYTHIAN, ANISIAN

Strata above the Tarporley Siltstone Formation are in spatial continuity with the East Irish Sea Basin succession, which crops out on the west Lancashire coast. This unit has been previously termed the 'Red Marl' (Wedd *et al.* 1923), 'Lower Keuper Marl' (Colter and Barr, 1975), 'Lower Mudstone Division' (Earp and Taylor, 1986) and 'unnamed mudstone Formation' (Nutt and Lowe, 1986). The boundary with the underlying Tarporley Siltstone Formation is gradational, and is drawn where mudstone becomes predominant over sandstone. The top of the formation is not seen preserved within the district. The Eldersfield Mudstone Formation is broadly comparable with the Unit A-Unit C mudstone interval of the offshore East Irish Sea Basin (Jackson *et al.*, 1995, fig. 54).

The Arrowe Park Hospital Borehole proved 99 m of mottled red-brown siltstone with interbedded blue-grey mudstone. These strata rest directly on beds assigned to the Tarporley Siltstone Formation. The Ford Pumping Station Borehole proved 96.03 m of hard, red shaley mudstone with subordinate fine sandstone. The upper c. 30 m of the formation has a higher sand content than the lower part. Calcite crystals were noted 7.62 m above the base of the formation, and in cavities between 65.53 and 66.75 m; thin beds of gypsum were recorded 46.02 and 88.1 m above the base of the formation.

The Saughall Massie Borehole proved the lower 54 m of the formation, consisting dominantly of mudstone with subordinate beds of fine-grained sandstone. The mudstone units are commonly brecciated by desiccation processes, with desiccation cracks up to 9 cm deep (64.73-64.82 m depth). Sandstone units are thinly laminated, with rare mud-draped ripple lamination. Contorted bedding is present at c 65.6 m, and sand-filled mudcracks occur at c.

72.5 and 82.5 m. A cubic structure less than 2 mm in diameter is present at 67.76 m. This is described as a pseudomorph after halite (a so-called 'hopper'); primary salt beds have not been proved within the north Wirral district. The core is fissured sporadically throughout its length; fissures are filled by calcite. Palynological analysis on a sample 29.92 m above the base of the formation yielded spore and pollen broadly indicative of a Early to Middle Triassic (Anisian) age (Thompson, 1999).

Selected provings from boreholes

SJ28NE (Upton)

⊙Borehole Nos. SJ28NE/166, 167, and 175-181, drilled for the Upton Relief Road.

These boreholes proved up to 3.7 m red, grey and reddish-brown 'shaley marl' from the middle part of the Eldersfield Mudstone Formation.

⊙Arrowe Park Hospital Borehole (SJ28NE/131); see Appendix 2

c. 99 m mottled red and brown siltstone with layers of blue-grey mudstone; some yellow, very fine-grained quartz sand; base present.

⊙Ford Pumping Station (SJ25NE/3); see Appendix 2

96.3 m hard shaly red mudstone with subordinate fine sandstone; base present.

SJ28NW (Hoylake)

⊙ SJ28NW/9.

0.5 m mudstone, reddish-brown with subordinate sandstone, reddish-brown, fine-grained

⊙ SJ28NW/15.

0.6 m mudstone, reddish-brown and greenish-grey, micaceous, laminated; some sandstone noted.

⊙ SJ28NW/16.

0.8 m clay (weathered mudstone?), reddish-brown and greenish-grey; micaceous.

⊙ SJ28NW/18.

Clay, reddish-brown, with mudstone lithorelicts. ?Fault breccia.

⊙ SJ28NW/20.

0.1 m sandstone, silty, reddish-brown, very fine-grained, one micaceous bedding plane; many small mudstone pebbles, reddish-brown.

⊙ Saughall Massie Borehole (SJ28NW/22)

c. 54 m mudstone, reddish-brown , blocky, with subordinate sandstone, ripple-laminated

Correlation with adjacent districts

In the Blackpool district, the Eldersfield Mudstone Formation, which includes two salt units, is between 181 and 311 m thick (Wilson and Evans, 1990). The formation identified on the Wirral peninsula is probably equivalent to the 'lower mudstone' unit of the Mercia Mudstone Group of Earp and Taylor, (1986), which is up to 410 m thick in the Chester district. Warrington (1999) suggests that the palynological assemblage from these beds in the Saughall Massie Borehole correlates with that of the Singleton Mudstone Member (formerly within the

Hambleton Mudstone Formation, now part of the Eldersfield Mudstone Formation) of the Blackpool district.

Sedimentology

The formation has been interpreted as the deposit of an extensive shallow lacustrine environment which was prone to drying out (Wilson, 1993). This interpretation agrees well with the descriptions of the Ford and Saughall Massie borehole sequences, where both gypsum and calcite were noted in the former, and desiccation cracks and a pseudomorph after halite were observed in the latter. Elsewhere in the East Irish Sea Basin, the lower part of the Eldersfield Mudstone Formation consists of reddish-brown laminated and blocky mudstones with interbedded gypsum and greenish-grey fine-grained sandstone beds (Wilson, 1990). Both laminated, non-laminated, and blocky mudstones have been described from borehole sections of the equivalent Bollin Mudstone Formation in the Cheshire Basin. Laminated sequences from the Cheshire Basin were thought by Arthurton (1980) to be the result of loess, partly from dust-storms, settling out in a body of standing water, although some of the ripple-laminated units can may represent sporadic sheet-flood events. Blocky-mudstone sequences from the Cheshire Basin are thought to have been deposited sub-aerially, and subsequently brecciated by evaporitic mineral growth (Arthurton, 1980).

5 QUATERNARY

The north Wirral district has had a varied Quaternary history. Deposits relating to the collapse of the Devensian East Irish Sea ice-sheet and subsequent Holocene marine incursions into the northern part of the Wirral cover much of the north Wirral district.

5.1 TILL (LATE DEVENSIAN)

Much of the north Wirral area is covered by a till ('Boulder Clay') sheet of variable thickness. In general, the surface of the till has a gently undulating form, with the till rounding off the sharper features of the solid formations beneath it. Slope gradients rarely exceed 2.5 degrees.

Boreholes prove the till has a variable composition. The deposit is a mixture of firm to stiff reddish-brown sandy and silty clay with rare pebbles. Sand and gravel-dominated patches and lenses, documented from boreholes, are fairly common within the till.

The junction between the till and underlying bedrock is usually marked by a concave break in slope. This feature is especially well-marked in the Wallasey, Bidston and West Kirby areas. In the Egremont and Arrowe Park areas, however, the base of the drift was less well featured, and was in places defined by hand-auguring and borehole evidence. Throughout most of the north Wirral district, the basal contact of the till with bedrock is between 20-30 m OD. Exceptions to this are the area around Liscard Cemetery [3085 9230], where the base is at c. 40 m OD, between Prenton and Tranmere, where the base reaches over 55 m OD, and the tract of land between Arrowe Park and Thurstaston, where the base of the till reaches a maximum of 65 m OD. The base of the till is below modern-day sea level in buried channels, which are restricted to the northern part of the district.

A ridge between Newton Bridge and Saughall Massie reaches in excess of 25 m AOD. Two boreholes have been sunk on the ridge: the Saughall Massie Borehole proves rockhead is at -8 m OD, and a borehole at Three Lanes End (SJ28NW-24) proves rockhead at -4.5 m OD. The boreholes show the ridge is therefore composed entirely of till, and is not merely thin glacial cover on bedrock. It is likely the ridge is a constructional ice-contact glacial feature, possibly a shallow-sided morainal bank of similar origin to those described by Eyles and McCabe (1989).

Till is exposed in actively eroding coastal cliff sections at Caldy. Exposures show c. 8 m of clay, which is orange-brown, stiff, pebbly and rarely sandy. Till is also exposed on the foreshore south of West Kirby Marine Lake. The composition and relationships of lithologies within the till are best displayed by a series of boreholes sunk in the tract of land between Grange and Hoylake (Appendix 5). These prove the deposit to be composed of clay with rare pebbles, interbedded with sand and gravel. Sand layers are laterally persistent over hundreds of metres.

Sedimentology

Sections exposed at Dawpool, to the south of the north Wirral district, are described in detail by Slater (1928) and Brenchley (1969). Both authors divide the drift exposed in the cliff sections into three, classified by Brenchley (1969) as a 'Lower' and 'Upper Boulder Clay' with an intervening 'Middle Sands and Gravels' unit. This stratigraphy could not be confirmed at the poorly exposed Caldy cliff sections. Brenchley (1969) suggests the till is of mixed origin, with the 'Lower Boulder Clay' the only true glacial deposit. The 'Middle Sands and Gravels' are interpreted as mainly fluvio-glacial, and the 'Upper Boulder Clay' is envisaged as settling out in glacial lakes. Therefore, the entire till sequence could be explained within just one episode of ice retreat (Brenchley, 1969), and not two, as suggested by Slater (1928).

Buried Channels

Buried Channels have been incised into the bedrock within the north Wirral district. They are of variable width, up to at least 2 km, and roughly follow the current Birket, Fender and Floats watercourses. The sub-drift surface of the Mersey was studied by Howell (1973). Howell's (1973) research indicates the buried valley morphology is atypical of a valley formed by glacial action alone. The buried channels are thought to have been drainage channels of Tertiary (Neogene) age that have been selectively overdeepened by later glacial processes. The buried channels do not have smoothly-graded longitudinal profiles. Numerous hollows were identified within channel bases, for example, at The Floats and Bromborough Pool. The hollows are thought to be a result of the localised scouring of meltwater confined at the base of a glacier. Most borehole records through the buried channels show that the basal deposit infilling the buried channels is till. After glacier retreat, the channel systems were rejuvenated by eustatically-lowered Pleistocene sea levels and subsequently filled with a complex drift of Holocene age, including sand, silt, clay and Peat (see section 4.4).

5.2 GLACIOFLUVIAL SAND AND GRAVEL (LATE DEVENSIAN)

The small patch of Glaciofluvial Sand and Gravel at Fornall Green Lane [2310 8895] is likely to be an outcrop of a lenticular sand and gravel layer within the till. It is possible that other patches of Glaciofluvial Sand and Gravel exist beneath the urbanized areas, but are not mappable individually.

5.3 TIDAL FLAT DEPOSITS (INCLUDING PEAT) (HOLOCENE)

Much of the coastal hinterland of the Wirral, and The Floats from Bidston Moss to the Mersey Estuary, are covered by a variable thickness of interbedded sand, silt, clay and peat. Individual areas of different composition could not be delineated during the resurvey, and the related deposits have been grouped together as 'Tidal Flat Deposits' on the mapface, although some of the deposits (notably the peat and some sand beds) are interpreted as terrestrial in origin (Kenna, 1986). The Tidal Flat Deposits have had a long history of research, dating back into the last century (e.g. De Rance, 1871), and continuing to the present day (e.g. Greenwood, 1999).

The Tidal Flat Deposits have a very gently undulating upper surface, between 4 and 6 m OD. The base of the deposit is commonly below OD, and Holocene deposits have been proved at levels down to -5.3 m OD at Newton Carr (SJ28NW/13) and in the region of -10 m OD between Leasowe and Bidston Moss (Kenna, 1986).

Peat has been augured beneath 0.6 m of Blown Sand, at [2609 9158], between Leasowe Castle and Leasowe Lighthouse. The previous BGS survey, carried out in 1913, shows an area of peat between Bankfield [2578 9137] and the lighthouse [2527 9129]; field evidence from the 1998 survey suggests this area is currently underlain by Blown Sand, which may have been dumped and landscaped during construction of the sea wall earlier this century.

Satisfactory correlation between Peat beds proved at Newton Carr, Dove Point, Fender Bridge, Dawpool and Bidston Moss (see Appendix 5) is hampered by a lack of borehole evidence from intervening areas. Also, removal of Peat beds by washouts, absence of Peat due to non-deposition, and repetition of Peat beds by re-deposition are factors that hamper Peat correlation (Kenna, 1986). Cowell and Innes (1994) suggest the peat sequences of the north Wirral district were deposited diachronously, and therefore Peat beds of a similar age cannot be simply correlated together. The stratigraphy of the deposit is most comprehensively proved by a series of boreholes at Newton Carr, between West Kirby and Meols (SJ28NW/7-20; see Appendix 5). Up to three peat beds are proved. The relationship of the deposits to the underlying till suggests the general sequence is one of transgressive and regressive overlap (Kenna, 1986). The sequence proved within the Tidal Flat Deposits is described using the peat beds as reference levels:

Base Holocene - base 'middle Peat' bed (interval includes 'unit 1' of Kenna, 1986, and 'lower peat/lower marine facies' of Innes *et al*, 1990)

The lowermost peat is proved in SJ28NW/13, and is 0.2 m thick. This is overlain by 2.65 m blue-grey silt of probable Holocene age (Kenna, 1986). At Leasowe, this clay, which is beneath the 'middle Peat' bed, is penetrated by roots from the 'middle Peat' bed (Travis, 1929). Marine-estuarine diatoms and valves of *Mya sp., Mytillus edulis* and *Cardium sp.* have been recovered from the clay from sections north of Parkfield House [c.2420 9110] (Kenna, 1986).

Base 'middle Peat' bed - base 'upper Peat' bed (interval includes 'lower Peat and forest bed' of Travis, 1929, 'units 2-3' of Kenna, 1986, and 'middle Peat/middle marine facies' of Innes *et al*, 1990)

The 'middle Peat' bed is dark brown or black, laminated and laterally impersistent (Kenna, 1986). It has been proved in boreholes SJ28NW/13, 16 and 20, where it is between 0.2 and 0.8 m thick. The base of the peat is between -2.45 and -3.5 m OD, and its upper surface is between -2.1 and -3.1 m OD. The 'middle Peat' bed rests on either Holocene blue clay or directly on deposits of supposed late Devensian age (Travis, 1929; Kenna, 1986). Pollen and twigs from oak and birch are common within the 'middle Peat' bed; rarer are pollen from hazel, and remains of beetle and insect eggs (Travis, 1929). The 'middle Peat' bed is overlain by interbedded brown silty clay, blue-grey silt and grey sand; these are the 'Leasowe Marine Beds' of Kenna, (1986). Brackish-marine diatoms have been identified from this unit, along with *Scrobicularia plana*, apparently in growth positions (Kenna, 1986). The 'Leasowe Marine Beds' are up to 2.96 m thick (Travis, 1929). The upper surface of the 'Leasowe Marine Beds' is penetrated by roots from the 'upper Peat' bed.

Base 'upper Peat' bed - base Blown Sand (interval includes the 'upper Peat and forest bed' of Travis, 1929, 'units 4-8' of Kenna, 1986, and 'upper Peat and upper marine facies' of Innes *et al*, 1990)

The 'upper Peat' bed is proved in boreholes SJ28NW/11, 16, 17 and 20. The base of the Peat bed is between 1.7 and 2.4 m OD, and the top is between 2.4 and 3.35 m OD, and the thickness is between 0.7 and 1.3 m. The composition of the peat bed is variable, from a peat-rich sand to a true carbonaceous peat (Travis, 1929). Preserved oak, pine and birch are common; hazel and alder are rarer (Travis, 1929). At Newton Carr, the 'upper Peat' bed is overlain by a sequence of interbedded sand and silt, which was termed the 'upper marine facies' by Innes *et al* (1990).

North of Parkfield House the upper Peat bed is overlain by the *Tellina balthica* sand, a laterally inpersistent olive-coloured sand bed up to 0.4 m thick (Kenna, 1986). This sand has yielded marine-estuarine shells and diatoms (Kenna, 1986). The *Tellina balthica* sand is overlain by a thin Peat bed. Where the *Tellina balthica* sand and overlying thin Peat bed are absent, the 'upper Peat' bed north of Parkfield House is overlain by a so-called 'soil bed' ('unit 7' of Kenna, 1986). A probable lateral equivalent of this unit has been observed north of Wallasey Golf Links [c. 2800 9300] (Kenna, 1986). Pollen including bog bean and bog myrtle was recovered from the 'soil bed'. (Kenna, 1986). North of Parkfield House, the thin Peat bed or 'soil bed' is overlain by a variable thickness of laminated, peaty *Bithinia tentaculata* sand. The Older Tidal Flat Deposits are covered in part by Blown Sand.

Sedimentology

Travis (1922) suggested the peat beds were interdune deposits, and that the overlying clays and sands were marine, with the alternation and repetition of the sequence being due to sea-level fluctuations. Travis (1929) later postulated that a coastal dune fringe was built up in times of low sea level, and that this allowed the accumulation of Peat both in dune-slacks and in landward areas of the dunes. When sea levels rose, the dune barriers were breached and marine deposits were laid down. A further sea-level drop allowed the next stratigraphically higher peat to accumulate.

Kenna's (1986) interpretation suggests that the blue-grey silt under the 'middle Peat' represents the first Flandrian marine phase. Pollen taken from the 'middle Peat' indicates deposition in proximity to salt-marsh conditions, c. 6420 years BP. The 'Leasowe Marine Beds', between the 'middle' and 'upper Peat' beds, are interpreted as upper tidal flat deposits, as indicated by brackish marine-diatoms. The Upper Peat/ Forest Bed were deposited in a fen carr- raised bog setting. Pollen spectra from the basal part of the 'upper Peat' bed indicate a Flandrian II age, whereas those from the middle and upper parts of the 'upper Peat' bed give a Flandrian III age. The *Tellina balthica* sand is interpreted as an estuarine deposit. The assemblage of pollen from the thin Peat bed overlying the *Tellina balthica* sand suggests an open woodland environment. The 'soil bed' and *Bithinia tentaculata* sand are thought to represent deposition in dune-slacks, the former dated at 925^{+}-50 years BP to 540 years BP, the latter post-dating c. 540 years BP.

Innes *et al.* (1990) interpret the Newton Carr data as three periods of terrestrial and freshwater/ brackish water-dominated depositional environments (Table 3).

Table 3: Interpretation of the Tidal Flat Deposits sequence, incorporating data from Kenna (1986) and Innes *et al* (1990).

Stratigraphical Unit	5.3.1.1 DOMINANT ENVIRONMENT	**Chronozone (F=Flandrian)**
top 'upper Peat' bed - base Blown Sand	Mixed marine and terrestrial: estuarine- open woodland- dune slack	FIII
'upper Peat' bed	Terrestrial: Fenn carr- raised bog	FII-FIII
top 'middle Peat' bed - base 'upper Peat' bed ('Leasowe Marine Beds')	Marine: Upper tidal flat	FII
'middle Peat' bed	Terrestrial; proximal to salt-marsh	FII
top 'lower Peat' bed - base 'middle Peat'	Marine	FII
'lower Peat' bed	Terrestrial: pine-alder woodland	FI-FII

Innes *et al.* (1990) challenge the idea of 'catastrophic' breaching of sand dunes, as suggested by Travis (1929). They state that the pollen record shows a stable succession from terrestrial to marine conditions. This was interpreted as the result of gradual groundwater movements in lagoonal- perimarine situations.

Cowell and Innes (1994) have studied the distribution of Peat beds in the Merseyside area, including the Newton Carr deposits. They note that the 'middle Peat' bed at Newton Carr is present in boreholes 11, 16, 17 and 20. Contemporaneous marine deposits in boreholes 13-15 indicate there was a shoreline between the two transects of boreholes during the deposition of the 'middle Peat' bed.

5.4 MARINE AND COASTAL ZONE DEPOSITS (UNDIFFERENTIATED) (HOLOCENE)

These deposits occupy the intertidal zone in the Mersey and Dee estuaries, and along the north Wirral coast. The north and western coastlines of the Wirral are flanked by extensive tidal flats, which are submerged at high tide. The deposits are composed of sand and mud, which is commonly current- and wave-rippled. The deposits form large bars and sandbanks, such as Lime Wharf off West Kirby, and Mockbeggar Wharf, Great Burbo and North Banks off the north Wirral coast. Silt and clay contents are high within the Dee Estuary.

Deposits flanking the Mersey have for the most part been built on, and their presence has been inferred from borehole evidence. Tranmere Pool, between Tranmere railway station and Cammel Laird shipyard, is a former estuarine embayment floored by sand and silt. Cammel Laird shipyard and the Tranmere oil terminal are areas of manmade land built out onto estuarine deposits.

5.5 ALLUVIUM (HOLOCENE)

Thin tracts of alluvium are developed along Arrowe Brook, The Fender and part of Greasby Brook. The Alluvium is typically composed of firm to stiff brown clay with lenses of gravel, sand and silt. Boreholes along the course of the Fender between Prenton and Woodchurch prove alluvium to be in the region of 3.05 m thick.

5.6 SALT-MARSH DEPOSITS (HOLOCENE)

A thin strip of salt-marsh is developed on the seaward fringe of the sand dunes at the Royal Liverpool Golf Club at Hoylake (centred on [2058 8810]). The area forms part of the Wirral Coastal Nature Reserve. The deposit consists of fine-grained sand, silt, and commonly has a fairly high organic content. A small salt-marsh deposit also occurs at New Ferry [8435 8545].

5.7 BLOWN SAND (HOLOCENE)

The north and west shores of the north Wirral district are for the most part fringed by an apron of Blown Sand. Blown Sand extends inland for over a kilometre in the Wallasey area. Blown Sand typically has a subdued, sheet-like topography, with slope gradients generally less than 0.5 degrees; the top of the deposit is typically below the 10 m contour. Dunes have developed in places along the coast, principally at the Royal Liverpool Golf Club (Hoylake) [2070 8810] and Wallasey Golf Links [2830 9300], where they attain a height of 26 m. In some of the more built up areas, such as New Brighton, Wallasey and Hoylake, sand dunes have been flattened, moulded in shape or completely removed by man. The sand is mostly fine- to coarse-grained and of variable sorting. Blown Sand deposits are currently fairly stable; evidence from old maps indicates that dune aggradation and erosion rates are probably negligible. Dune development was stimulated by the most recent sea-level fall during early Flandrian III times.

Main Borehole sections

SJ28NW (Hoylake)

SJ28NW/1 (Royal Liverpool Golf Club, previously 'Hoylake Golf Links')

> A shallow borehole drilled in 1898-99 proved 21.33 m Blown Sand ('quicksand') on 3.04 m till ('clay') on bedrock.

SJ28NW/2

> 2.89 m yellow sand on interbedded clay, sand and gravel.

SJ28NW/3

> 4.57 m brown sand on interbedded till, sand and gravel.

SJ39SW (New Brighton)

SJ39SW/497 (Kwik Save, New Brighton)

> 2 m fine- to medium-grained 'dense' sand on bedrock.

6 STRUCTURE

The Triassic rocks within the northern and western parts of the district have gentle dips of between 2 and 10 degrees north-eastwards. However, in the Rock Ferry area the dip, based on formation younging directions, is gentle to the south-west. The true dip at most exposures is masked by cross-bedding, although most of the major set bounding surfaces have a northerly component to their dip-azimuth (see Appendix 4).

The district lies on the Llyn-Rossendale ridge, an inter-basin high separating the extensional Permo-Triassic basins of the East Irish Sea to the north and Cheshire to the south. A series of seismic lines have been shot over parts of the Wirral peninsula, and coverage is fairly good for the southern and western parts of the north Wirral district but poor in the north and east. Interpretations of these lines are given in Evans *et al* (1996) and Evans (1998). Interpretation of the seismic profiles is somewhat hampered by the paucity of deep boreholes with good geophysical and lithological logs.

The major structures in the north Wirral district are normal (extensional) faults. Folding is apparently not as important as once thought by Owen (1946). Several subparallel, north- to north-easterly-trending faults cross the north Wirral district. Downthrows are mainly to the west; easterly downthrows are comparatively rare.

The *Stanley Fault* has been conjectured to resolve the stratigraphical mismatch between Hilbre Point (Helsby Sandstone Formation) and the majority of West Kirby (Wilmslow Sandstone Formation). The fault has an estimated westward throw of at least 70-100 m.

The *Grange* and *Caldy faults* both throw the Delamere Member of the Helsby Sandstone Formation against the Wilmslow Sandstone Formation. Their positions at Caldy have been proved by both field and seismic evidence. Further north, their positions at Newton Carr have been interpreted using both borehole evidence and seismic interpretation. Both faults are estimated to have westerly throws in the region of 70 m. The Grange Fault was proved by the Hoylake Water Works No.2 Borehole, where it was intercepted at 178.36 m below ground level.

The *Thurstaston Fault* has been proved from seismic evidence. Displacement is presumed to be in the region of 20 m eastwards. The fault is truncated by the Frankby Fault in the Heswall district (SJ28SE), to the south of the area covered by this report.

The *Frankby Fault* throws the Eldersfield Mudstone Formation against the Helsby Sandstone Formation. The fault has been defined using seismic, field and borehole evidence. The fault has a throw of approximately 120 m to the west.

The *Greasby Fault* throws the Helsby Sandstone Formation against the Tarporley Siltstone Formation. The throw is estimated to be no more than 40 m to the east.

An unnamed fault immediately west of Arrowe Park Hospital has been proved by both borehole and field evidence. The Arrowe Park Hospital Borehole proves in the region of 104 m of the basal Eldersfield Mudstone Formation. Less than 600 m to the west, the Tarporley Siltstone Formation is exposed. A fault with an estimated throw of 100 m to the east solves the space problem created, assuming a dip of 8 degrees north-eastwards.

The *Woodchurch Fault* is a major down-west fault, with an estimated throw of 200-400 m. The location of the fault is estimated from seismic surveys; the fault was intercepted by the Ford Pumping Station Borehole at a depth of 231.70 m.

Numerous faults typically throwing less than 10 m have been proved by field mapping between the Woodchurch and Seacombe Faults, in the Oxton to New Brighton area. Most of the smaller faults throw to the west.

The *Barnston Fault* has a throw presumed to be no more than 40 m to the north-west. The fault has been proved from seismic evidence.

The Chester Pebble Beds Formation is fault bounded in the north Wirral district. The formation is faulted against either the Wilmslow or Helsby Sandstone formations; faults are therefore estimated to have throws in excess of 250-300 m.

The unnamed fault east of Storeton Hill is likely to be fairly minor, with an estimated westerly throw perhaps as low as 20 m.

The *Seacombe Fault* throws the Helsby and Wilmslow Sandstone formations against the Chester Pebble Beds to the west of the district. The fault has a throw estimated to be at least 320 m to the west.

Seismic interpretation indicates a structural model with the main synthetic faults being down-west, and extensional antithetic faults down-east (Evans 1998). Evans *et al* (1996) consider a small reverse fault antithetic to the Woodchurch Fault, to indicate compressive stresses associated with Cenozoic (Alpine) basin inversion. Minor faulting within the Sherwood Sandstone Group is commonly associated with barite or calcite-cemented 'cataclastic' fractures, zones which may be several metres wide.

The base of the Helsby Sandstone Formation is regarded by many (e.g., Hull, 1869; Colter and Barr, 1975; Warrington, 1970) to be the equivalent surface to the Hardegsen Unconformity, which can be mapped across much of northern Europe. Others (e.g., Thompson, 1970a; Colter, 1978; Evans *et al*, 1993) have considered the base of the Thurstaston Hard Bed to be this surface, but for reasons discussed earlier, the base of the Hard Bed is no longer taken as the base of the Helsby Sandstone Formation. Evans (1998) considers the possibility that the base of the Delamere Sandstone Member is the equivalent of the Hardegesen Unconformity, which appears a more reasonable view when considering the widespread lateral extent of the Delamere Sandstone Member compared to the Thurstaston Hard Bed.

7 ECONOMIC GEOLOGY

7.1 BRICK CLAY

Clay for brick making has been extracted from both the till and Tidal Flat Deposits (Table 4). Today, the Newton Carr brickworks [245 897] is the only brick pit in operation in the district.

Table 4: Details of former brick pits, north Wirral district.

Name	**NGR**	**Deposit worked**	*Restoration*	**Use in 1999**
Newton Carr Brickworks	2445 8970	Till		working clay pit
Prenton Dell	2950 8600	Till	partial	Electric sub-station/public open space
Coronation Park	2605 8755	Till	full	Residential housing/parkland
Moreton Brickworks	2555 9075	Till	full	Golf driving range
Moreton Brickworks	2520 9060	Till	none	derelict
Leasowe Road	2800 9195	Older Tidal Flat Deposits	full	public open space
Oxton/Arno (Home Lane)	3015 8700	Till	full	public open space
New Ferry Brick and Iron Works	3415 8545	Till	full	Residential housing/public open space
Belvedere Road	3005 9225	Till	full	Public open space
Seacombe Brickfields	3135 9085; 3125 9060	Till	full	Industrial/public open space

The till between the A553 and East Farm Mews [2366 8554] and between Arrowe Park and Irby Hill has been dug for clay ('marl'). Almost every field in these areas has at least one small pit, rarely exceeding 100 m in diameter and usually less than 4 m in depth. Clay extracted was used up until the mid 1800s to improve the sandy soils (Wedd *et al.,* 1923). Mudstone from the Mercia Mudstone Group was also dug for this purpose.

7.2 BUILDING STONE

There are numerous sandstone quarries in the north Wirral district. At the present time, none are actively worked. The Chester Pebble Beds have been quarried in three quarries at Tranmere: [3239 8774], [3234 8786] and [3221 8791]. The Helsby Sandstone Formation, (particularly the pebbly units), has provided most of the building stone for the Wirral. Major quarries are Storeton Hill [3140 3000], The Arno, Oxton [3044 8726], Flaybrick Cemetery, Bidston [2934 8956], The Breck, Wallasey [2978 9176] and Irby Hill [2515 8590]. A small quarry at Lingdale, Claughton [2982 8864] was active at the time of the last survey (Wedd *et al.*, 1923). The Wilmslow Sandstone Formation was largely unexploited as it is on the whole a weakly cemented rock that is unsuitable for use as a building stone.

7.3 HYDROCARBONS

Facies relationships within the Permo-Trias of the Wirral are similar to those of the reservoirs of the Formby and East Irish Sea hydrocarbon fields. Although economic hydrocarbons have not been discovered within the Cheshire Basin, the strata exposed on the Wirral peninsula give the best analogue available for understanding the interrelationships between the facies and formations offshore and on the Fylde. The Wirral Peninsula has played host to many oil-company fieldtrips, where the interplay between aeolian and fluvial systems can be clearly displayed.

7.4 GROUNDWATER

The Sherwood Sandstone Group forms the major aquifer in the district. The aquifer is not wholly homogeneous since beds of mudstone and siltstone provide local horizontal divisions, so that the horizontal permeability may be greater than the vertical one. Fissure flow is normally predominant over intergranular flow (Williams *et al.*, 1972; Bretton and Skinner, 1974). Transmissivities for the Sherwood Sandstone Group in the Cheshire Basin are typically between 14 and 2000 cubic metres per day. The aquifer is confined in the central northern part of the district by the Mercia Mudstone Group. Locally occuring clay-rich till can also act as a confining layer to the aquifer. Aquifer replemishment is almost entirely from rainfall, although there is minor input from the stream systems on the peninsula.

The Mercia Mudstone Group is a non-aquifer; limited reserves of water may occur in thin sandstone units that may be present throughout the unit. Sand and gravel lenses in the drift are potential minor aquifers. Made Ground can also contain groundwater where it overlies low-permeability deposits.

8 MAN-MADE DEPOSITS

8.1 WORKED GROUND

The main areas of worked ground in the district are quarries and pits (see Section 7). The most extensive road and rail cuttings occur at Wallasey, Seacombe and New Ferry, and along the M53.

8.2 MADE GROUND

The major areas of Made Ground in the district are associated with landfill, coastal expansion and defence, and the docklands. The three main areas of landfill are at Bidston Moss [2920 9120], Wallacre [2880 9160], and Grange [2210 8790]. Bidston Moss is by far the largest deposit, estimated to be up to 30 m thick in places. The limits of the tip at Grange are poorly defined due to landscaping; boreholes locally prove up to 2 m of Made Ground.

Boreholes from Seacombe Docks [3160 9035] show that the Made Groud is in the region of 4 m thick; fill is generally thicker under the docks to the south of The Floats. Made Ground is also associated with road junctions and embankments along the M53. Made ground of variable thickness can be assumed to be present in all urban, built-over and landscaped areas.

Several coastal areas of the Wirral have been built on land that was previously intertidal (i.e. these areas of fill on either Older or modern Tidal Flat Deposits). The main sites of this type are Tranmere Oil Terminal, part of the Cammel Laird shipyard site, the majority of the docks fringing The Floats, and a thin strip of land north of Red Noses.

8.3 INFILLED GROUND

Disused clay pits, most of which have been backfilled are found over much of the drift-covered parts of the district. The largest areas of Infilled Ground are:

Moreton Clay Pit, Moreton [2560 9080]

Leasowe Road, Leasowe [2800 9190]

Holm Lane, Oxton [3020 8700]

Numerous small infilled pits are common in the tract of land between Meols and Frankby, and between Irby Hill and Prenton.

8.4 LANDSCAPED GROUND

Landscaped ground depicted on the mapface has been restricted to golf-courses and large industrial sites, where areas of shallow cut and fill could not easily be identified or represented. In reality, a large proportion of the urbanised area of the north Wirral district has been landscaped to some extent, especially the areas of sand dunes that have been urbanized, for example, at Meols. Specifically, newly built-on areas are commonly landscaped or terraced to reduce gradients prior to construction.

9 GEOLOGICAL HAZARDS

This section is intended as a summary of the principal geological hazards identified in the area at the last date of survey. It is not exhaustive and should not be used under any circumstances to replace any part of a geological investigation.

9.1 UNCONSOLIDATED DEPOSITS (EXCLUDING BLOWN SAND)

Unconsolidated deposits in the north Wirral district include **Till, Head, Salt-marsh, Tidal Flat Deposits, Marine and Coastal Zone Deposits (undifferentiated), and Made Ground.** Unconsolidated deposits are internally heterogeneous, and can be highly compressible compared with other drift deposits or bedrock, and may give rise to excessive or differential settlement of superposed structures. For this reason particular care should be taken in the siting of any construction on such deposits. The presence of relatively impermeable till beneath sand may cause the presence of a perched water table. Running conditions may be encountered in such unconsolidated deposits if encountered below the water table.

Currently, there is considerable urban expansion taking place on the Older Tidal Flat Deposits of the Birket and Fender valleys. It should be taken into consideration that the upper surface of the alluvium between Moreton, Leasowe and Bidston is only 4-6 m OD; mean high water spring tide is 4.37 m OD, and the highest astronomical tide is 5.37 m (Kenna, 1986). The interbedded peat deposits also present (individually up to c. 1 m thick) may be highly compressive and be potentially unstable for the placement of superimposed structures.

9.2 BLOWN SAND (FROM NUTT AND LOWE, 1986)

Characteristically this sand has no plasticity, swelling or cohesion and its permeability is very high. The water table may be at any depth according to local circumstances. It is, however, well defined when present and may cause problems in deep excavation trenches and in the construction of buildings with basements. Usually this deposit provides unsatisfactory foundations for surface structures, unless treated, and needs to be removed if possible. Likewise, it can produce problems when trenched because of its loose nature (the deposit may 'run' if saturated) and water content.

9.3 LANDSLIP

The solid and drift formations of the north Wirral are not significantly affected by landslipping, although soil creep is to be expected on the steeper slopes. Unprotected areas of coastline, such as the Dawpool Cliffs south of West Kirby [2186 8547 southwards] and the New Ferry coast [3401 8593]-[3434 8534], may be subject to coastal erosion, which removes land mostly by landslip and bankslip processes. Historically, other parts of the coastline, particularly at Dove Point, have been subject to fairly severe coastal erosion, estimated at up to 182 m between c.1823 and 1903 (Wedd *et al.,* 1923). These processes have been greatly reduced by the construction of sea-defences. These include sea-walls and groynes on the northern coast, and concrete wave-breaks and barriers at Wallasey on the Mersey, and Dawpool on the Dee.

9.4 AQUIFER VULNERABILITY (AS DESIGNATED BY THE EA, 1994)

Soils from urban areas are designated to have a high leaching potential.

The Sherwood Sandstone Group is a designated major aquifer. It has a high permeability and has a high aquifer vulnerability.

The Mercia Mudstone Group is a designated non-aquifer. It has a low-to negligible permeability, and consequentially has a low aquifer vulnerability.

The presence of relatively impermeable clay-rich superficial deposits on bedrock (such as till and Older Tidal Flat Deposits) may affect transmission between the surface and the underlying aquifer.

Appendix 1 List of boreholes referred to in text

SJ28NW (Hoylake)

Hoylake Water Works No. 1 (SJ28NW 4)

Date drilled: pre 1910

Drilled by: Hoylake and West Kirby Gas and Water Company

NGR: [2246 8627]

Total length: 126.52

Hoylake Water Works No. 2 (SJ28NW 5)

Date drilled: pre 1910

Drilled by: Hoylake and West Kirby Gas and Water Company

NGR: [2252 8630]

Total length: 294.82

Newton No. 1, Grange (SJ28NW 6)

Date drilled: pre 1910

Drilled by: Hoylake and West Kirby Gas and Water Company

NGR: 2331 8634]

Total length: 238.72

Saughall Massie (SJ28NW 22)

Date drilled: 11/1984

Drilled by: North West Water

NGR: [2431 8845]

Total length: c. 150.00

SJ28NE (Upton)

Ford Pumping Station (SJ28NE 3)

Date drilled: c. 1913

Drilled by: Birkenhead Corporation

NGR: [2795 8826]

Total length: 243.84

Co Op Dairy Borehole, Woodchurch (SJ28NE 8)

Date drilled: 11/1930

Drilled by: Birkenhead and district Co-Op

NGR: [2981 8675]

Total length: 184.40

Creamery, Saughall Massie (SJ28NE 9)

Date drilled: ?1930s
Drilled by: Wirral Milk Supplies
NGR: [2585 8856]
Total length: 91.44

SJ28NE/61

Date drilled: 6/1966
Drilled by: Soil Mechanics
NGR: [2868 8709]
Total length: 8.08

Arrowe Park Hospital Borehole (SJ28NE 131)

Date drilled: 11/1986
Drilled by: Hydrotechnica
NGR: [2708 8659]
Total length: c. 210.00

SJ29SE (Leasowe)

Bidston Coal Trial Borehole (SJ29SE 2)

Date drilled: 05/1892
Drilled by: Bidston Exploration Co.
NGR: [2834 9088]
Total length: 868.68

SJ38NW (Tranmere)

Prenton Pumping Station (SJ38NW 5)

Date drilled: 1898
Drilled by: Birkenhead Corporation
NGR: [3151 8605]
Total length: 259.08

Spring Hill Pumping Station (SJ38NW 10)

Date drilled: c. 1891
Drilled by: Birkenhead Corporation
NGR: c. [3098 8808]
Total length: 274.42

SJ39SW (New Brighton)

Liscard Pumping Station (SJ39SW 55)

Date drilled: c. 1890

Drilled by: Birkenhead Corporation

NGR: [3029 9241]

Total length: 275.30

Vernons Flour Mills (SJ39SW 61)

Date drilled: unknown

Drilled by: Isler & Co

NGR: [3176 9030]

Total length: 213.41

Appendix 2 Deep borehole sections from the north Wirral district

Graphic lithological logs of the major deep boreholes from the north Wirral district have been drawn up by the author (with the exception of Arrowe Park Hospital, which is by Hydrotechnica with stratigraphic interpretation by E Hough). Original copies of the borehole records are available from the NGDC, British Geological Survey, Keyworth, Nottingham, NG12 5GG.

Hoylake

BRITISH GEOLOGICAL SURVEY

Sheet 1 of 1

Borehole/Well No. 1:527 (1cm : 5·27m)

Location Hoylake Water Works No. 1

NGR/Lat. & Long. SJ 28 NW-4

KB/Ground level c. 57·9m

Logged by ? W C Simmonds, 1913.

Stratigraphy	Carbonates Calc. R | Calc. A | Calc. L Average grain size C P G VC C M F VF Sl C	Sedimentary structures	Graphic lithology	Lithological description
Delamere Pebbly Sandstone Mbr; Helsby Sandstone Fm.	3·04			3·04 'Keuper Sandstone'
previously 'Wilmslow Sandstone Formation; redefined 'Thurstaston soft sandstone Member'				60.98 'Upper Mottled Sandstone'
Thurstaston Hard Bed	64·02			1·52 'Hard Bed'
Wilmslow Sandstone Formation	65·54			60·98 'Upper Mottled Sandstone'
	base of borehole 126.52			

Hoylake

BRITISH GEOLOGICAL SURVEY

Sheet 1 of 1

Borehole/Well No. 1:1228 (1cm : 12.28m)

Location Hoylake Water Works No.2

KB/Ground level c. 57.9 m

NGR/Lat. & Long. SJ28NW-5

Logged by ?W.C. Simmonds, 1913

Stratigraphy	Carbonates Calc. R | Calc. A | Calc. L Average grain size C P G VC C M F VF SI C	Sedimentary structures	Graphic lithology	Lithological description
Delamere Pebbly Sandstone Mbr, Helsby Sandstone Fm	9.15			9.15 'Keuper Sandstone'
previously Wilmslow Sandstone Fm; re-defined Thurstaston Soft Sst Fm.				169.21 'Upper Mottled Sandstone' Hard bed c. 57.92 m below top.
Thurstaston Hard Bed	c. 67.07			
Wilmslow Sandstone Formation	178.36			Faulted contact (Caldy Grange
Helsby Sandstone Formation (undiff)	base of borehole 294.82			116.46 'Upper Pebble Beds'

Hoylake

BRITISH GEOLOGICAL SURVEY

Sheet 1 **of** 1

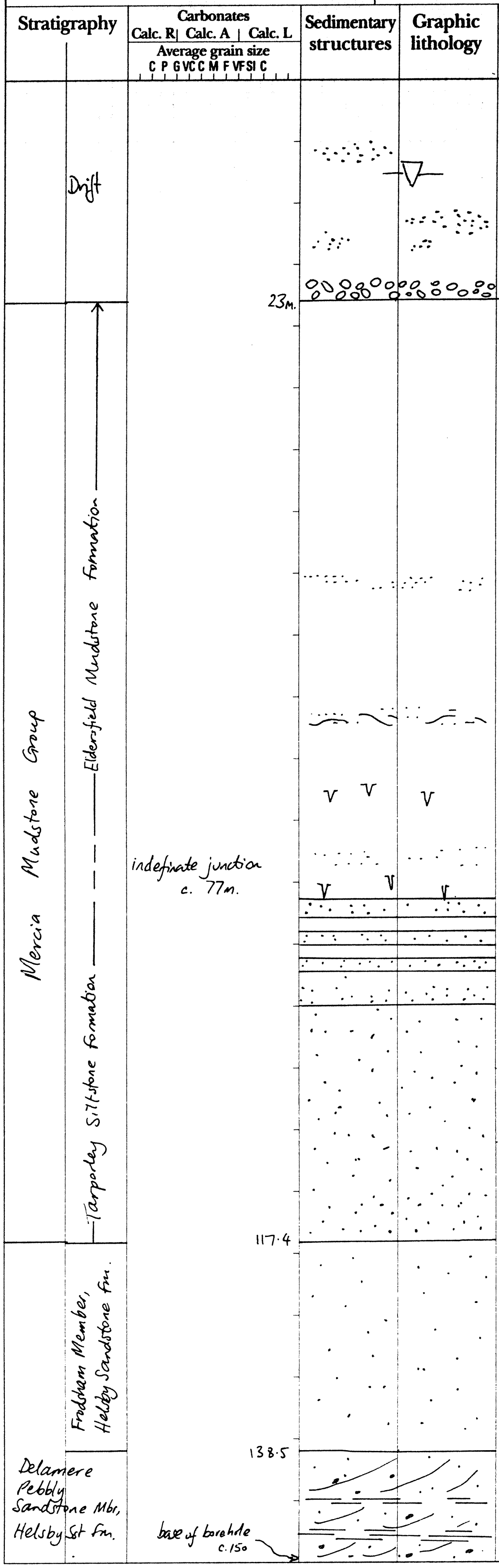
Borehole/Well No. 1:625 (1cm: 6.25m).

Location Saughall Massie

NGR/Lat. & Long. SJ28NW/22

KB/Ground level c. 15m.

Logged by North West Water



Lithological description

23m Clay with sandy lenses.

Gravel below 20m.

Red-brown mudstone with micaceous layers.
minor fault, re-cemented at c. 27.5.

Grey-green interlaminated mudstone, siltstone and sandstone
Grey-green mudstone.

Massive, blocky red mudstone.

Interbedded sandstone and shale; contorted bedding c. 65.5

sand-filled desiccation cracks c. 72.5

Interbedded sandstone and mudstone
sand-filled desiccation cracks c. 82.5

Silty sandstone; becomes sandier with depth.

Hard siltstone/fine sandstone. Many bedding structures.
Interlaminated. Sandier & red-brown towards base.

21.1 red, 'soft' fine-grained sandstone. Little evidence of bedding; Cataclastic faults/fractures noted. Rounded grains.

11.5 Dull red fine-grained pebble-free sandstone. Coarser to base. Sporadic mudstone pellets. Interbedded with thin mudstone. Cross-bedded.

Hoylake

BRITISH GEOLOGICAL SURVEY

Sheet 1 of 1

Borehole/Well No. 1: 995 (1cm : 9.95m).

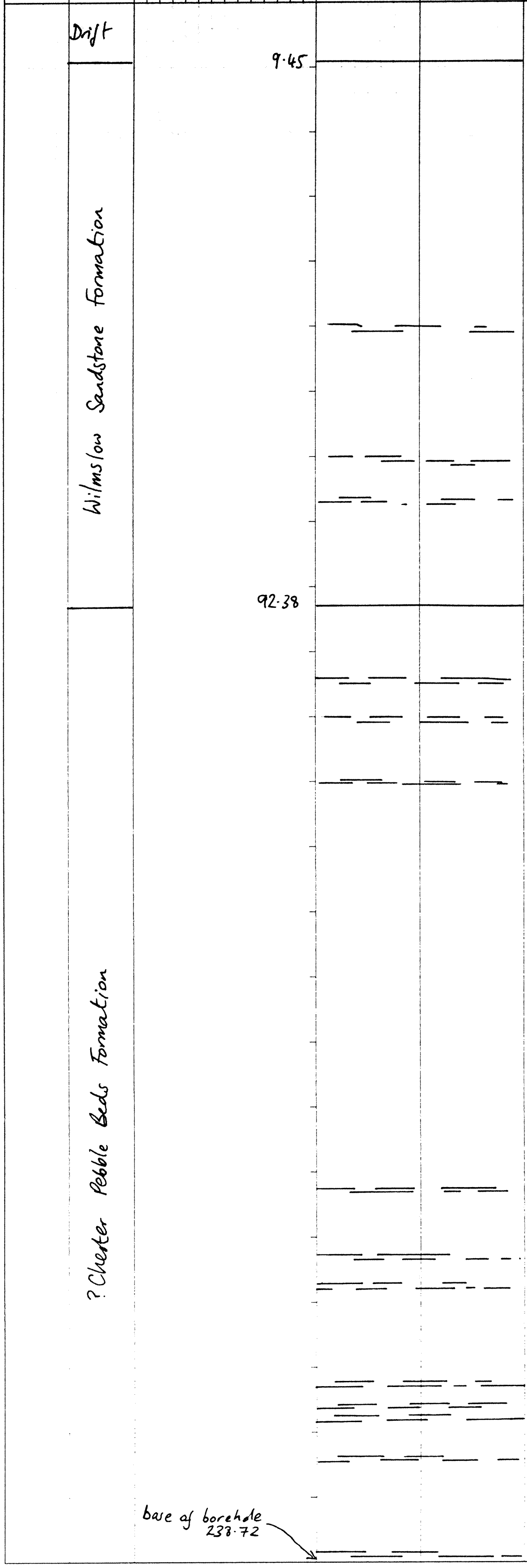
Location Newton No. 1 (Grange)

NGR/Lat. & Long. SJ28NW-6

KB/Ground level c. 21.0 m.

Logged by

Stratigraphy	Carbonates Calc. R | Calc. A | Calc. L Average grain size C P G VC C M F VF SI C	Sedimentary structures	Graphic lithology	Lithological description



9.45 Drift

82.93 Sandstone with subordinate shale/marl beds.

146.34 Sandstone, in places hard, with subordinate red shale beds (& mudstone)

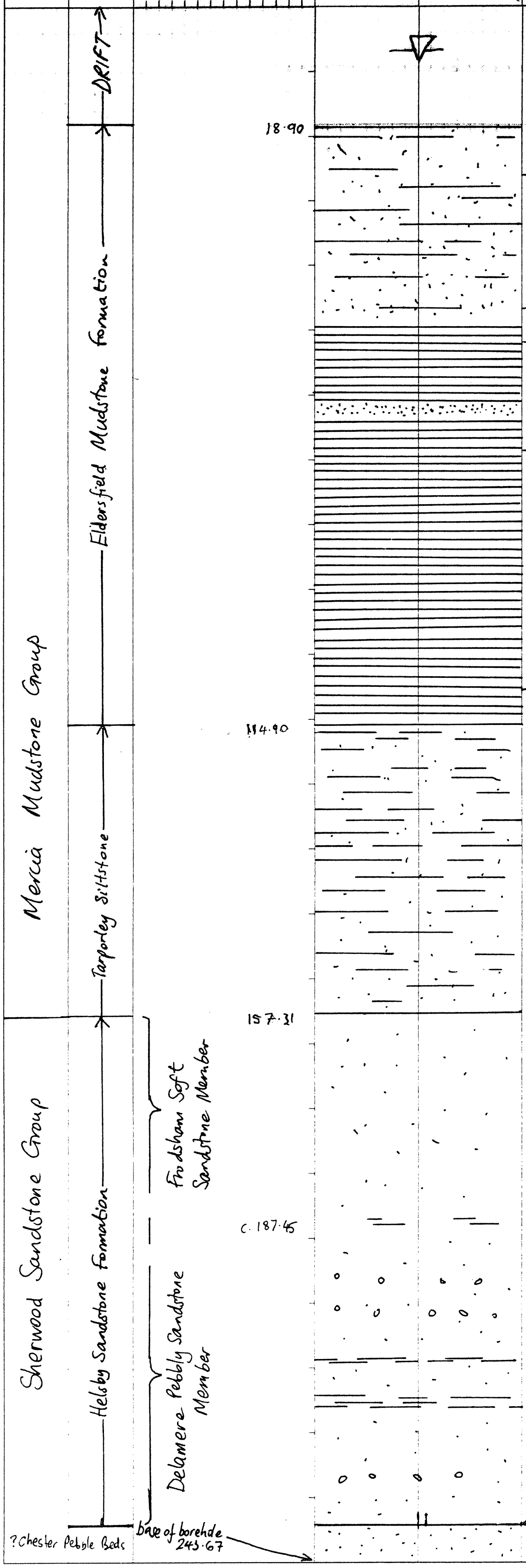
Arrowe Park Sheet

BRITISH GEOLOGICAL SURVEY

Sheet of

Borehole/Well No. 1:1016 (1cm:10·16m)	**Location** Ford Pumping Station	**NGR/Lat. & Long.** SJ28NE-3
	KB/Ground level c. 10m.	**Logged by** WC Simmons, 1913.

Stratigraphy	**Carbonates** Calc. R | Calc. A | Calc. L **Average grain size** C P G VC C M F VF SI C	**Sedimentary structures**	**Graphic lithology**	**Lithological description**



18·90 Drift

96·03 Hard shaley red mudstone with subordinate fine sandstone.

- 26·8 gypsum noted.

Mostly 'sandy marl' above 50m.

- 48·15 - 49·37 Calcite noted

- 68·38 gypsum noted

- 107·28 calcite noted

42·38 Micaceous sandstone and shale (previously 'Waterstones')

74·39 Sandstone, pebbly sandstone and subordinate mudstone.

c 30·14

c. 44·25

Faulted contact (Woodchurch Fault)

11·97 Fine grained red and white sandstone. (upper 2·13m 'fault rock').

BRITISH GEOLOGICAL SURVEY

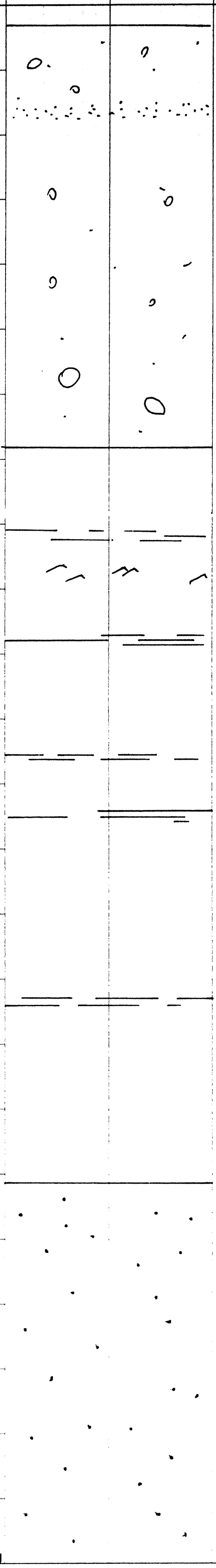
Sheet 1 of 1

Arrowe Park Sheet

Borehole/Well No. 1: 381 (1 cm : 3·81 m)	Location Creamery, Saughall Massie KB/Ground level c. 15m	NGR/Lat. & Long. SJ28NE -9 Logged by E Timmins & sons

Carbonates: Calc. R | Calc. A | Calc. L

Average grain size: C P G VC C M F VF SI C



Stratigraphy		Sedimentary structures / Graphic lithology	Lithological description
	0·6		0·6 Fill
DRIFT	25·90		25-30 Brown boulder clay and grey sand
? Mudstone Formation ? Mercia Mudstone Group Tarporley Siltstone Formation	69·03		43·13 Red marl; sandy Micaceous; grey grey with harder bands
Sherwood Sandstone Group Helsby Sandstone Formation	base of borehole 91.44		22·41 Grey fine-grained hard sandstone very feintly laminated.

Arrowe Park Sheet

BRITISH GEOLOGICAL SURVEY

Sheet of

Borehole/Well No. 1: 7·68 (1cm : 7·68m)	**Location** Co-Op Dairy Woodchurch	**NGR/Lat. & Long.** SJ28NE - 8
	KB/Ground level 34·7	**Logged by**

Stratigraphy	Carbonates Calc. R | Calc. A | Calc. L Average grain size C P G VC C M F VF Sl C	Sedimentary structures	Graphic lithology	Lithological description
DRIFT				28.65 'Soft layers of sand and loam'
Wilmslow Sandstone formation	28·65			34·74 'Soft red sandstone with layers of loam.'
Chester Pebble Beds	63·39			121.01 'hard red and white sandstone'.
	base of borehole 184·4m			

BRITISH GEOLOGICAL SURVEY

Sheet 1 of 1

LEASOWE SHEET

Borehole/Well No. 1:3625 (1cm:36.25m.)

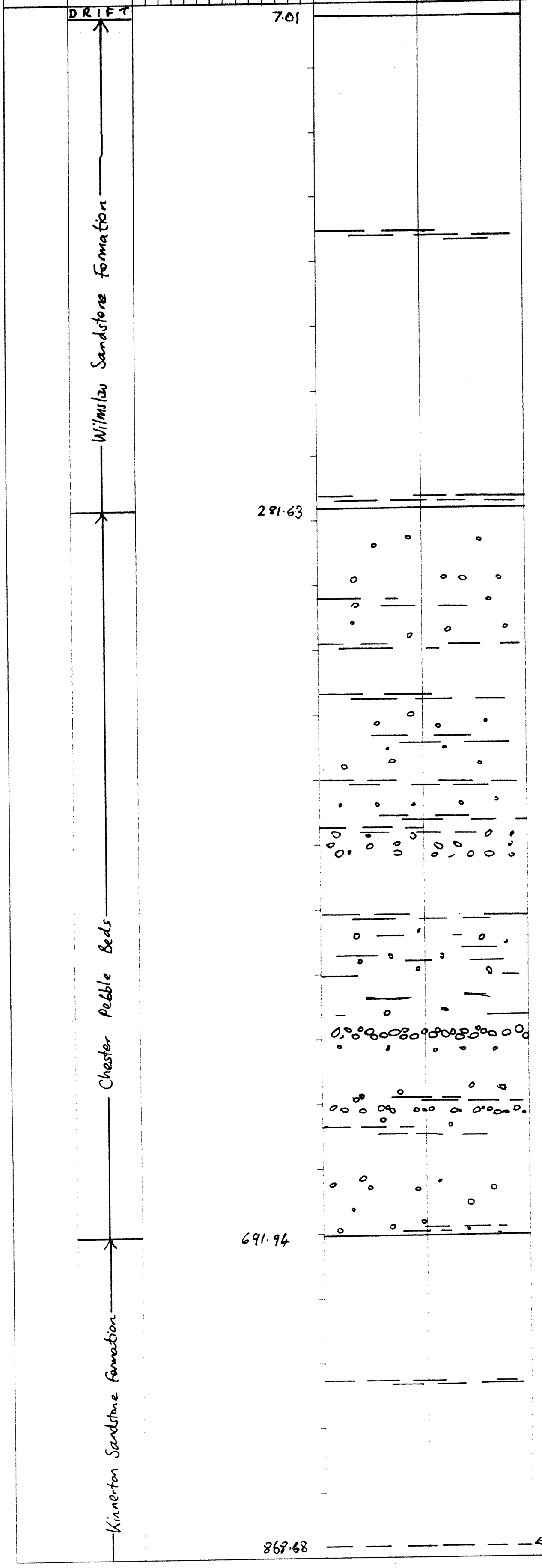
Location Bidston Coal Trial Bore

KB/Ground level 9.14m (approx)

NGR/Lat. & Long. SJ29SE-2

Logged by De Rance, 1882.

Stratigraphy	Carbonates: Calc. R | Calc. A | Calc. L Average grain size: C P GVCC M F VFSI C	Sedimentary structures	Graphic lithology	Lithological description



Lithological description

(all junctions appear fairly reliable) Drilled c.20m below the base of the Helsby Sst formation (makes Wilmslow Sst c.294m total)

7.01 Drift (Alluvial complex of the Birkett).

274.62m Red and Yellow sandstone; sporadic marl partings.

410.31m Red sandstone, pebbly sandstone and subordinate blue and red marl partings. Sandstone is commonly micaceous.

176.74 Dark red coarse and fine sandstone with one marl parting noted.

Base of borehole (depth 868.68, or -859.54 OD)

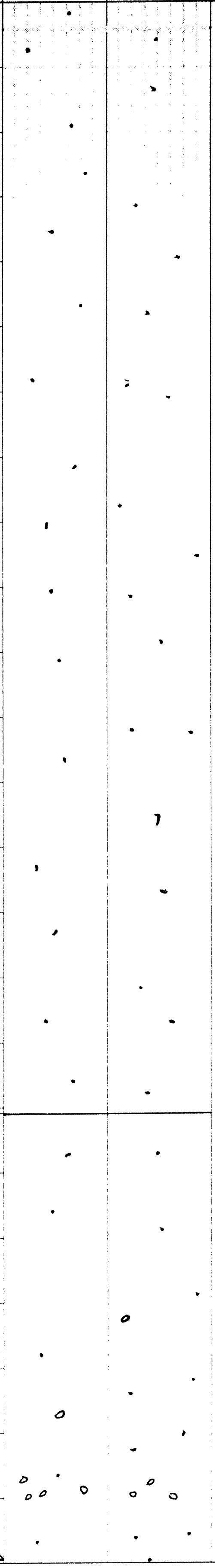
Tranmere Sheet

BRITISH GEOLOGICAL SURVEY

Sheet of

Borehole/Well No. 1:1081 (1cm : 10.81m)	**Location** Mount Rd, (Prenton Pumping station)	**NGR/Lat. & Long.** SJ38NW-5
	KB/Ground level 52·9	**Logged by** JWM Richardson

Stratigraphy	Carbonates Calc. R | Calc. A | Calc. L Average grain size C P G VC C M F VF SI C	Sedimentary structures	Graphic lithology	Lithological description



Wilmslow Sandstone Formation

185·78 yellow and red pebble-free sandstone

(upper 1·52 Drift, then to 4·5m taken previously as Helsby Sandstone)

Junction taken at first pebble

185·78

73·30 Coarse red and grey sandstone; sporadic, rare, pebbles.

Chester Pebble Beds

Base of borehole 259·08

Tranmere Sheet

BRITISH GEOLOGICAL SURVEY

Sheet of

Borehole/Well No. 1:1143 (1cm: 11·43m)	**Location** SpringHill, Oxton	**NGR/Lat. & Long.** SJ38NW-10
	KB/Ground level 36·48m.	**Logged by** WCSimmons

Stratigraphy	Carbonates Calc. R | Calc. A | Calc. L Average grain size C P G VC C M F VF SI C	Sedimentary structures	Graphic lithology	Lithological description
Helsby Sandstone	19·81			19·81 Red sandstone junction observed 'in well'
Wilmslow Sandstone Formation				172.21 Red, grey and white sandstone uncertain junction
Wilmslow Sandstone Fm ?	base of borehole 274.42			82.4 Red sandstone 'in thin beds'. Pebble-free Strata 'probable Wilmslow sandstone' (memoir p. 137)

New Brighton Sheet

BRITISH GEOLOGICAL SURVEY

Sheet 1 of 1

Borehole/Well No. 1:1147 (1cm: 11·47m)

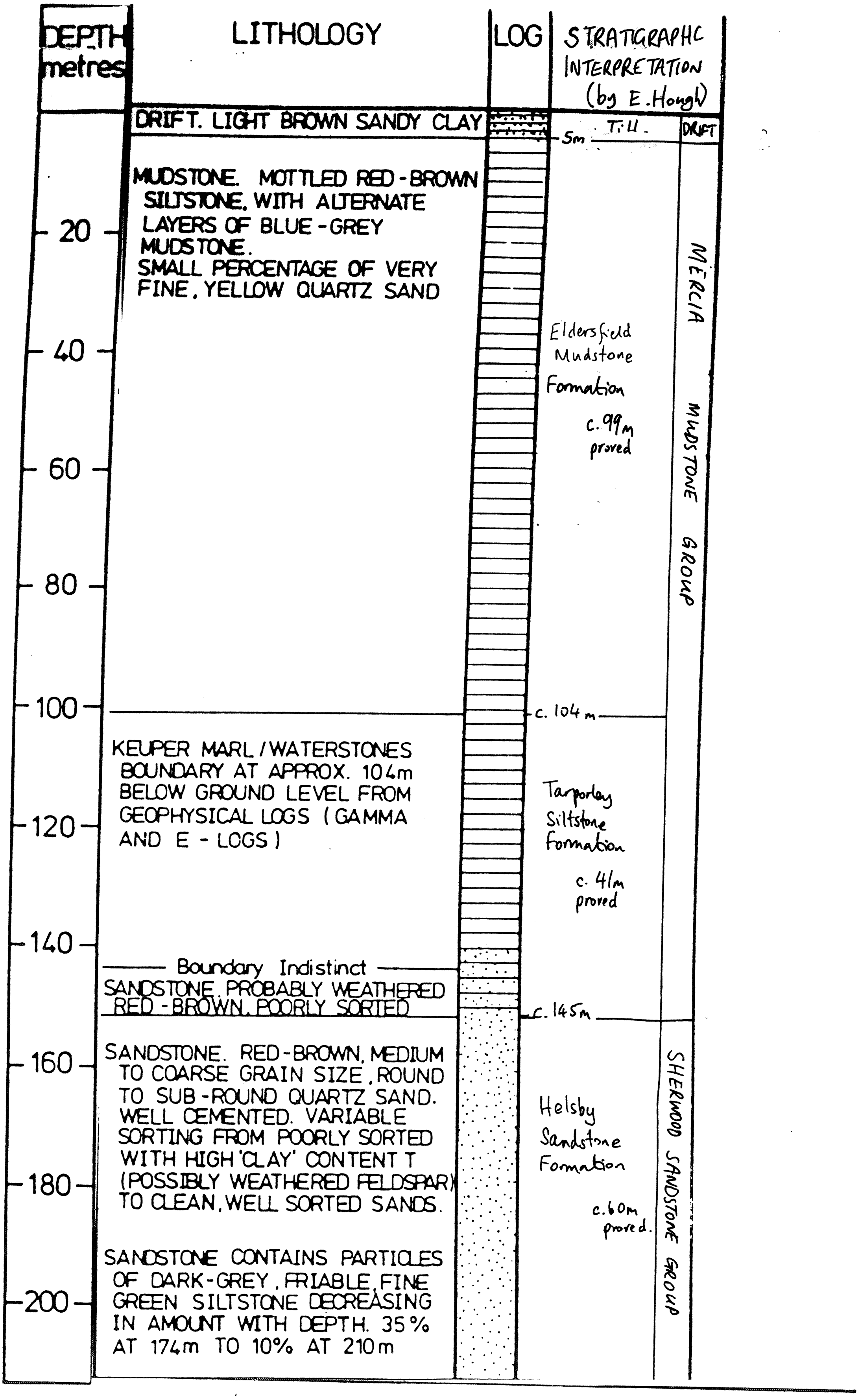
Location Liscard Pumping Station (no. 2 bore)

KB/Ground level

NGR/Lat. & Long. SJ 39SW - 55

Logged by Water Company, c. 1930s?

Stratigraphy	Carbonates Calc. R | Calc. A | Calc. L Average grain size C P G VC C M F VF SI C	Sedimentary structures	Graphic lithology	Lithological description
DRIFT	8·00	▽		8·00 Drift
Helsby Sandstone Formation	60.1			52·10
Wilmslow Sandstone Formation	Poorly defined junction 237·8			177·70 (junction placed at c.59 m in Liscard no. 1)
probable Wilmslow Sandstone Fm	base 275·3 m			37·5 ? Fine- to coarse-grained sandstone; no pebbles noted. Memoir, p.141 'not sufficient evidence to place within CPB'



DRIFT. LIGHT BROWN SANDY CLAY

MUDSTONE. MOTTLED RED-BROWN SILTSTONE, WITH ALTERNATE LAYERS OF BLUE-GREY MUDSTONE. SMALL PERCENTAGE OF VERY FINE, YELLOW QUARTZ SAND

KEUPER MARL / WATERSTONES BOUNDARY AT APPROX. 104m BELOW GROUND LEVEL FROM GEOPHYSICAL LOGS (GAMMA AND E - LOGS)

Boundary Indistinct

SANDSTONE. PROBABLY WEATHERED RED-BROWN, POORLY SORTED

SANDSTONE. RED-BROWN, MEDIUM TO COARSE GRAIN SIZE, ROUND TO SUB-ROUND QUARTZ SAND. WELL CEMENTED. VARIABLE SORTING FROM POORLY SORTED WITH HIGH 'CLAY' CONTENT T (POSSIBLY WEATHERED FELDSPAR) TO CLEAN, WELL SORTED SANDS.

SANDSTONE CONTAINS PARTICLES OF DARK-GREY, FRIABLE, FINE GREEN SILTSTONE DECREASING IN AMOUNT WITH DEPTH. 35% AT 174m TO 10% AT 210m

CLIENT: WIRRAL HEALTH AUTHORITY

JOB: GROUNDWATER SUPPLIES TO ARROWE PARK AND CLATTERBRIDGE

DRAWING: FIGURE 6
COMPOSITE BOREHOLE LOG
ARROWE PARK HOSPITAL

NO: 5·1168/306
SCALE: AS SHOWN
DRAWN: JE
CHECKED: RCSM
DATE: NOVEMBER 1986

HYDROTECHNICA

Pengwern Court High Street Shrewsbury Shropshire SY1 1SR UK
Telephone: 0743 64930/241101 Telex: 35156 ASPNWL G

Appendix 3 Graphic logs of the main exposures in the north Wirral district

Graphic lithological logs of some of the major exposures from the north Wirral district have been drawn up and interpreted by the author. Numbers refer to locations listed on field slips, and to field notebook cards logged at NGRC, Keyworth. Figure 5 shows locations.

Hoylake

SJ28NW-1 Hilbre Point (land-joined 'Red Rocks') [2030 8850]

SJ28NW-2 Red Rocks Island, off Hilbre Point [8870 2010]

SJ28NW-3 Grange Hill [2257 8608]

SJ28NW-4 Caldy Hill [2246 8548 - 2248 8558]

SJ28NW-5 Monks Way, Grange [2208 8689]

SJ28NW-6 A540 (Grange Road) cutting [2194 8693]

Upton

SJ28NE-1 Lower Flaybrick Road, Bidston [2926 8985]

SJ28NE-2 Arrowe Brook, Arrowe Park [2656 8578 - 2662 8610]

SJ28NE-3 and 4 Irby Hill Quarry [2215 8595]

SJ28NE-5 Arrowe Brook, Greasby [2649 8712]

Leasowe

SJ29SE-1 Red Noses, New Brighton [2996 9407]

SJ29SE-2 Red Noses, New Brighton (composite log) [2980 9393]

SJ29SE-3 St Hilary's Brow, Wallasey [2973 9195]

SJ29SE-4 Boundary Road, Bidston [2861 9027-2875 9023]

SJ29SE-5 The Breck, Wallasey [2980 9170]

Tranmere

SJ38NW-1 The Arno Quarry, Prenton [3048 8730]

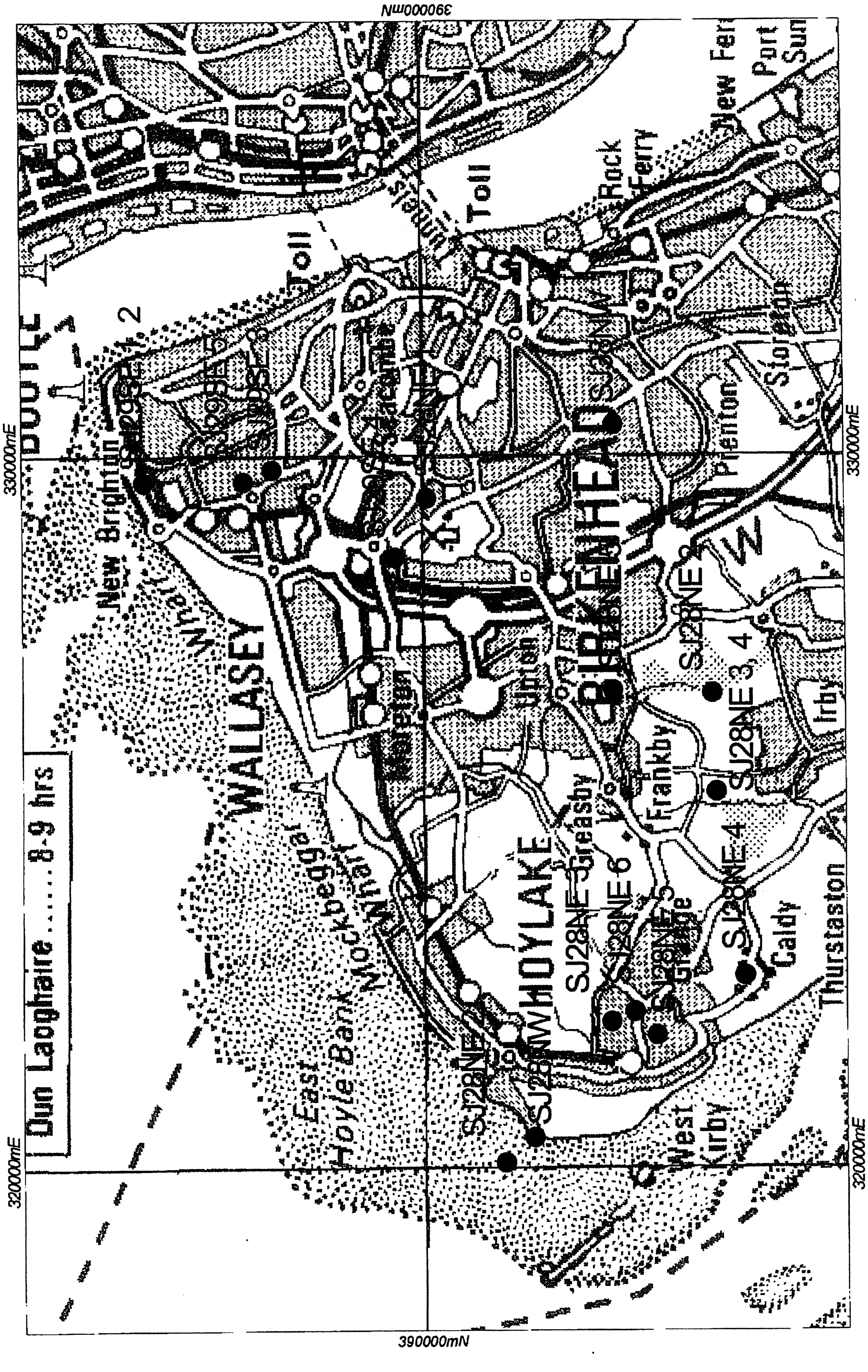


Figure 5. Location map of the graphic logs of the main sections in the district.

SJ28NW-1 (pat 1)

BRITISH GEOLOGICAL SURVEY

Sheet 1 of 2

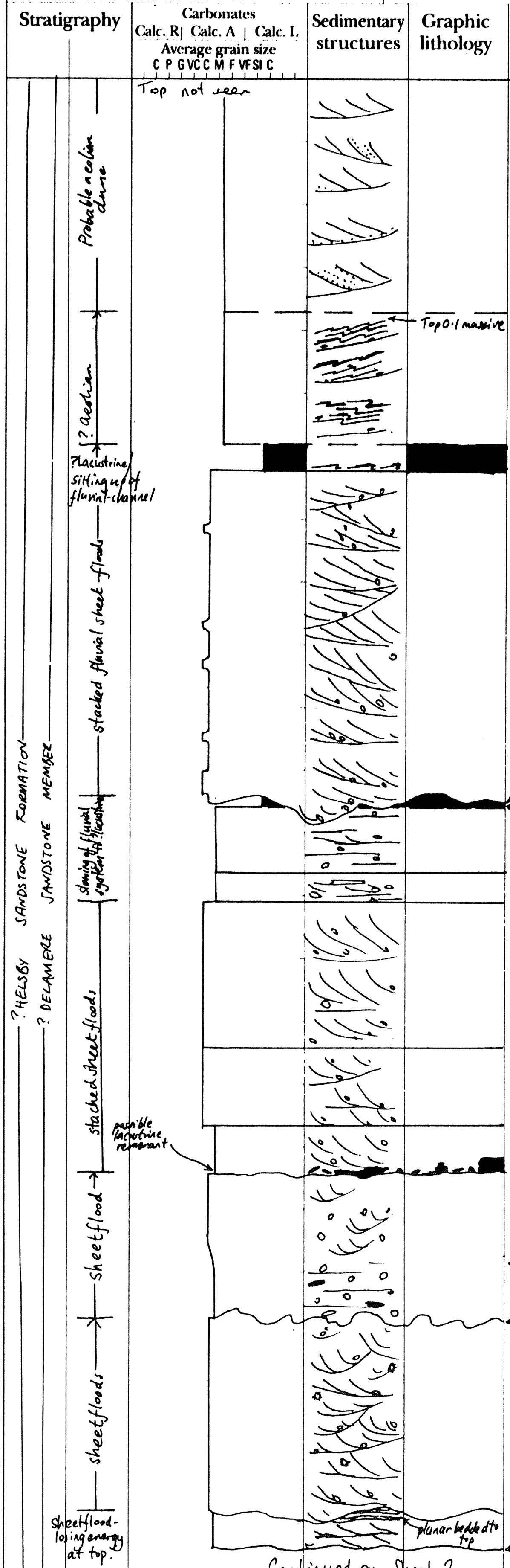
Borehole/Well No. 1:40 (1cm : 40cm)

Location Hilbre Point (Red Rocks - attached to land)

KB/Ground level

NGR/Lat. & Long. 2030 8850

Logged by E Hough



Lithological description

1.5 (top not seen) Planar low angle cross-bedded sandstone. Sets to 0.35. Very well sorted. Pebble-free. Possible bimodal-sorting. Sporadic small mud plates and quartz granules to 2mm. Possible deflation on some surfaces

forsets 28/065
mainsurfaces ?8/127?

0.83 ripple cross-laminated pebble-free sandstone.. Climbing ?wind ripple-foreset azimuth to c.188. Ripplesets c. 0.13 thick - have darker, silty drapes. Well sorted. With mudclasts.

sheet-floods across base of lake

0.16 green + yellowish red mdst. Lower part - sandy ripples with mud-drapes. Upper part, structureless mud

2.1 Thinly bedded low angle cross-bedded sandstone. Gritty and sporadically carbon-rich. Pebbles to 2.5.
foresets - variable amounts, to 001.
mainsurfaces :- 7/057
Some grey-bleached bands
Sporadic coarser units (5-10cm).

erosional base

0.06 impersistent mud band

0.45 planar-bedded sandstone; sporadic pebbles. Moderately - Moderately well-sorted. Rare low angle cross-bedding. mainsurfaces 10/062

0.2 planar bedded / low angle cross-bedded sandstone. Tabulate, rounded sst pebbles to 8cm.

0.9 Cross bedded pebbly sandstone, sets to 0.3.

0.5 Cross-bedded pebbly sandstone with mudclasts on foresets. Moderate - to poorly-sorted. Small angular quartz grains.
foresets 13/201 main surfaces 7/069

0.3 sparsly-pebbly low angle cross-bedded sandstone. Moderately sorted. Mudflake / clast / bed - remenant at base, to 0.1

0.55 low angle cross-bedded (trough) Poorly-sorted sandstone. Pebbles to 4cm. - quartzite + quartz - grains (rounded) forsets to 022, main surfaces 4-6/043

gradational contact

c.0.4 Planar-parallel-bedded pebbly sandstone. Rounded mudclasts to 0.3, also grey + brown sandstone, angular milky quartz. Very poorly sorted.

irregular / ?erosional base

1.22 trough and planar-cross-bedded pebbly sandstone. Poorly sorted. Pebbles of sandstone, quartz, mudclasts & calcareous material.
foresets 14/352
main surfaces 17/085
?quartz-lined vugs to 3½cm. (May be calcite?)

0.22 very low angle cross-bedded sandstone Moderate - Moderately well-sorted. foresets to 129

laterally, 4cm mudstone at this point.

Erosional base 12/051

Continued on Sheet 2

SS28NW-1(part 2)

BRITISH GEOLOGICAL SURVEY

Sheet 2 of 2.

Borehole/Well No. 1:40 (1cm : 40cm)

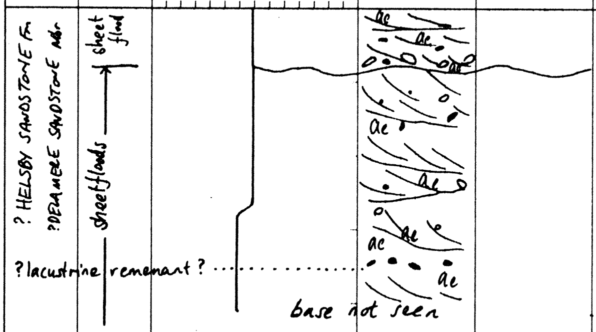
Location Hilbre Point - Red Rocks (not the island)

KB/Ground level

NGR/Lat. & Long. 2030 8850

Logged by E Hough

Stratigraphy	Carbonates Calc. R | Calc. A | Calc. L Average grain size C P G VC C M F VF SI C	Sedimentary structures	Graphic lithology	Lithological description



0·32 Low angle cross-bedded poorly sorted sandstone. Intraformational sst. pebbles to 0·06 at base. Some red-brown mudclasts. Some medium-grained reworked aeolian grains. Subangular spherical quartz pebbles up to 1cm. foresets to 0·64

1·3 Low angle cross-bedded red-brown pebbly sandstone. Pebbles & mudclasts to 6cm/3cm respectively. Many reworked aeolian grains Laterally, mudclasts concantrated 0·4 from base (channel-plug remenant?). Poorly sorted.

SJ28NW-2

BRITISH GEOLOGICAL SURVEY

Sheet 1 of 1

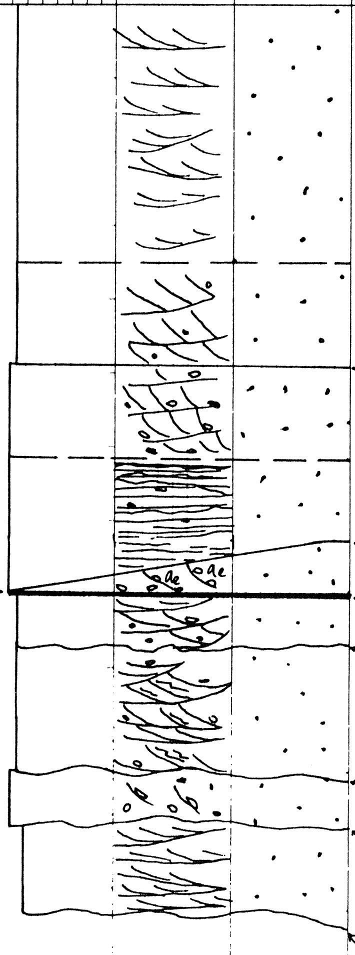
Borehole/Well No. 1:40 (1cm : 40cm).	Location Red Rocks Island	NGR/Lat. & Long. 38870 32010
	KB/Ground level	Logged by E Hough

Stratigraphy	Carbonates Calc. R | Calc. A | Calc. I. Average grain size C P GVC C M F VF Si C	Sedimentary structures	Graphic lithology	Lithological description

?HELSBY SANDSTONE FORMATION

?DELAMERE SANDSTONE MEMBER

Fluvial Channels/sheetfloods — FLUVIAL sheetfloods — ? sheetflood or channel — sheetflood — ?aeolian — sheetfloods



c. 1·4 planar assymptotic cross bedded sandstone ordered in sets 0·1–0·5m. Slightly micaceous on bedding planes. ?Current-laminated. foresets to 293. main surfaces 8/037, 6/226. Moderately well-sorted. Red and yellow-coloured.

c. 0·55 redandyellow medium-angle cross-bedded sandstone. Sporadic quartz pebbles <0.5cm. Well sorted

← Planar contact 4/327

c. 0·5 poorly exposed. High angle planar cross-bedded pebbly sandstone. Pebbles: quartz, chert, mudclasts. Very poorly sorted. Sporadic sandstone granules. Mottled yellow. foresets 24/341.

c. 0·45. 10cm-scale parallel-laminated sets (erosionally-based). Angular quartz pebbles to 2cm. Poor-Mod. sorted. Foresets 10/240. Some coarse sandstone and siltstone clasts.

← planar base

Up to 0·27 poorly sorted sandstone; with rounded mudclasts and pebbles to 2cm. Cross-bedded. Reworked aeolian grains. Foresets 8/003

← MAJOR SURFACE 6/003, 6/030

0·26 Moderate to low-angle asymptotic cross-bedded sandstone. Sl. pebbly. Foresets 15/268

← irregular base

0·69 Moderate to low-angle asymptotic cross-bedded sandstone. Pebbly: angular and rounded quartz, angular, subrounded red-brown mudstone <1·5cm. SOME upto 4cm further to north ?ripple-laminated.

← erosional base

c. 0·24 massive and high-angle fairly pebbly sandstone. Pebbles mostly quartz, <1cm. Reddish-brown. tabular oriented along foresets. Some intraformational mudclasts. Foresets 7/274.

← erosional base (4/001)

c. 0·45. Low angle planar cross-bedded sandstone. Sporadic sub-rounded quartz pebbles to c.1cm. Also subangular mudclasts & silty sandstone. Foresets have silty laminae on them. Reddish-brown. Sets 0·1–0·2. Foreset dips 8/323, 17/356, 18/358

← erosional base

Generally, section is slightly micaceous throughout, reddish-brown (yellow mottling coming in above major surface). Sporadic cataclastic fractures, preferentially cemented: sub-vertical, striking 166 and 039.

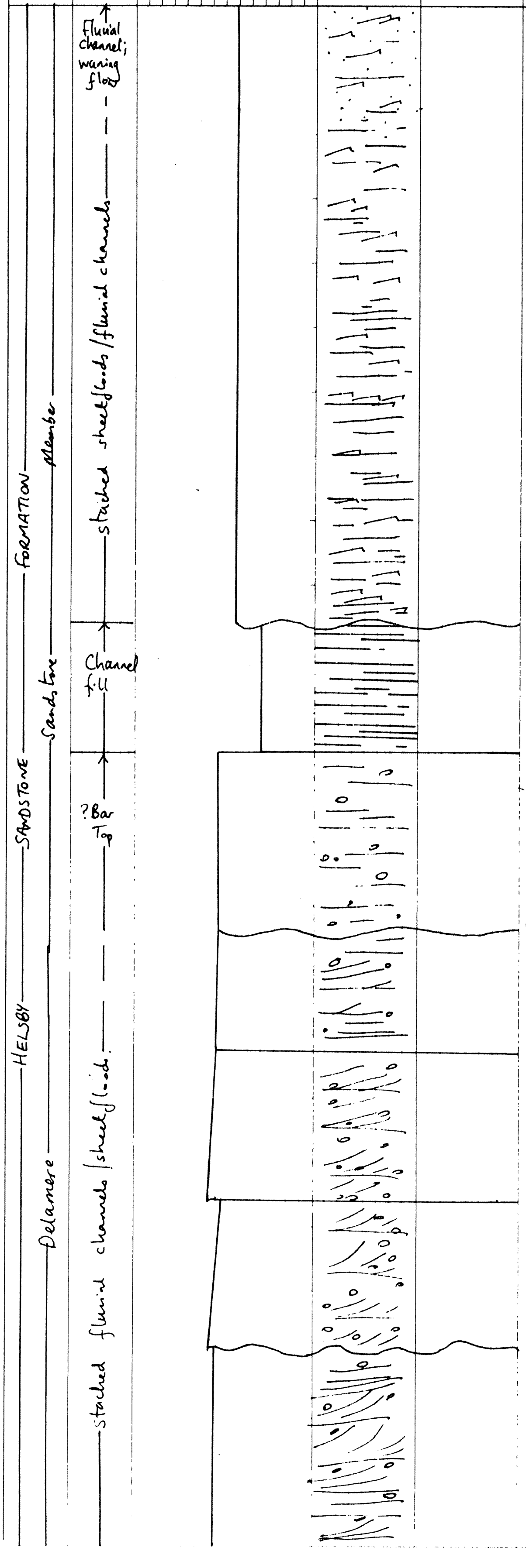
SJ28NW-3

BRITISH GEOLOGICAL SURVEY

Sheet 1 of 1

Borehole/Well No. 1:16 (1cm : 16cm)	Location Grange Hill, Quarry KB/Ground level c. 65-70	NGR/Lat. & Long. 2257 8608 Logged by E Hough

Stratigraphy | Carbonates Calc. R | Calc. A | Calc. L Average grain size C P GVC C M F VF Sl C | Sedimentary structures | Graphic lithology | Lithological description



c.0.2 silty sandstone, ripple-laminated, fine-grained

General dip 8/101

gradational contact
1.28 Sandstone, ripple-laminated, fine-grained, moderately sorted

erosional base
0.35 Laminated siltstone

planar base
0.45 Sandstone. Pebbly.
Medium- to thin-bedded.

Wavy base
0.3 Sandstone, planar/low angle cross-bedded.
Medium- to coarse-grained. Poorly sorted.
Sporadic granule/small pebble

planar base
0.37 Channel set Sandstone pebbly medium- to coarse-grained Gross-fining up poor- to moderate sorted, low angle cross-bedded.

planar base
0.38 Channel set Sandstone, pebbly, medium- to coarse-grained Gross upward-fining. Poor- to moderate sorted, low angle cross-bedded.

erosional base
0.72 Sandstone, pebbly, cross-bedded. Sporadic quartz pebbles & mudflakes. Planar/low angle cross-bedded. Medium- to coarse-grained Moderately sorted.

SJ28NW-4 (pt.1)

BRITISH GEOLOGICAL SURVEY

Sheet 1 of

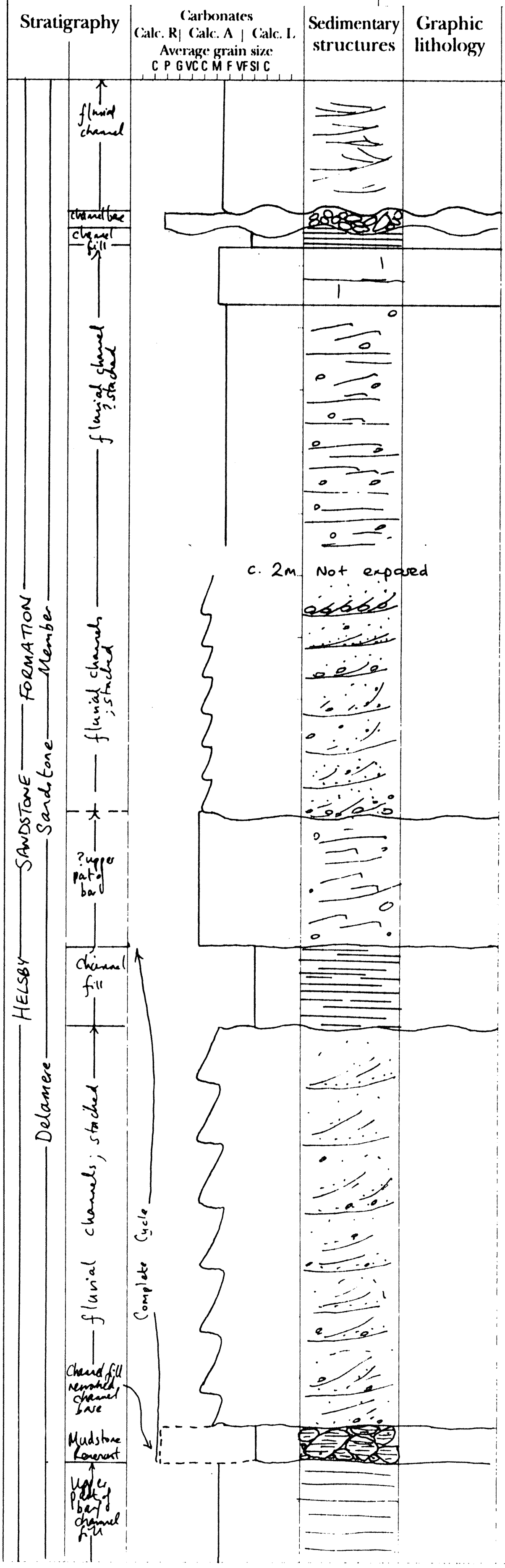
Borehole/Well No. 1: 23 (1cm: 23cm)

Location Caldy Hill

KB/Ground level c. 70 - 75

NGR/Lat. & Long. 2248 8548 - 2248 8558

Logged by E Hough



Lithological description

22/10/1998

0.5 Sandstone. Low angle cross-bedded.

erosional base 18/069

0.3 Conglomerate

0.3 Siltstone

0.2 Sandstone. Fairly massive. 10cm units; many re-worked aeolian grains.

0.9 Sandstone. Thin-medium-bedded. Ripple-laminated pebbly sandstone.
Occasional coarse-grains.

c. 0.9 Coarse-grained lagged sheetfloods.
Sandstone, pebbly.

0.5 Sandstone, coarse-grained, pebbly (small pebbles), ripple-laminated.

0.3 Mudstone

wavy base

c. 1.5 Fine-medium grained sandstone, with coarse-grained sheetflood lags. Pebbly.

0.12 Mudstone conglomerate

0.6 upper 0.4 planar bedded sst
lr 0.2 low ang xbedded sst
Poorly sorted

BRITISH GEOLOGICAL SURVEY

Sheet 2 of 2

Borehole/Well No.

Location Caldy Hill

KB/Ground level

NGR/Lat. & Long.

Logged by

Stratigraphy

HELSBY SANDSTONE FORMATION

Delamere Sandstone Member

Lower part fluvial channel

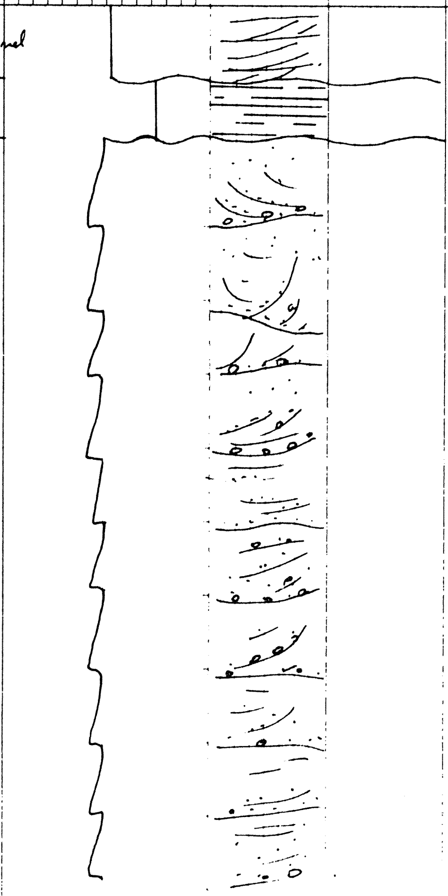
Channel fill

Stacked fluvial channels (sheetfloods)

Carbonates
Calc. R | Calc. A | Calc. L
Average grain size
C P G VC C M F VF SI C

Sedimentary structures

Graphic lithology



Lithological description

0-0.2 Mudstone, hard, red.

wavy base c. 11/016.

2-3 Sandstone, medium-to coarse-grained, pebbly. Angular grains Ordered in sets c. 0.25 thick, granule/Pebble-based. Cross-bedded. Sets cut off older sets.

SJ28NW-5

BRITISH GEOLOGICAL SURVEY

Sheet 1 of 1

Borehole/Well No. 1: 6 (1cm: 6cm)

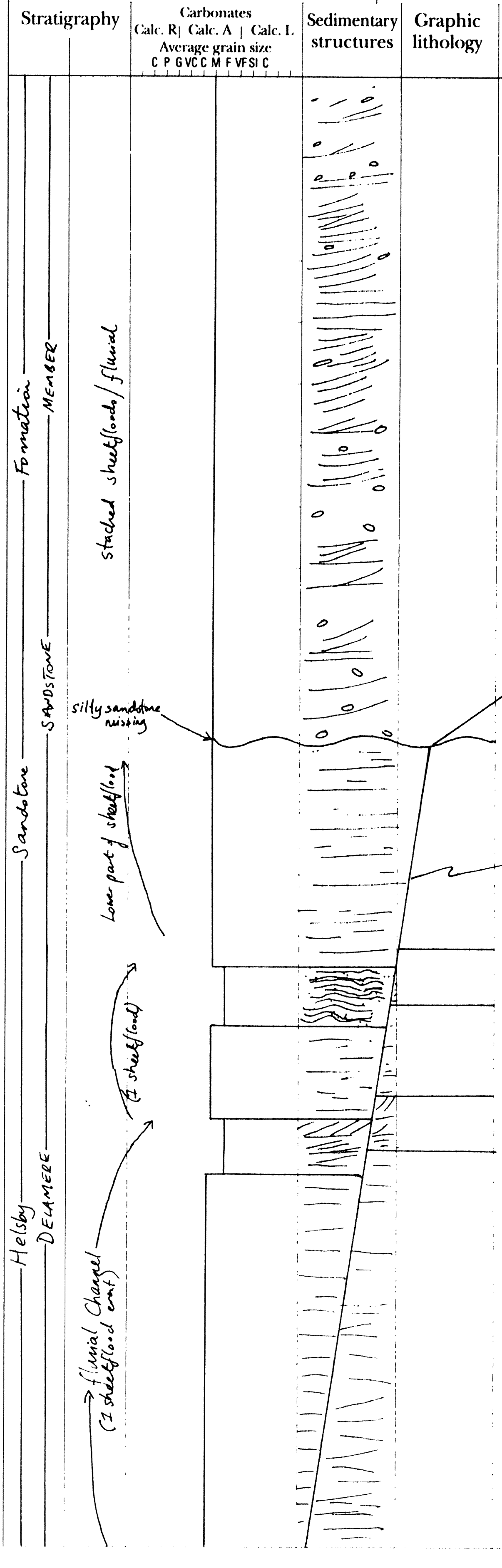
Location Grange Road, Opposite Monk's Way

KB/Ground level c. 48

NGR/Lat. & Long. 2208 8689

Logged by E HOUGH

14/10/98



Lithological description

0.65 low angle cross-bedded pebbly sandstone. Some planar foresets. Pebbles to 2.3cm.

Fault terminates at base of upper sandstone unit

0.22 Sandstone, red, medium-grained, well-sorted.

syndepositional fault; throw to east

0.07 silty sandstone parting. Fine-grained, moderately-well sorted. Wavy-planar-bedded.

0.09 Sandstone, red, medium-grained, well-sorted.

0.05 Silty sandstone parting pale cream. Moderately-well sorted, planar/low angle cross-bedded.

0.47 reddish brown sandstone, rare pebbles to 2.5cm. Mostly planar-bedded. Medium to coarse-grained, moderately sorted.

SJ28NW-6

BRITISH GEOLOGICAL SURVEY

Sheet 1 of 1.

Borehole/Well No. 1:50 (1cm :50cm)

Location GRANGE ROAD CUTTING

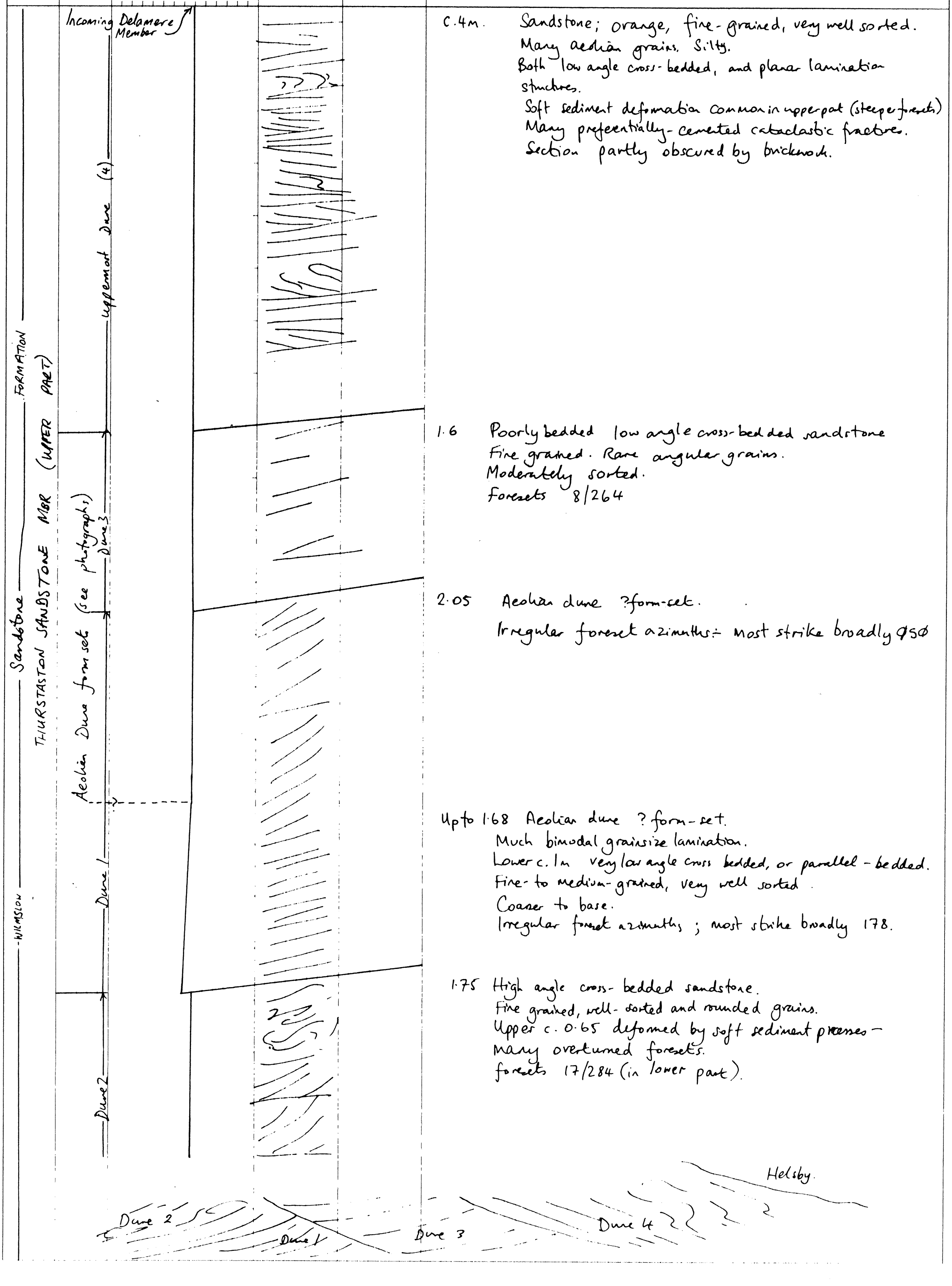
KB/Ground level C. 40 OD.

NGR/Lat. & Long. 2194 8693

Logged by E Hough

Stratigraphy	Carbonates Calc. R | Calc. A | Calc. L Average grain size C P G VC C M F VF SI C	Sedimentary structures	Graphic lithology	Lithological description

14/10/98



C.4m. Sandstone; orange, fine-grained, very well sorted. Many aeolian grains. Silty. Both low angle cross-bedded, and planar lamination structures. Soft sediment deformation common in upper part (steeper foresets) Many preferentially-cemented cataclastic fractures. Section partly obscured by brickwork.

1.6 Poorly bedded low angle cross-bedded sandstone Fine grained. Rare angular grains. Moderately sorted. Foresets 8/264

2.05 Aeolian dune ?form-set. Irregular foreset azimuths:- most strike broadly 050

Upto 1.68 Aeolian dune ?form-set. Much bimodal grainsize lamination. Lower c.1m very low angle cross bedded, or parallel-bedded. Fine- to medium-grained, very well sorted. Coaser to base. Irregular foreset azimuths; most strike broadly 178.

1.75 High angle cross-bedded sandstone. Fine grained, well-sorted and rounded grains. Upper c. 0.65 deformed by soft sediment processes - Many overturned foresets. foresets 17/284 (in lower part).

SJ28NE-1 (part 1)

BRITISH GEOLOGICAL SURVEY

Sheet 1 of 2

Borehole/Well No. 1:20 (1cm: 20cm).

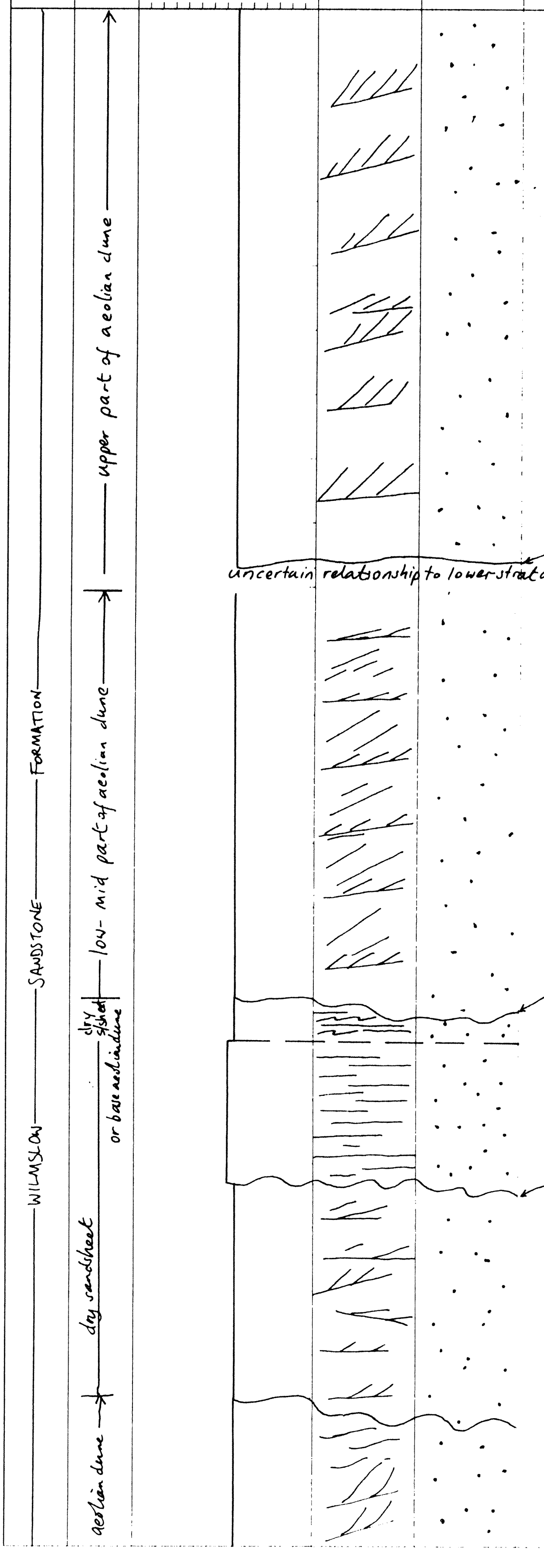
Location Lower Flaybrick Rd, Bidston

NGR/Lat. & Long. SJ 32926 38985

KB/Ground level

Logged by E Hough

Stratigraphy	Carbonates Calc. R | Calc. A | Calc. L. Average grain size C P G VC C M F VF SI C	Sedimentary structures	Graphic lithology	Lithological description



c. 1.74 high angle planar cross-bedded very well sorted 'dune' sandstone.

foresets 22/325 (f)
main bounding surfaces 22/328 (m)
approximate dip of section 7/039

1.27 Sandstone; yellow-buff, sets to 25cm.
f azimuth to NW.
m 7/206, 7/247, variable
f 22/295, 16/225
moderately well sorted.

0.12 planar bedded on mm-scale; hint of wind-ripple lamination.
6/245 Moderately sorted.

0.46 erosionally-based; planar bedded on cm-scale.
yellow colour.

0.68 yellow sandstone. Well sorted. Low angle planar-cross-bedded. Strongly erosional base.

0.5-0.7 high-angle cross-bedded sandstone with assymptotic foresets.

f to NW.

SJ28NE-1 (part2)

BRITISH GEOLOGICAL SURVEY

Sheet 2 of 2

Borehole/Well No. 1:20 (1cm: 20cm)

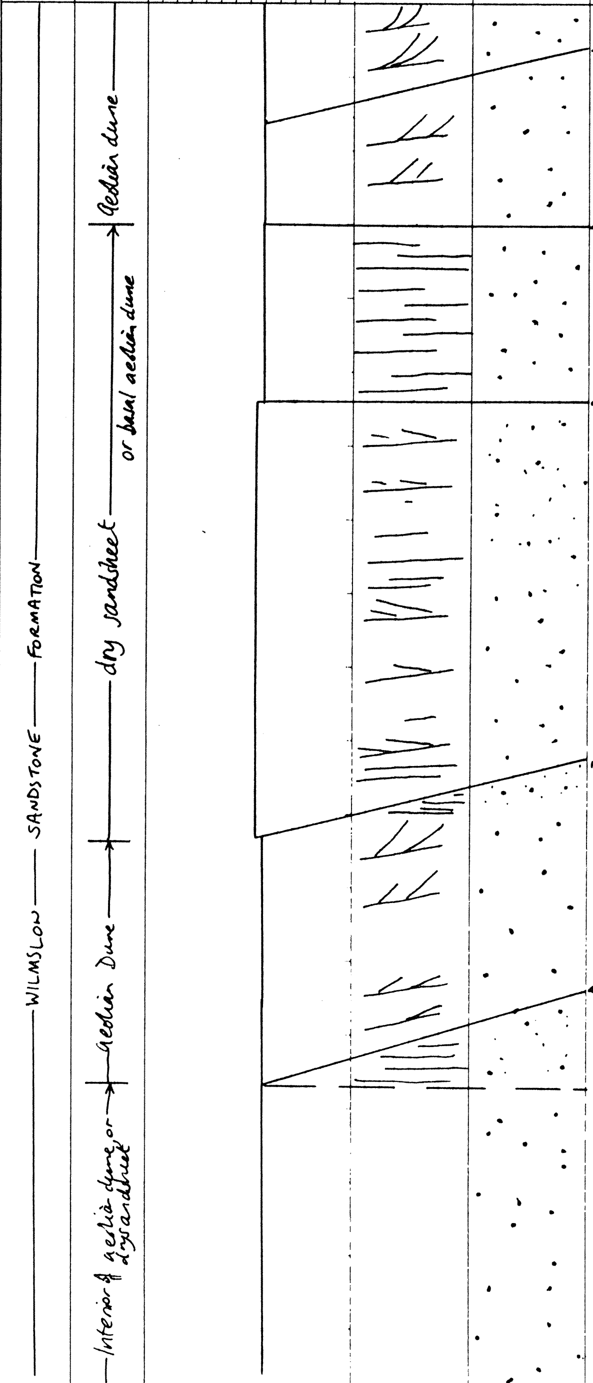
Location Lower Flaybrick Road, Bidston

KB/Ground level

NGR/Lat. & Long. SJ 32926 38985

Logged by E Hough

Stratigraphy | **Carbonates** Calc. R | Calc. A | Calc. L **Average grain size** C P GVC C M F VF SI C | **Sedimentary structures** | **Graphic lithology** | **Lithological description**



← erosional base 12/219

0.38 high angle planar cross-bedded
buff-yellow colour.

← sharp base 8/156

0.48 planar-bedded
buff-yellow colour

← sharp base

1.18 planar and low angle planar cross-bedded sandstone.
sets to 0.3.

m 8/156
f 18/306
Well sorted

← angular base

0.63 moderately highangle planar cross-bedded sandstone;
cross beds shallower lower down.
Many aeolian (frosted spherical) quartz grains
Upper 3cm; silty, planar bedded.

← angular base 3/289

0.07-0 silty sandstone, planar-bedded
VFG-FG

0.86. Moderately well-sorted.
Structureless; many aeolian grains.

SJ28NE-2 L/96/11

BRITISH GEOLOGICAL SURVEY

Sheet 1 of 1

Borehole/Well No. 1:100 (1cm : 1m)

Location ARROWE BROOK

KB/Ground level 45-50 OD.

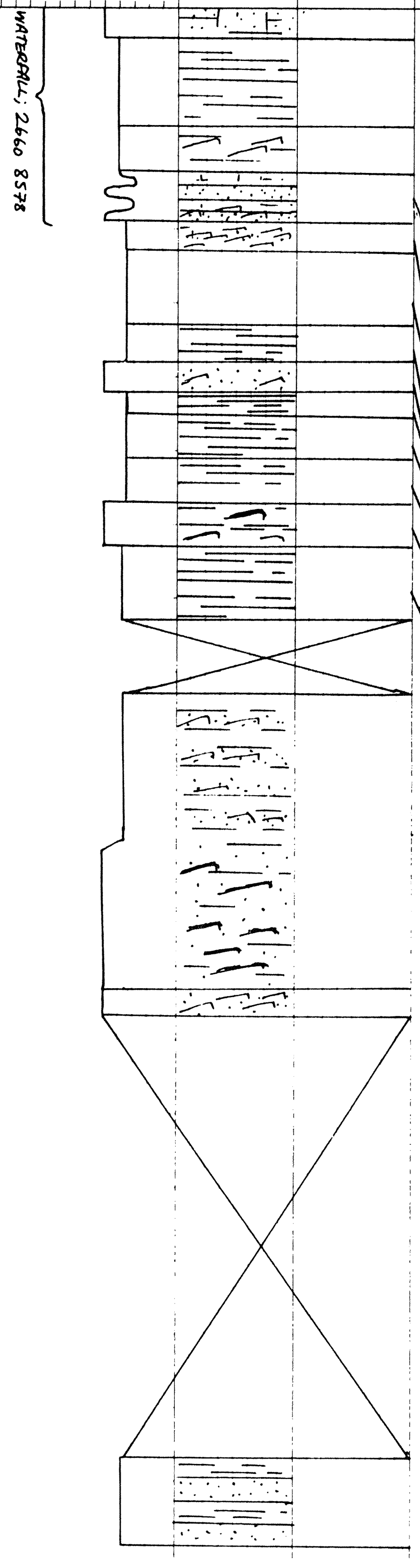
NGR/Lat. & Long. 2656 8578 - c. 2662 8610

Logged by E Hough

Stratigraphy | Carbonates Calc. R | Calc. A | Calc. L. Average grain size C P G VC C M F VF SI C | Sedimentary structures | Graphic lithology | Lithological description 30/9/1998

TARPORLEY SILTSTONE FORMATION

Rippled sheetfloods across the base of lakes, interlaminated by stiller water deposition in lakes/standing water



c.0.4 v. fine grained silty sandstone. Well bedded, blocky, no ripples. 4/282.

c.1.2 blocky red siltstone. hard, micaceous. thinly laminated. 8/101 (variable)
Some massive beds, 2-8cm intervals.

0.27 sandy siltstone, reddish-brown. Thinly bedded; rippled bedding-planes. Bedding planes 5-10cm vertical intervals.
Slightly micaceous. 2/272.
Mostly low sinuous in-phase current ripples. Flow to 057
Camber into stream.

Ripple Crest	Trend	Wavelength
straight; no bifurcation	062	8cm
Straight/arcuate slight bifurcation	179	c. 2-5cm.

0.7 Mudstone-sandstone interbeds. >5cm-scale. well bedded, blocky.
Lr. 0.2: Interferance ripples, w/ sinuous in-phase ripples. Grey & red in colour. 4/302 (variable)

c.0.4 Mudstone (poorly exposed). w/ Thin rippled sandstones.

c.1.0 Mudstone-dominated, poorly exposed.

c.0.5 Thinly laminated red mudstone

c.0.4 Sandstone (small waterfall) Rare ripples; grey.

0.3 Thin lam grey mudstone

c 0.6 Hard grey fissile mudstone; poorly exposed.

c.0.6. Soft grey mudstone; poorly exposed.

0.6 Sandstone; grey, thinly laminated. Bifurcating ripples, sinuous, in-phase. With mudstone drapes/interlaminae. 3/296 (variable).

c.1 Grey mudstone, laminated. Fractures trend 193.

c.1 NOT EXPOSED.

c.4 Grey fissile mudstone, laminated, with grey rippled sandstone interbeds. Ripples - Interference and bifurcated, along with straight-crested. Sandstone-dominated, with mud drapes to base.

c.0.4 Sandstone; good current-ripples

c.6 NOT EXPOSED.

1.2 Red mudstone & silty sandstone interbeds units c.30cm thick.

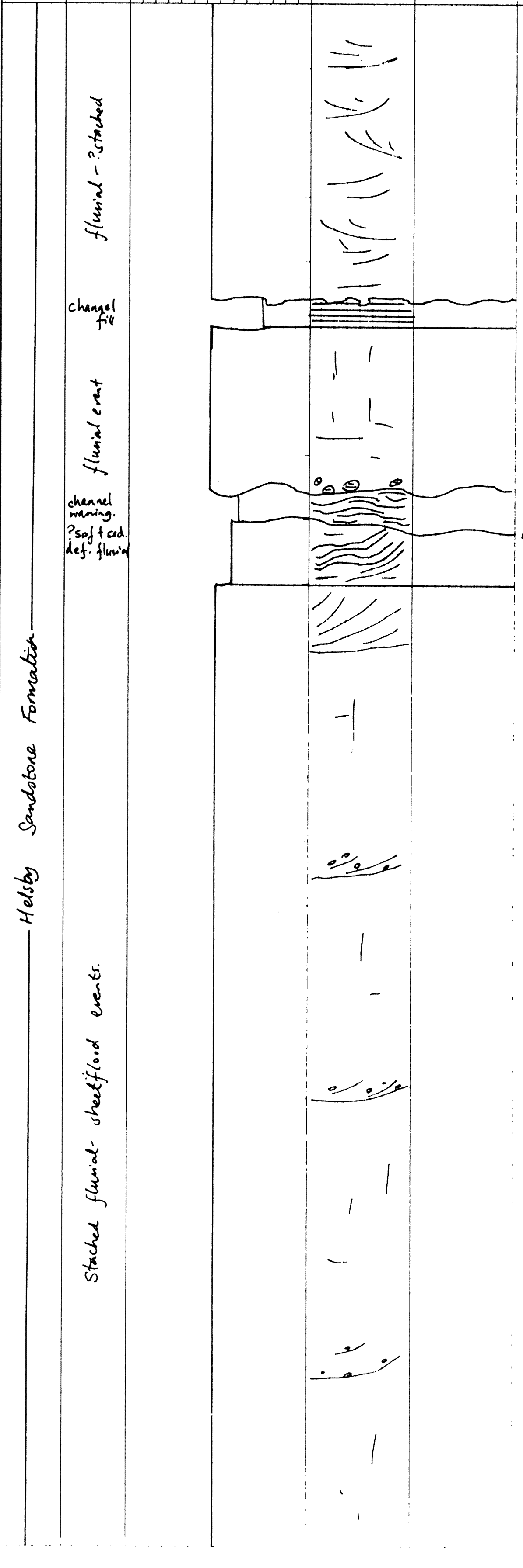
SJ28NE-5

BRITISH GEOLOGICAL SURVEY

Sheet 1 of 1

Borehole/Well No. 1:13 (1cm : 13cm).
Location Irby Hill Quarry (Face 3)
NGR/Lat. & Long. 2521 8589
KB/Ground level c. 55m
Logged by E Hough

Stratigraphy
Carbonates Calc. R | Calc. A | Calc. L
Average grain size C P G VC C M F VF SI C
Sedimentary structures
Graphic lithology
Lithological description
7/10/98



0.58 Sandstone. Cross-bedded.

Loaded base - possibly after desiccation
0.07 Red laminated mudstone
up to 0.35 Massive reddish-brown sandstone.
Mudclasts on Lr surface
Poorly sorted, angular grains.

Wavy base
0.06 silty sandstone Red & yellow wavy parallel-laminated
Erosional base.
0.15 yellow sandstone. Thin yellow parallel wavy lamination.
becomes high angle cross bedded to south
2.04 Sandstone, reddish-brown.
Commonly massive; rare low angle cross-bedding.
Poorly sorted, micaceous, angular-rounded grains.
Upper 0.1 high angle cross-bedded.
Rare Quartz & sandstone pebbles to 1.5cm.
Low angle cross bedding picked out by
sparsely pebbly-layers.

SJ28NE-4

BRITISH GEOLOGICAL SURVEY

Sheet 1 of 1

Borehole/Well No. 1:25 (1cm: 25cm).

Location Irby Hill Quarry (face ①)

KB/Ground level c. 55

NGR/Lat. & Long. 2515 8595

Logged by E Hough

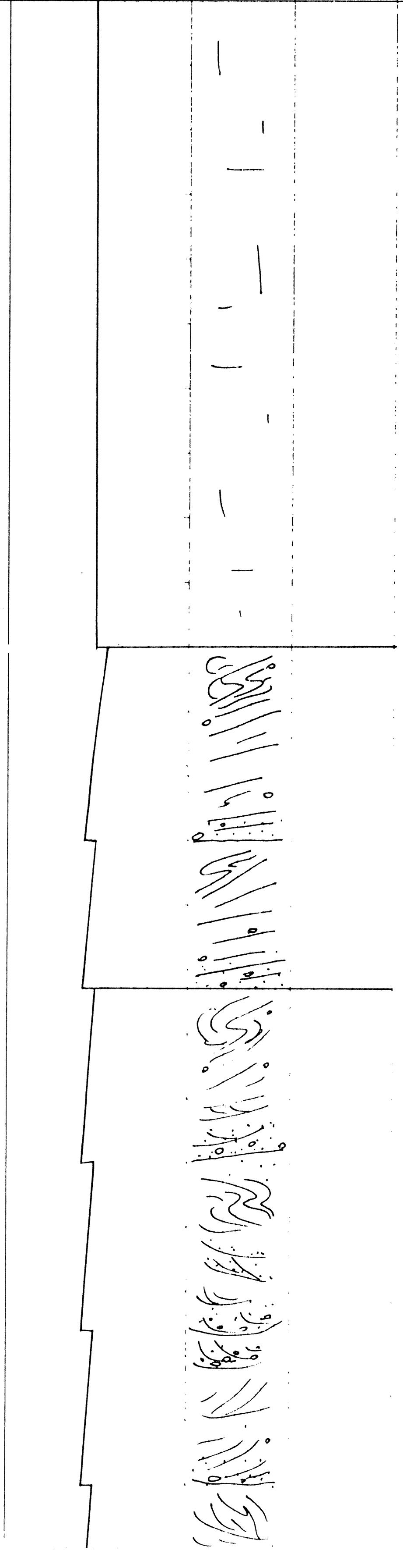
Stratigraphy	Carbonates Calc. R | Calc. A | Calc. L Average grain size C P G VC C M F VF SI C	Sedimentary structures	Graphic lithology	Lithological description 7/10/98

Helsby Sandstone Formation

?Fluvial ?

Fluvial sheet floods stacked

Fluvial sheet floods - stacked



c.2.5 (to top of section)
Mostly massive sandstone.

1.34 Sandstone: low angle planar cross-bedded and massive.
Reddish-brown and yellow sandstone.
Units c. 0.6 thick - fining-upwards.
Some slumping and oversteepening of foresets.
Sporadic angular quartz pebbles.

2.17 Sandstone: low angle planar and trough cross-bedded.
Fining upwards units 0.7 thick with basal 0.15 of coarser/granules. Reddish-brown.
Angular grains.
Slight soft sediment deformation to top of sets.

Irby Hill Quarry,
Irby Hill

(locals claim quarry was worked until early 1950s)

Face 2: Sandstone, ripple-laminated, generally fining-upwards sets with low angle cross-bedding affected by wavy soft-sediment deformation. Fractured; no displacement across fractures. Thin mudstone to base.

Top-down:

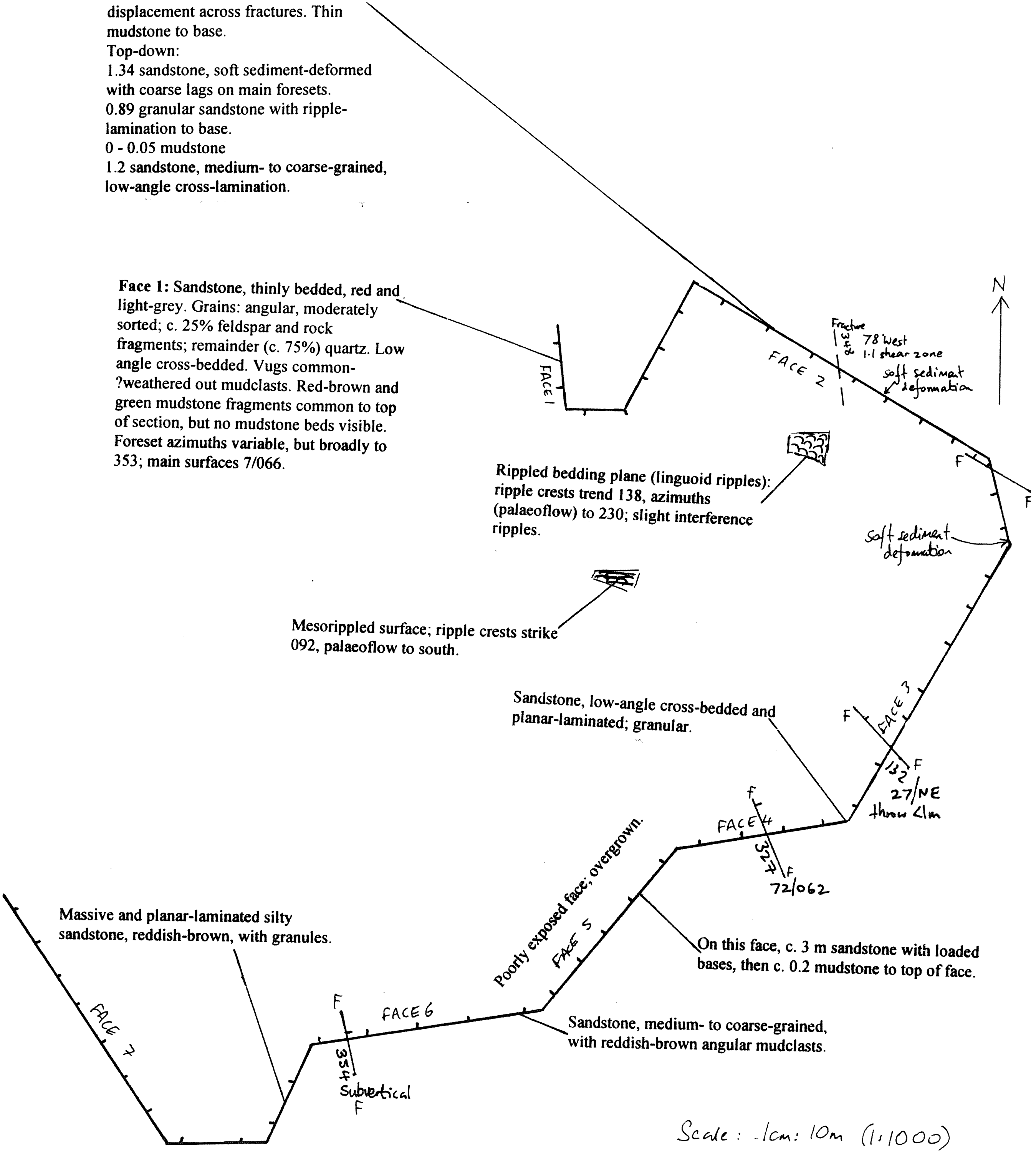
1.34 sandstone, soft sediment-deformed with coarse lags on main foresets.

0.89 granular sandstone with ripple-lamination to base.

0 - 0.05 mudstone

1.2 sandstone, medium- to coarse-grained, low-angle cross-lamination.

Face 1: Sandstone, thinly bedded, red and light-grey. Grains: angular, moderately sorted; c. 25% feldspar and rock fragments; remainder (c. 75%) quartz. Low angle cross-bedded. Vugs common-?weathered out mudclasts. Red-brown and green mudstone fragments common to top of section, but no mudstone beds visible. Foreset azimuths variable, but broadly to 353; main surfaces 7/066.



Rippled bedding plane (linguoid ripples): ripple crests trend 138, azimuths (palaeoflow) to 230; slight interference ripples.

Mesorippled surface; ripple crests strike 092, palaeoflow to south.

Sandstone, low-angle cross-bedded and planar-laminated; granular.

Poorly exposed face; overgrown.

On this face, c. 3 m sandstone with loaded bases, then c. 0.2 mudstone to top of face.

Massive and planar-laminated silty sandstone, reddish-brown, with granules.

Sandstone, medium- to coarse-grained, with reddish-brown angular mudclasts.

Scale : 1cm: 10m (1:1000)

Face 7: 2.9 m sandstone, reddish-brown, silty, medium-grained, angular grains. Ordered as co-sets c. 2 m thick. These are composed of sets 0.3 - 1.5 m of low-angle cross-bedded and parallel-wavy-lamination.

F——|——F Fault

SJ28NE-3

BRITISH GEOLOGICAL SURVEY

Sheet 1 of 1

Borehole/Well No. 1:13 (1cm : 13cm).

Location Irby Hill Quarry (Face 3)

NGR/Lat. & Long. 2521 8589

KB/Ground level c. 55m

Logged by E Hough

Stratigraphy | **Carbonates** Calc. R | Calc. A | Calc. L; **Average grain size** C P G VC C M F VF Si C | **Sedimentary structures** | **Graphic lithology** | **Lithological description** 7/10/98

Helsby Sandstone Formation

fluvial - ?stacked

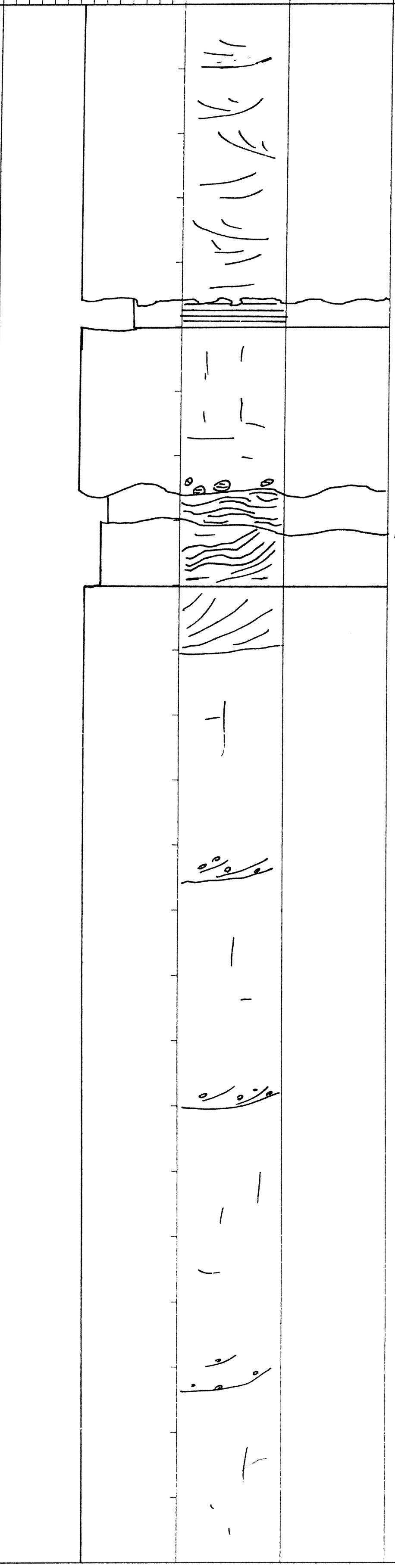
channel fill

fluvial event

channel waning.

?soft sed. def. fluvial

Stacked fluvial- sheetflood events.



0.58 Sandstone. Cross- bedded.

Loaded base - possibly after desiccation

0.07 Red laminated mudstone

up to 0.35 Massive reddish-brown sandstone.
Mudclasts on Lr surface
Poorly sorted, angular grains.

wavy base

0.06 silty sandstone Red & yellow wavy parallel- laminated

Erosional base.

0.15 yellow sandstone. Thin yellow parallel wavy lamination.
becomes high angle cross bedded to south

2.04 Sandstone, reddish- brown.
Commonly massive; rare low angle cross- bedding.
Poorly sorted, micaceous, angular- rounded grains.
Upper 0.1 high angle cross- bedded.
Rare Quartz & sandstone pebbles to 1.5cm.
Low angle cross bedding picked out by
sparsely pebbly- layers.

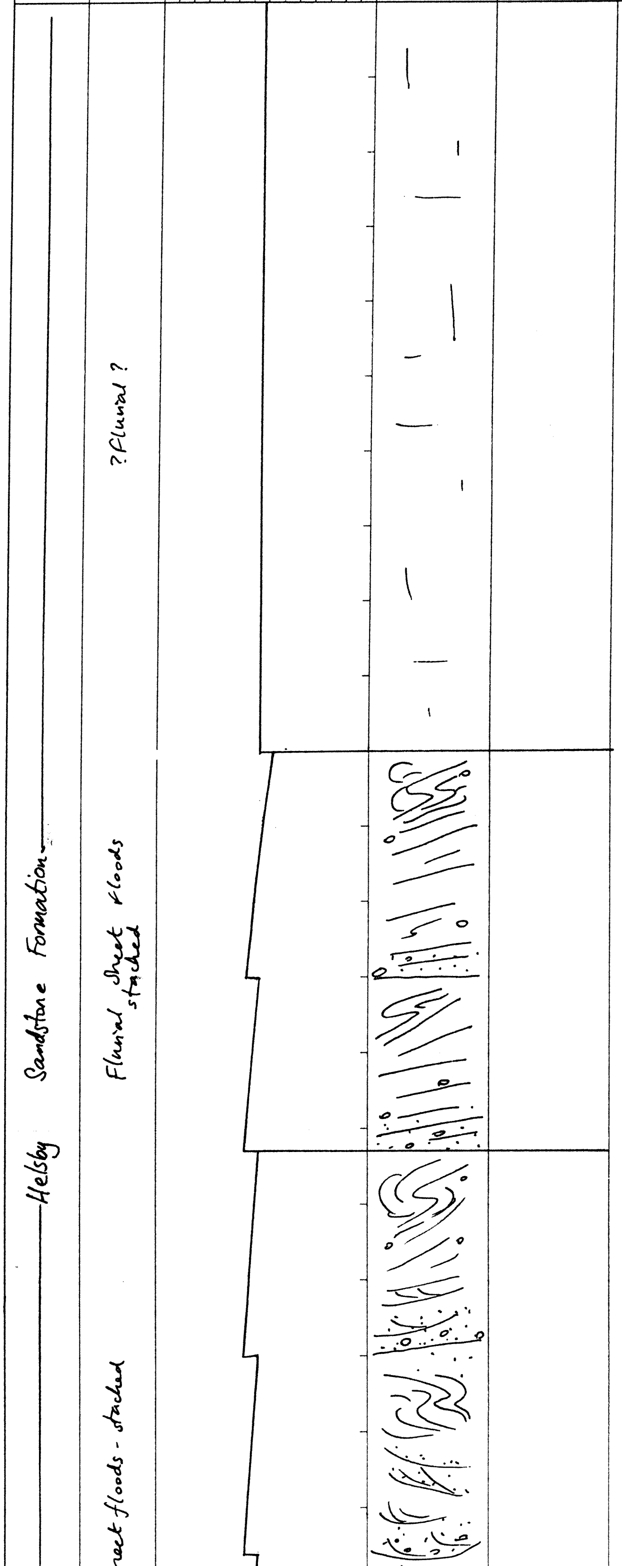
SJ28NE-4

BRITISH GEOLOGICAL SURVEY

Sheet 1 of 1

Borehole/Well No. 1:25 (1cm: 25cm).	Location Irby Hill Quarry (face ①)	NGR/Lat. & Long. 2515 8595
	KB/Ground level c. 55	Logged by E Hough

Stratigraphy	Carbonates Calc. R | Calc. A | Calc. L Average grain size C P G VC C M F VF Sl C	Sedimentary structures	Graphic lithology	Lithological description 7/10/98



c.2.5 (to top of section)
mostly massive sandstone.

1.34 Sandstone: low angle planar cross-bedded and massive.
Reddish-brown and yellow sandstone.
Units c. 0.6 thick - fining-upwards.
Some slumping and oversteepening of foresets.
Sporadic angular quartz pebbles.

2.17 Sandstone: low angle planar and trough cross-bedded.
Fining upwards units 0.7 thick with basal 0.15 of coarser/granules. Reddish-brown.
Angular grains.
Slight soft sediment deformation to top of sets.

SJ28NE – 5

BRITISH GEOLOGICAL SURVEY

Sheet / of /

Borehole/Well No. 1:20 (1cm : 20cm)

Location Arrowe Brook, Greasby

KB/Ground level c. 23m

NGR/Lat. & Long. 32649 38712

Logged by E Hough

Stratigraphy

Carbonates Calc. R | Calc. A | Calc. L
Average grain size
C P G VC C M F VF Sl C

Sedimentary structures

Graphic lithology

Lithological description

(High intertidal E mudflat)

Lake 'muddy'

Perennial 'sandy'

Perennial Lake with sheetflood sands accross base

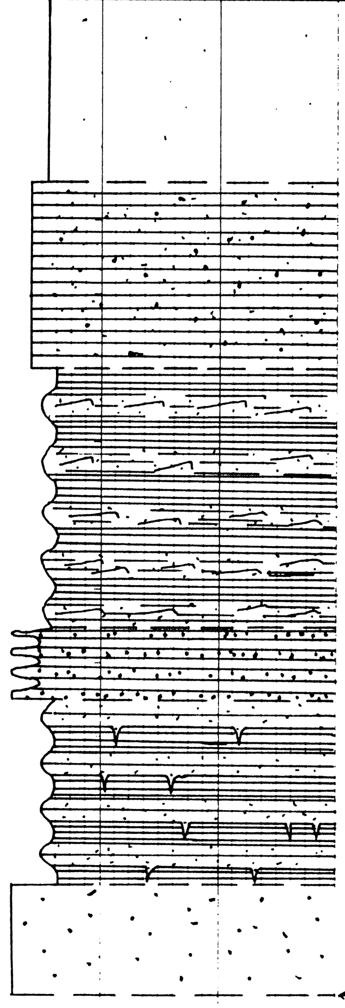
(Low-mid intertidal B sand flat)

Ephemeral Lake

?Sandflat

Lithofacies, after Ireland et al., (1978)

TARPORLEY SILTSTONE FORMATION



c.0.5 red mudstone

c.0.5 thinly bedded silty sandstone

0.7 siltstone - claystone inter-laminae
?ripple laminated

0.2 fine-grained sandstone - siltstone inter-laminae - sandstone with pebbles of rounded mudclasts.

c.0.5 siltstone - claystone inter-laminae.
silt-filled mudcracks in claystone laminae.
6/341

c.0.3 fine-grained sandstone.

Lake - area of standing water, not necessarily land-locked

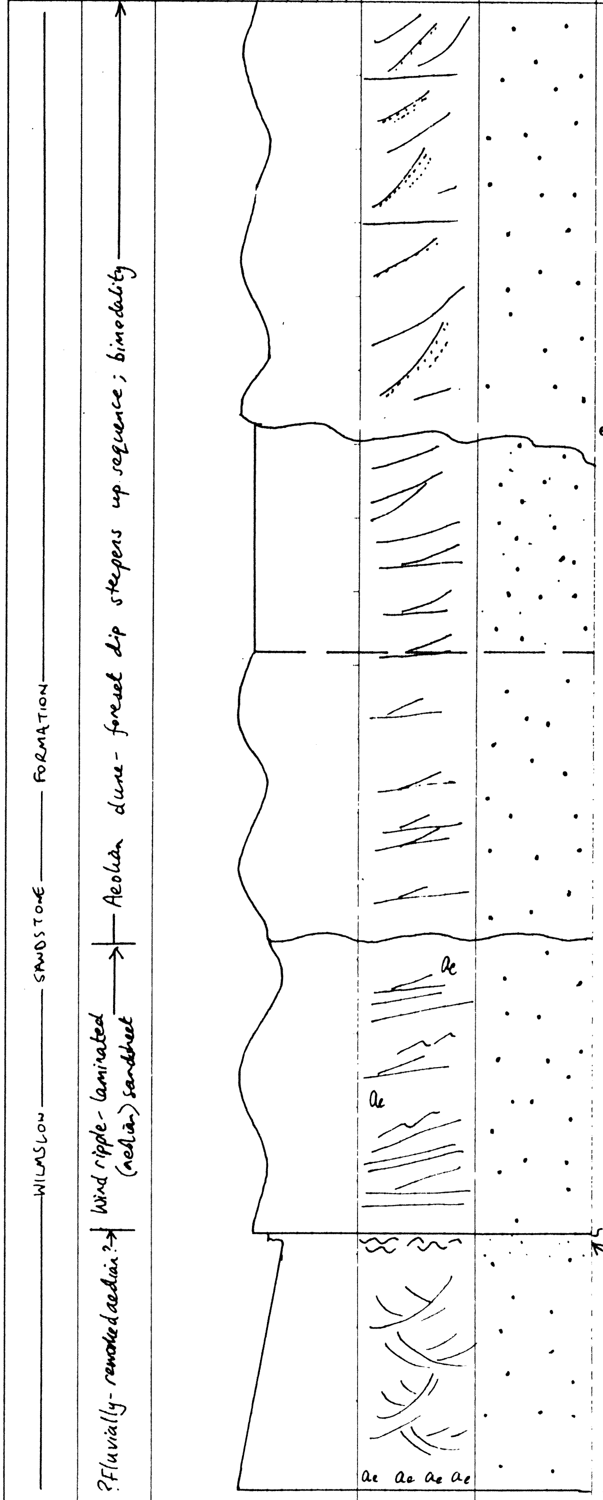
SJ29SE-1

BRITISH GEOLOGICAL SURVEY

Sheet of

Borehole/Well No. 1:10 (1cm : 10cm)	Location Red Noses, New Brighton KB/Ground level -	NGR/Lat. & Long. SJ 32996 39407 Logged by E Hough

Stratigraphy	Carbonates Calc. R | Calc. A | Calc. L Average grain size C P G VC C M F VF SI C	Sedimentary structures	Graphic lithology	Lithological description



0.56
Low and high-angle cross-bedded sandstone with some bimodal grainsize lamination.
Sets to 0.26.
NNE palaeoflow.

erosional base

0.3
Red-brown low angle cross-bedded slightly silty sandstone.
Foresets(f) 14/305
Moderately sorted
Nodular weathering

uncertain base

0.39
Low angle cross-bedded sandstone
Light reddish-brown
Well sorted

irregular base

0.4
Low angle, parallel and ripple-laminated thinly bedded red-orange-brown sandstone.
Medium-poor sorted

sharp base

0.09
Thinly bedded silty sandstone.
Mod-well sorted
Wavy non parallel bedded (basal 0.02 mottled gr-gy)

0-0.33
Planar trough cross bedded

⇒ Wedges out laterally;
laterally is 0-0.33 planar bedded orange sandstone, well sorted, medium-grained 7/149 strike 223 with lower 0.12 bimodal sorted.

sharp base 2/083

BRITISH GEOLOGICAL SURVEY

Sheet of

Borehole/Well No. 1:20 (1cm: 20cm)

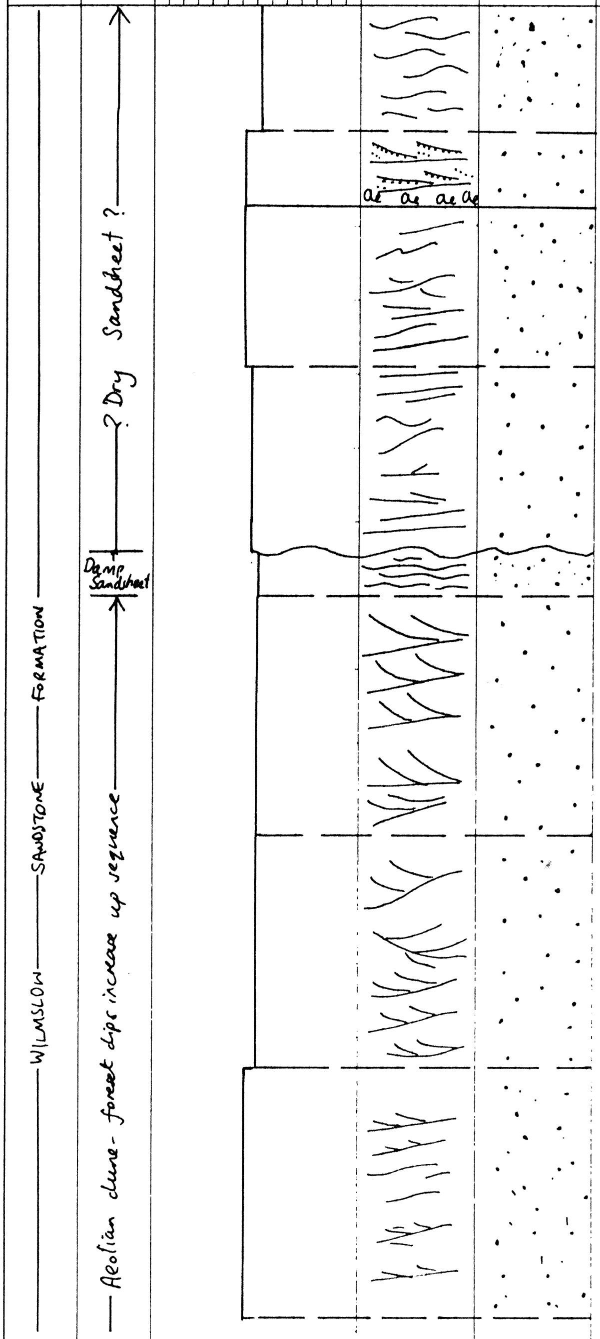
Location Red Noses, New Brighton (Composite Log)

KB/Ground level

NGR/Lat. & Long. SJ 32980 39393

Logged by E Hough

Stratigraphy	Carbonates Calc. R | Calc. A | Calc. L Average grain size C P G VC C M F VF SI C	Sedimentary structures	Graphic lithology	Lithological description



0.29 wavy thinly bedded silty sst
moderately sorted
Cream-buff-coloured.

0.2 Low angle (some bimodal sorting) cross-bedded

0.43 red and yellow slightly silty sst.
low angle wavy & planar, some ?ripples?

0.51 planar, low angle & sporadic wavy-bedded st.
Ocherous-yellow, mottled cream.
Very well sorted
Mostly rounded grains.

0.13 Thinly bedded planar non-parallel wavy cream silty st.

0.65 high angle asymptotic foresets
Mod. well sorted.
Light yellow colour.

0.62 Erosionally-based planar and low angle
cross-bedded sets. [Exposed to east of steps]

0.47 Low angle wavy and cross-bedded soft
silty sandstone. Bright yellow.

Wilmslow sst

SJ29SE - 3

BRITISH GEOLOGICAL SURVEY

Sheet of

Borehole/Well No. 1:20 (1cm : 20cm)

Location St Hilary's Brow, Wallasey (N. side of road)

KB/Ground level

NGR/Lat. & Long. SJ 32973 39195

Logged by E Hough

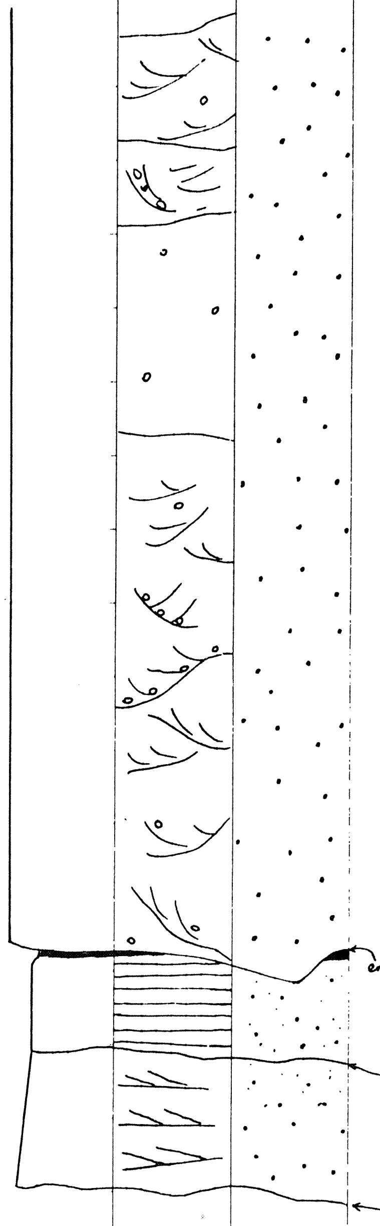
Stratigraphy	Carbonates Calc. R | Calc. A | Calc. L Average grain size C P G VC C M F VF SI C	Sedimentary structures	Graphic lithology	Lithological description

Section continues for c.2m (inaccessible) with m-scale trough-cross-bedded sandstone

HELSBY —— SANDSTONE —— FORMATION

Stacked fluvial channels/unconfined sheet floods?

Silting up of fluvial channel



2·52 max. Yellow sandstone, weathers grey brown. Erosive-based sets up to 0·9. Some massive sets. Sporadic pebbles commonly alligned along set bases, mostly rounded, some angular. to 56mm.

Sandstone - moderately well-sorted commonly medium-grained, some coarse-grains.

Main surfaces 8/083.

erosive-base

0·28 planar-bedded silty sandstone with 0·01 sandy siltstone at top (laterally discontinuous). Moderately well sorted.

slightly erosive base

slightly erosive base 4/064 strikes c. 342

Notes: palaeoflow either into or out of face (exposure at corner of St Hilary Brow/Wallasey Rd shows dep. to SSW)
Face oriented 082

Helsby st

SJ29SE-4 (part 1)

BRITISH GEOLOGICAL SURVEY

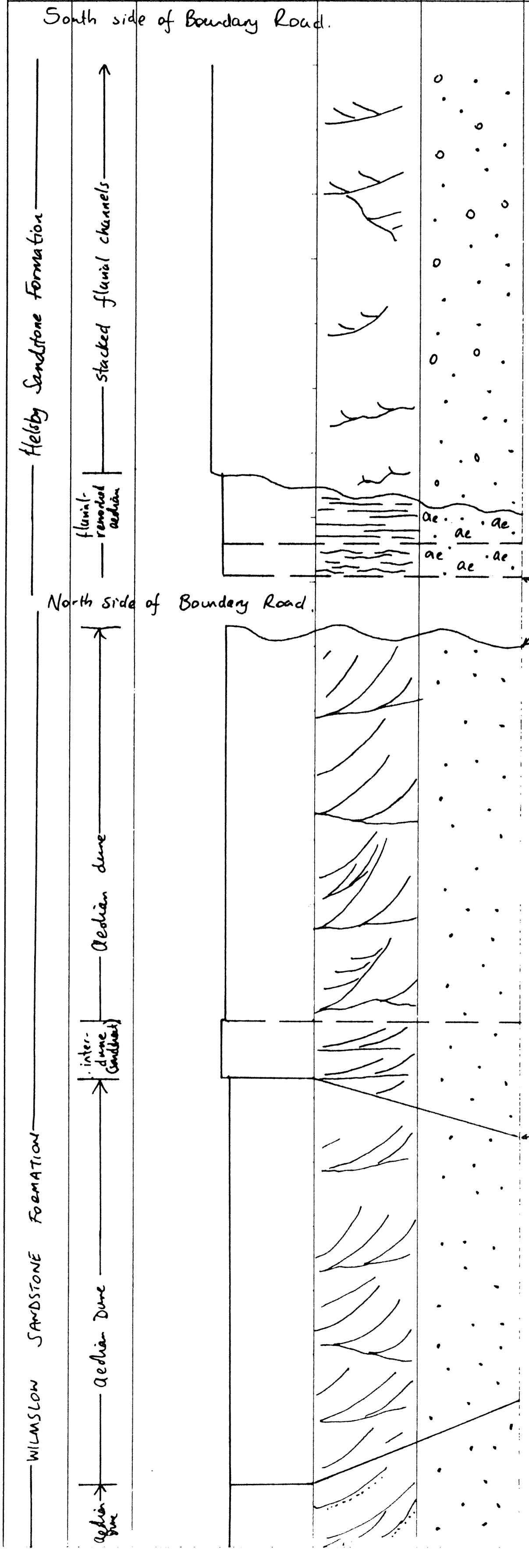
Sheet 1 of 2

Borehole/Well No.
1 : 40 (1cm : 40cm)

Location Boundary Road, Bidston
KB/Ground level

NGR/Lat. & Long. 2861 9027 – 2875 9023
Logged by E Hough

Stratigraphy	Carbonates Calc. R | Calc. A | Calc. L Average grain size C P G VC C M F VF SI C	Sedimentary structures	Graphic lithology	Lithological description



c. 2·5 (poorly exposed)
Low angle ? trough cross-bedded poorly sorted sandstone.
Pebbles in sandstone - quartz up to 5-6 cm.
Grey- buff colour.
Strongly erosional / irregular bases to sets, which are 0.3 min.
foreset bedding 11/279
main surfaces 18/249 (variable).

0·1 Thin-laminated poorly sorted sandstone. Degraded; silty.
0·18 Wavy planar, moderately sorted. Poorly exposed.
on N. side of road, this junction is erosional / undulating

c. 2·5 co-set. with reactivation surfaces c. 0·75 apart.
Fine-medium grained large scale asymptotic-bedded
low angle planar cross-bedded

0·37 - 0·75 very low angle slightly assymptotic planar cross- bedded
sandstone. Well sorted.
foreset dips 28/271

sharp base 12/084
2·5, wedges to 1·6. Large scale asymptotic cross-bedded sandstone
minor reactivation surfaces up to 0·75 apart.
foreset dips 23/321
Main surfaces 8/117
reactivation surfaces 6/277 (variable)
Moderately sorted.

1·9 (wedges to 0·65 laterally)
large-scale assymptotic cross bedded dune set.
foreset dips 18/343
main surfaces 16/072
Minor reactivation surfaces every c. 0·5

SJ29SE - 4 (part 2)

BRITISH GEOLOGICAL SURVEY

Sheet 2 of 2

Borehole/Well No. 1:40 (1cm: 40cm)

Location Boundary Road, Bidston

NGR/Lat. & Long. 2361 9027-2375 9023

KB/Ground level

Logged by E Hough

Stratigraphy	Carbonates Calc. R | Calc. A | Calc. L. Average grain size C P G VC C M F VF SI C	Sedimentary structures	Graphic lithology	Lithological description

WILMSLOW SANDSTONE FORMATION

Aeolian Dune

Aeolian Dune

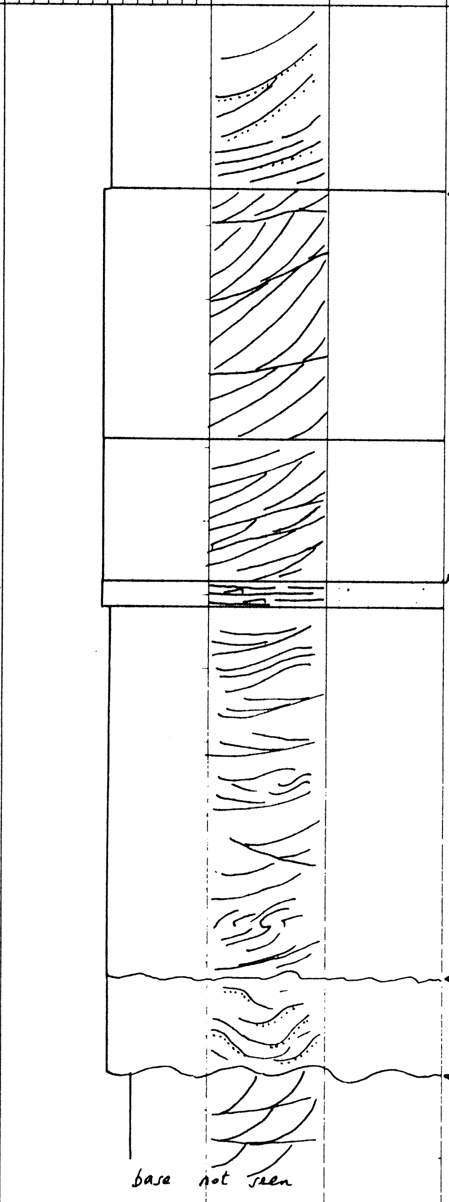
Aeolian Dune

Dry Sand-Sheet

Aeolian Dune (with soft sed. def)

? Sand Sheet (dry) -slumped

Aeolian Dune



Bimodal lamination evident.

}Basal c.0.3 very low angle cross-bedded

←sharp base

1.35 large-scale assymptotic-bedded dune
Foreset dips increase up-dip. - dip to SW
Very well sorted.
Yellow-orange.
Minor reactivation surfaces c.0.5m.

←sharp base, 12/064

0.77 low angle planar cross-bedded buff-yellow sandstone.
Moderately well-sorted.
Occasional angular grain; most well-sorted.
foreset bedding 12/011

←sharp base

up to 0.11. Planar bedded silty sandstone. Bedding (+ base) 4/084
? ripples indicate deposition to east. Many frosted quartz-grains. Moderately sorted.

c.2.0 Co-set of low angle and wavy-parallel (soft sed-def?) asymptotic-cross-bedded light yellow-orange sandstone. Many (aedian) frosted quartz grains:- well rounded, good sphericity. Sets bounded by reactivation surfaces. <1cm nodules- pref. cemented.
foreset dips 28/298
main surfaces dip 16/354

←irregular base (soft sed def?)

0.52 Wavy-parallel bedded 'trough' (soft-sediment slump)
Bimodally laminated. Good Aedian grains. Well sorted.

←wavy base- (soft. sed. def)

0.44 high-angle assymptotic cross-bedded sandstone. Moderately well-sorted, moderately spherical, well-rounded grains.
Yellow-buff/rusty-brown colour.

The Breck Quarry, Wallasey

Face 1: c. 6 m pebbly sandstone. Low angle cross-bedded and massive. Most surfaces convex-up, and erosionally-based. Medium- to coarse-grained. Poorly sorted. Pebbles are of low spherocity, are sub-rounded to rounded, and up to 50 mm. Clast types are mostly quartz, some ?chert and rare sandstone. Lateral accretion sand bodies to top of section. Overall, m-scale sets in c. 5 m co-sets. Lower 0.5 m exhibits vuggy weathering, and foreset azimuths to c.280. Erosional base (20/007).

ON

1.5 m essentially massive sandstone with some low angle surfaces. Well sorted, fine- to medium-grained, many spherical quartz grains.

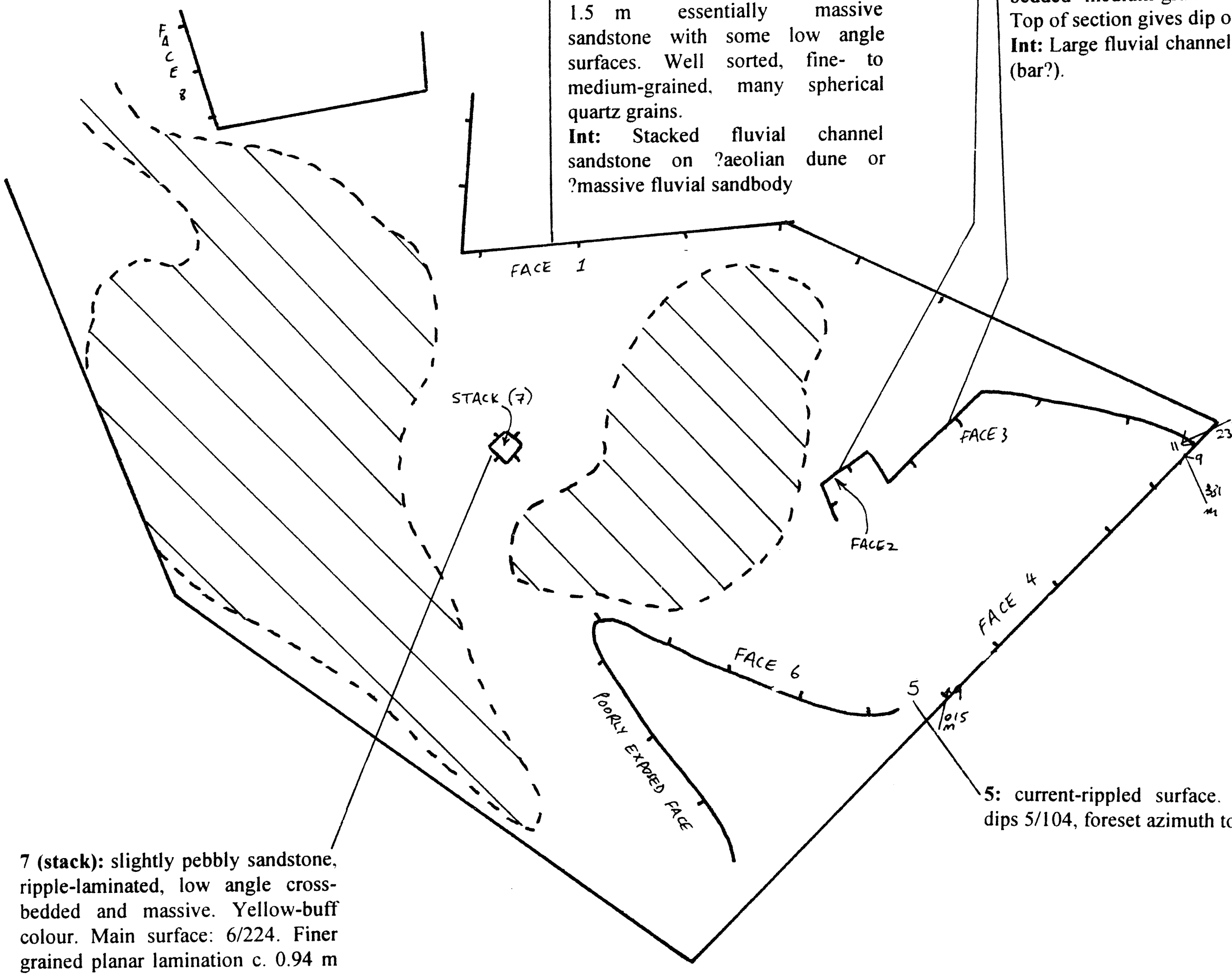
Int: Stacked fluvial channel sandstone on ?aeolian dune or ?massive fluvial sandbody

Face 2: 2.8 m pebbly sandstone. wavy-planar bedded. Bedding is on cm- 10cm- scale. Sandstone is medium-grained and moderately well sorted. Most grains are of good spherocity, although there are some angular grains. Pebbles are less than 1.5 cm in diameter. Dip: 3/017.

Int: Fluvial sandstone (channelized).

Face 3: c.5 m slightly pebbly. massive or rarely low angle cross-bedded medium-grained sandstone. Top of section gives dip of 9/340.

Int: Large fluvial channel sandstone (bar?).



5: current-rippled surface. Surface dips 5/104, foreset azimuth to 009.

7 (stack): slightly pebbly sandstone, ripple-laminated, low angle cross-bedded and massive. Yellow-buff colour. Main surface: 6/224. Finer grained planar lamination c. 0.94 m from base overlain by trough to 2m (wedges out), then c. 2 m cross-laminated unit with parallel set-bounding surfaces, with opposing directions of foreset dips.

Int: Lower energy fluvial channel with some sinuosity leading to lateral bar (or point bar ?) deposition.

1:2000

┬┬┬ Exposed rock-face

▨ Made ground/Quarry spoil

f - foreset dip m - main surface dip

Borehole/Well No. 1:20 (1cm : 20cm).

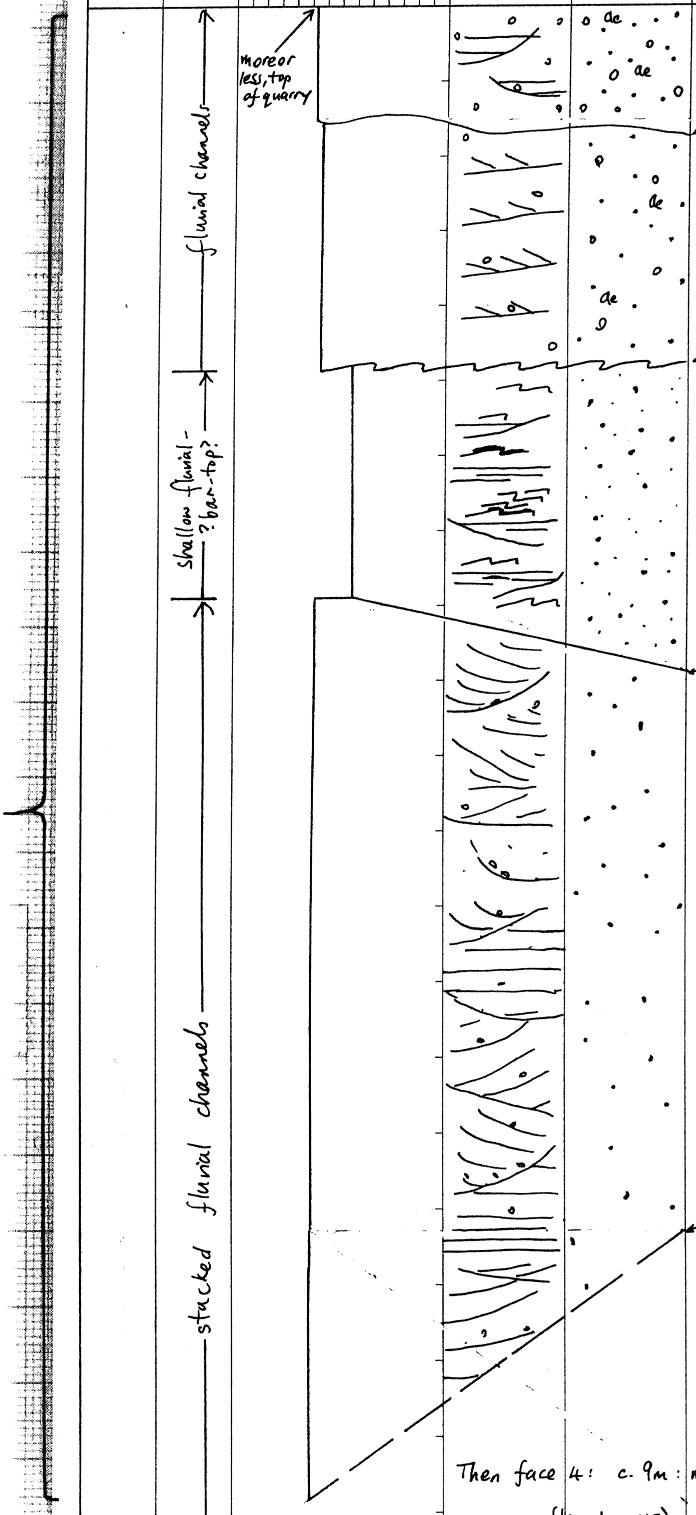
Location The Breck, faces 4 and 6

NGR/Lat. & Long. 2980 9170 (approx)

KB/Ground level

Logged by E Hough

Stratigraphy | **Carbonates** Calc. R | Calc. A | Calc. L / **Average grain size** C P G VC C M F VF Si C | **Sedimentary structures** | **Graphic lithology** | **Lithological description**



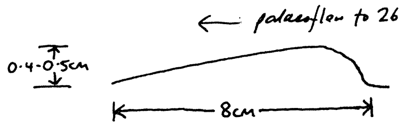
0.31 sandstone: pebbly, angular + rounded, mostly quartz, to 2cm. slightly micaceous. Planar bedded trough-set. foreset azimuths 030 - 040.

erosional base

0.66 low angle cross-bedded sst with sporadic pebbles to 0.5cm. Pebbles - rounded, quartz. Micaceous. Foreset dip 30/104

base - loaded into current-ripples (crest azimuth 149).

0.6-0.82 Current ripple-laminated silty sandstone (subordinate planar-bedded too). Moderately sorted. Yellow-buff colour. sets to 0.2



Some ripples have mud-draped tops.

sharp base (3/084)

1.62-2.2 Planar, occasionaly trough cross-bedded sandstone. (pebbly). sets 0.2-0.3m. foreset azimuth 311. Mainsurfaces 4/162 Moderately well sorted. Quartz pebbles to 3½-4cm; rounded, elongate.

Joints: main directions 68/253, 88/356.

base not seen

Then face 4: c. 9m: mostly massive, with some small-scale trough cross-beds (depositional flow to NE). c. ½m at top, of thinner bedded small troughs (as lower unit, above?) Poorly sorted, silty, fine- to coarse-grained. Sporadic angular pebbles alligned along low angle surfaces (22/253)

SJ38NW-1

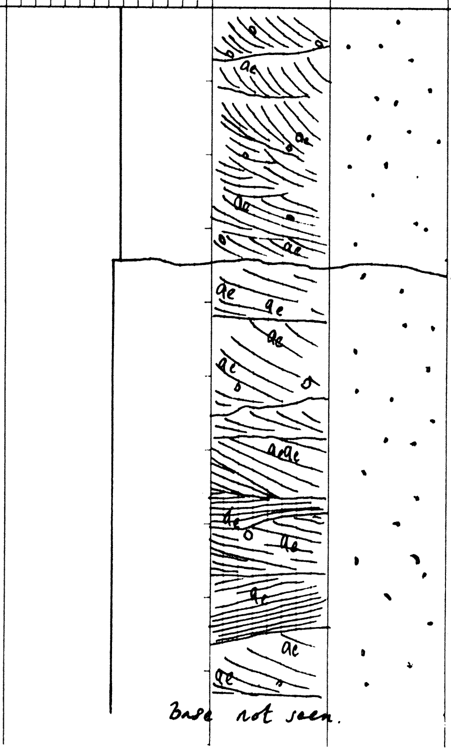
Helsby Sst.

BRITISH GEOLOGICAL SURVEY

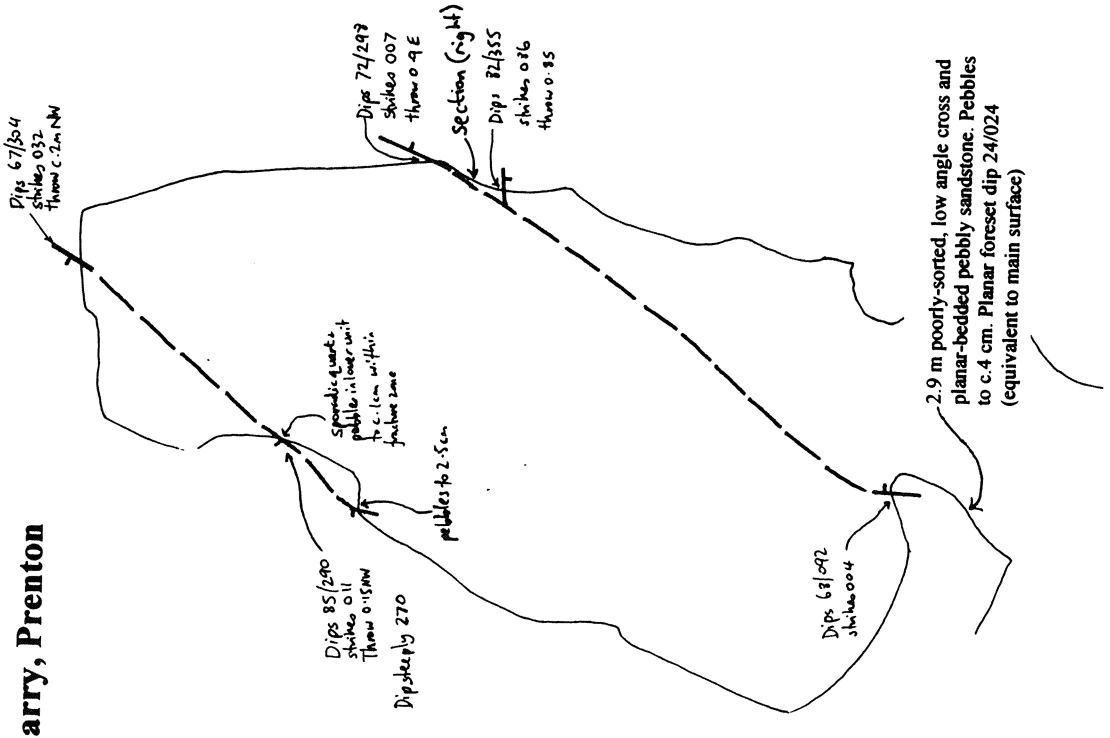
Sheet 1 of 1

Borehole/Well No. 1:40 (1cm: 40cm)	Location The Arno Quarry, Prenton KB/Ground level	NGR/Lat. & Long. 3048 8730 Logged by E Hough.

Stratigraphy		Carbonates Calc. R | Calc. A | Calc. L. Average grain size C P G VC C M F VF SI C	Sedimentary structures	Graphic lithology	Lithological description
HELSBY SANDSTONE FORMATION	fluvial channels (pebbles to 2·2cm) probable sheet flood series (possibility of aeolian re-working)				c. 1·5. Moderately well-sorted low angle cross-bedded sandstone in erosionally-based sets. Sets c. 1m. Orange-yellow fresh colour, pale green-grey weathered colour. Sporadic milky quartz pebbles to 2·2cm. Some aeolian grains, some angular feldspar grains. foresets 8/287 main surface gentley to c. 060. slightly erosional base 16/307 (irregular) 2·75 low angle cross, and planar-bedded wellsorted slightly pebbly sandstone. Pebbles - rare, up to 1cm. Pale yellow-brown fresh colour, pale green-grey weathered colour. Sets 0·3-0·7. Many aeolian grains. sharp or gently irregular bases to sets. foresets - variable amounts, broadly to 044 Main surfaces - 17/298



Base not seen.



2.9 m poorly-sorted, low angle cross and planar-bedded pebbly sandstone. Pebbles to c.4 cm. Planar foreset dip 24/024 (equivalent to main surface)

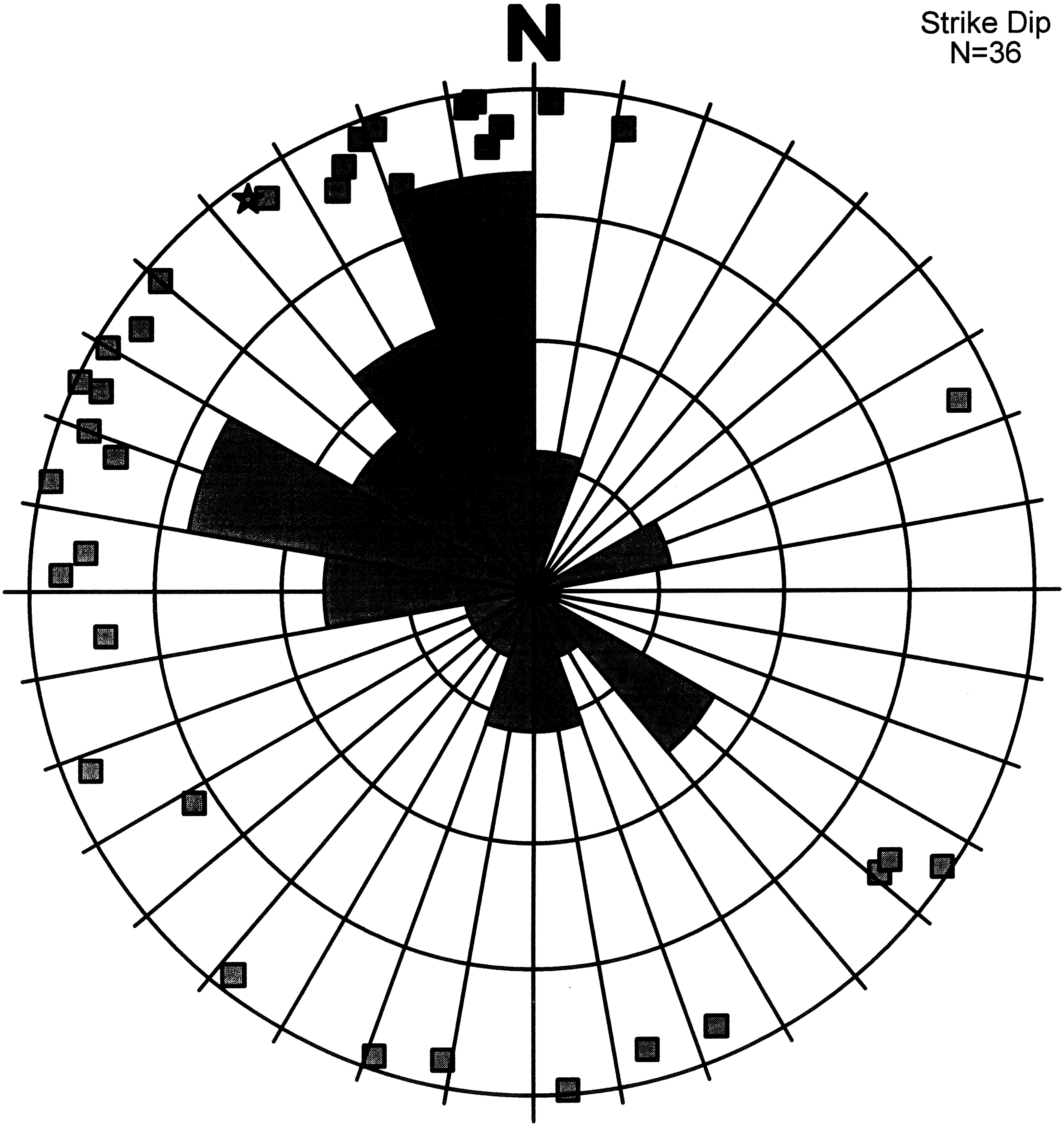
Arno Quarry, Prenton

Faults - generally within a 0·5-1m shear zone; no preferential cementing along fault zones.

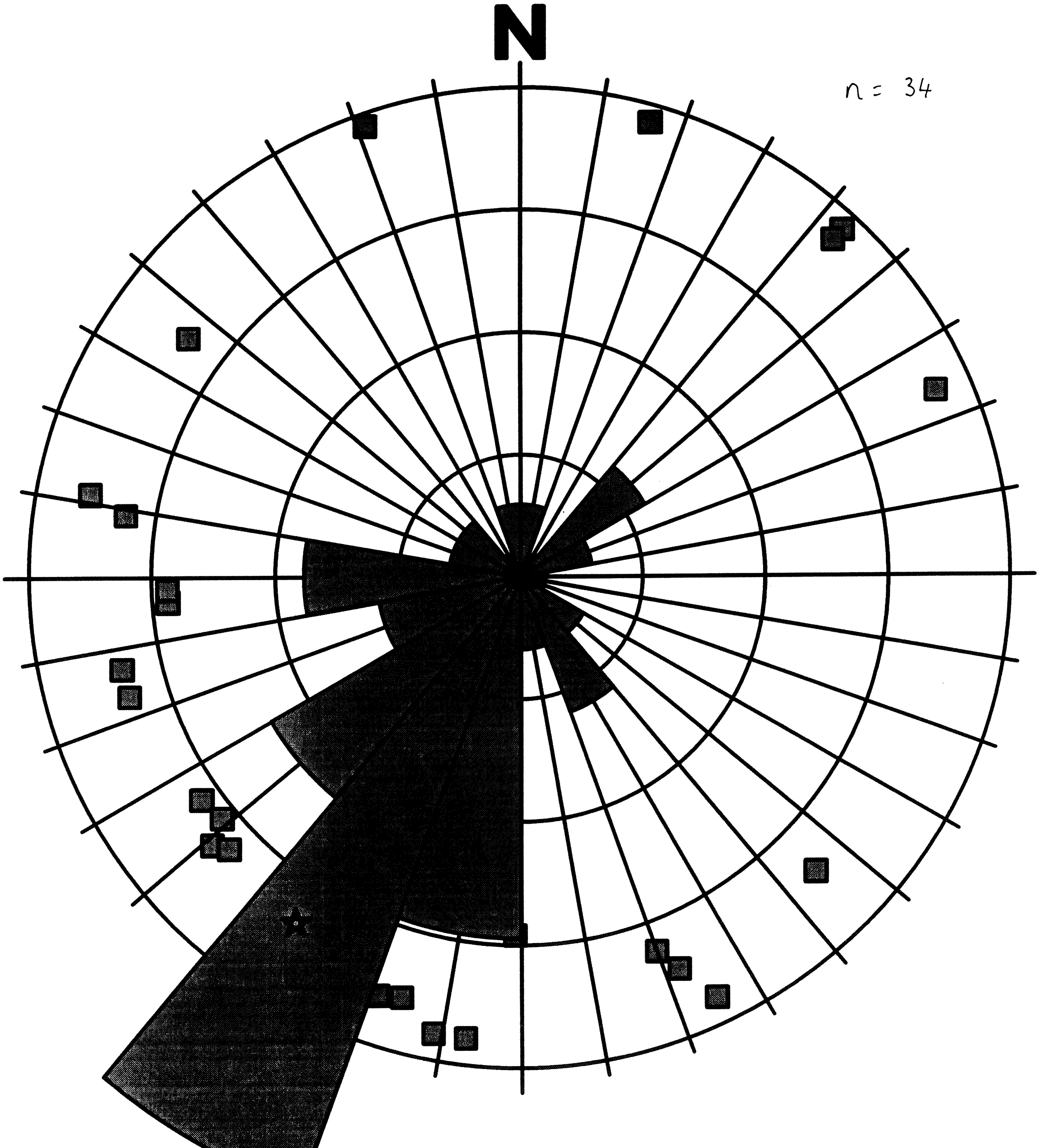
Appendix 4 Numerical data: stereoplots of major bounding surface and foreset dip azimuths

Major bounding surfaces and foreset dips and azimuths were taken; these have been plotted using the 'StereoNet' package without correction for structural dip (which is generally 6^o NE in the north Wirral district. On all plots, the mean azimuth is shown by '☆'.

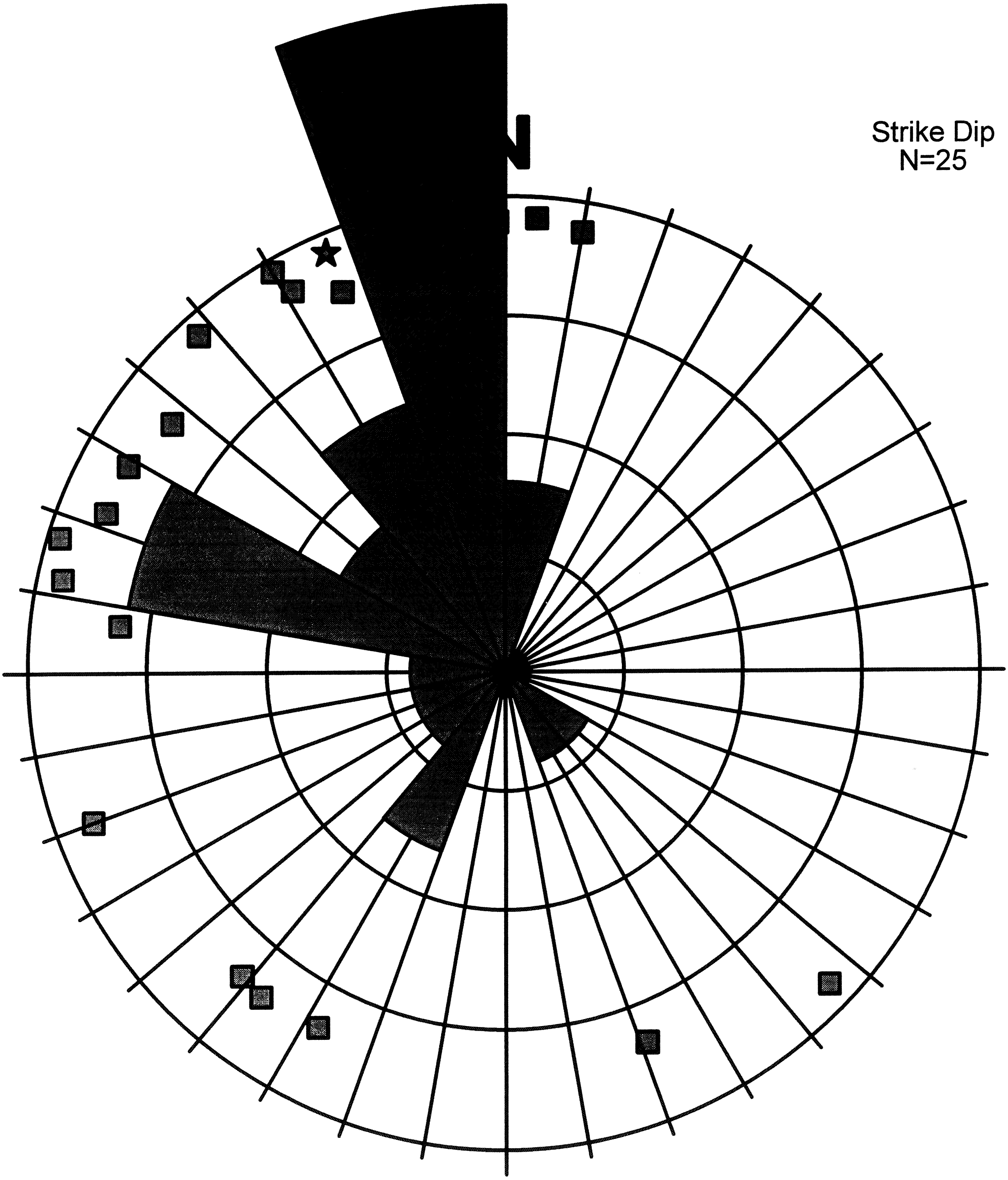
1. Wilmslow Sandstone Formation; major surface dip and azimuth (plane-to-pole)
2. Wilmslow Sandstone Formation; foreset dip and azimuth (plane-to-pole)
3. Helsby Sandstone Formation; major surface dip and azimuth (plane-to-pole)
4. Helsby Sandstone Formation; foreset dip and azimuth (plane-to-pole)



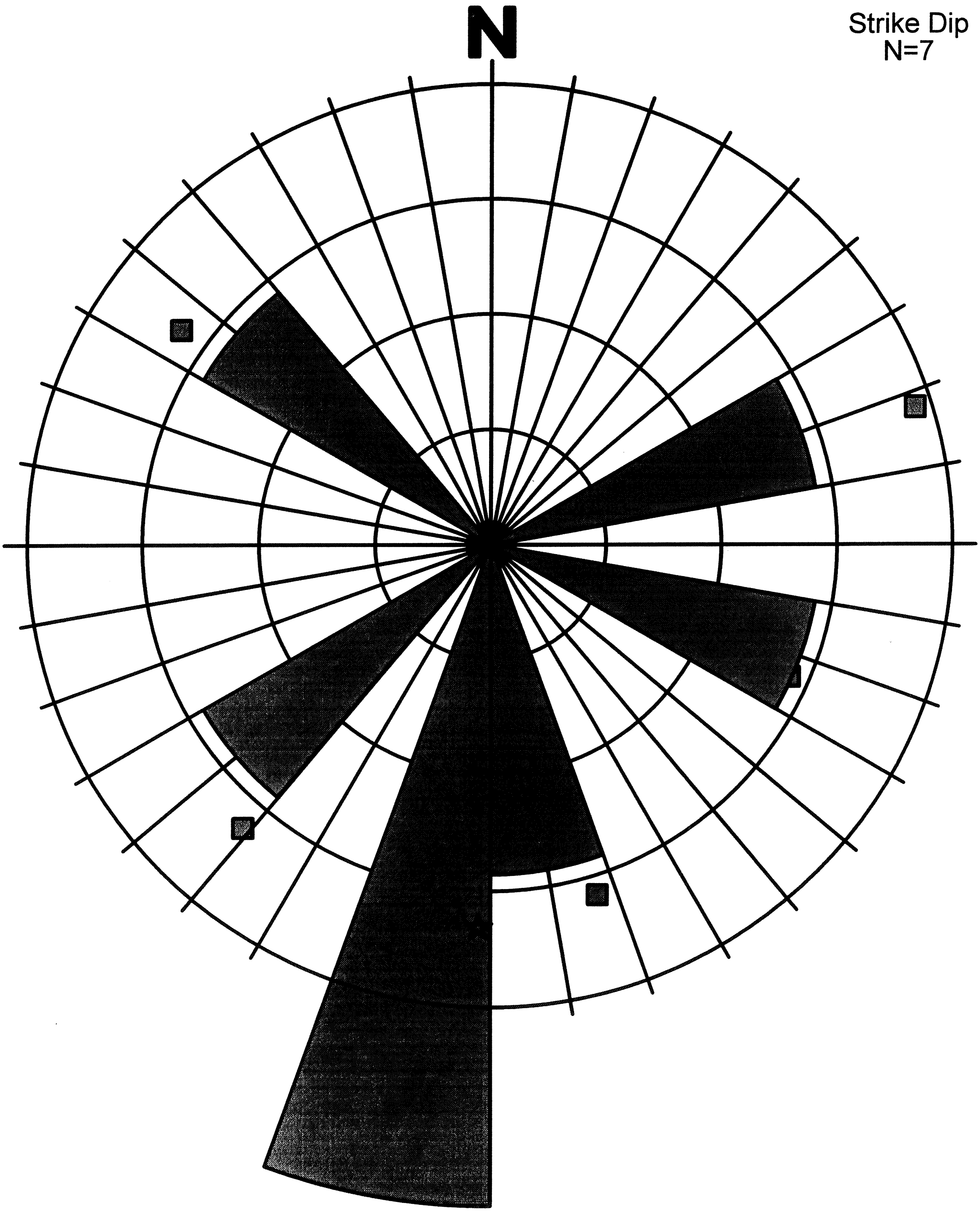
11.4a: Stereoplot of bounding surfaces and azimuths from the Wilmslow Sandstone Formation within the district. ☆ = Mean.



11.4b: Stereoplot of foreset surfaces and azimuths from the Wilmslow Sandstone Formation within the district. ☆ = mean.



11.4c: Stereoplot of bounding surfaces and azimuths from the Helsby Sandstone Formation within the district. ☆ = mean.



11.4d: Stereoplot of foreset surfaces and azimuths from the Helsby Sandstone Formation within the district. ☆ = mean.

Appendix 5 Drift sequences proved by the Newton Carr boreholes (SJ28NW-7-20, 22-24)

Borehole	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ground Level (OD)	13.8	6.3	6.2	5.4	4.5	6.4	4.7	5.1	4.7	4.4	4.4	4.8	4.7	4.5
Borehole (numbers from Innes *et al*)					5	6	7	8	9	10	12		13	14
fill						2								
yellow sand								0.8	0.5					
brown silt					1.5		3	1.5	1.4					1.8
blue-grey silt					1.6				2.5	1.05	1.1			2.1
peat					**2.3**					**2**	**2.4**			**2.8**
blue-grey silt					4		6.95	5		4.5		2.2		6.6
grey sand								7.5	7		3			
brown silty clay					4.6	5.8		8.2		6.5	6.4			
peat							**7.15**	**8.6**	**7.3**	**7.3**				**7**
blue-grey silt							9.8	9.6	8.2	7.6				8.1
peat							**10**							
Clay (base Holocene)	0.3	0.4												
Sand							*12*	*10.5*	*8.5*	*7.8*		*2.6*		*8.4*
Till	*16.8*	*9.2*	*9*	*2*	*10*	*11.4*	*12.5*	*11.5*				*7.7*		*11*
Sand		*11*	*11.6*	*4.1*	*10.6*		*12.7*	*14.55*	*14*			*11.2*		
Clay		*11.4*	*12.5*									*11.5*	*5.3*	
Base Quaternary	*16.8*	*11.4*	*12.5*	*6*	*10.6*	*11.4*	*12.7*	*14.55*	*14*	*13.2*	*np*	*11.5*	*np*	*11*

np= not proved

numbers relate to depth to base of deposit

Peat beds are in bold; Holocene deposits are normal font; older Quaternary deposits are in italic font

Peat proved by boreholes other than the Newton Carr boreholes (bold indicates two peat beds proved)

SJ28NE (Arrowe Park)

Borehole Nos.: 36-38, **43**, 44-47, **56**, **57**, 61, 83, 93, ?97, 99, 102-106

SJ29SE (Leasowe)

Borehole Nos.: 7-16, 21, 28-30, 54, 56-61, **62**, 63-68, **69, 70, 71 (possibly 3 beds proved)**, 72, **73**

SJ38NW (Tranmere)

Borehole Nos.: 74-77

SJ39SW (New Brighton)

Borehole Nos.: 46, 50-54, 60

Mersey Tunnel/M53 boreholes

(Currently held in BGS Miscellaneous Sheet File 96; numbers are the original contractors)

Borehole Nos.: W27, **W28**, **W30**, W31-W36, W38, W39, W42-W49, W50-W52, W54, W64, W65, W67, W70

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