1. Introduction

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This report details the work carried out by a team funded by the Aggregates Levy Sustainability Fund between March 2005 and March 2007 on a project devised to investigate the prehistoric and Romano-British archaeological landscapes of the eastern parts of South and West Yorkshire, including the adjacent parts of North Yorkshire and North Nottinghamshire. In synthesising the various forms of available map-based archaeological evidence the project has specifically focused upon past, present and future aggregates extraction sites, the aggregates industry having an ironic duality in being one of the key agents in both the destruction and investigation of the archaeological landscape in the study area. Whilst the project axis is centred upon the Magnesian Limestone belt, the study also contrasts the archaeological landscapes of the adjoining geologies. As well as assessing the effect that the aggregates industry has had upon the archaeology of the study area, the project has provided an opportunity to redefine the baseline knowledge of the cropmark landscapes of the region and so enable future work to be carried out within a more informed archaeological research framework that can be articulated within revisions of local Minerals Local Plans and Unitary Development Plans.

Background

The archaeological investigation of the Magnesian Limestone belt and its margins has relied largely on aerial photography over the last 30 years, the predominantly arable land use and well-drained soils being conducive to good cropmark formation. Aerial reconnaissance and mapping of the cropmark landscapes in the eastern parts of South and West Yorkshire have revealed areas of intense past settlement and land division. Over the last fifteen years, since the introduction of PPG 16 in 1991 (DoE 1990), there has been a gradual increase in the amount of ground investigation, often using a combination of aerial photograph interpretation, geophysical survey data and excavation, much of which over the wider study area has been as a consequence of extensive mineral extraction. A key factor in the inception of this project however was the archaeological analysis carried out during the construction of the M1-A1 Link Road (see below). The results of that work were used to propose a general local model for the chronology and development of the Iron Age and Romano-British landscape in the East Leeds area. This model however, could not be wholly reconciled with landscape interpretations prevalent in other parts of the region, most notably those associated with the phenomenon known as the 'brickwork' plan fields of South Yorkshire and North Nottinghamshire (Riley 1980). It was apparent that the questions being posed could never be answered satisfactorily on a site-by-site basis and, therefore, in the absence of a regional overview, this project was devised to provide a more global appraisal and synthesis of the cropmark landscape of this part of Yorkshire.

The project benefited immediately by being able to incorporate elements of the cropmark mapping carried out as part of the North Nottinghamshire, Vale of York and the Lower Wharfedale NMP projects, which effectively provided the cropmark mapping for the northern half and south-eastern tip of the study area. The work of the present project has supplemented this by mapping the cropmarks of an intervening tract of South Yorkshire to NMP standards. The cropmark evidence has been synthesized with available results from geophysical surveys and excavations to provide the most comprehensive overview yet available for the region. The results facilitate the drawing of more meaningful conclusions about past landscape, its geography, form, character and chronology, as well as the formulation of future research objectives for what is a fast diminishing archaeological resource.

The collated data resulting from the project form a GIS database, the relevant elements of which will be incorporated into the respective county archaeological records. Whilst the cropmark mapping has documented features of all periods, the scope of this report has been limited to address only the cropmark landscapes of the prehistoric and Roman periods, although in reality it is likely that a number of undated post-Roman sites will have been presented. The first five chapters of this report have been designed to provide an overview and rationale for the project. Included is a review of the archaeological perspectives and investigative approaches that developed with respect to cropmark sites in the different counties composing the study area up to the end of the 20th century. Aggregates extraction will continue to be a major industry within the study area and as such offers the best opportunity for predictive long-term research through large open-area excavation, an essential requirement for a better understanding of the cropmark landscape. Consequently, having assessed and classified the various forms of cropmarks revealed by the combined cropmark mapping projects (Chapter 6), Chapters 7 assesses the archaeological importance of the active quarries within the study area, how they have contributed to our archaeological understanding to date, and what potential they offer for the future. Whilst aggregate-associated archaeological work accounts for much of the landscape investigation work that is carried out, some of the most important evidence has been derived from less frequent large-scale development works, such as new road schemes and fringe developments, often in areas where cropmark visibility is not good. Chapter 7 has been structured such that it concludes with a number of landscape case studies which take into account the wider archaeological landscape investigations around a number of quarries. The final chapters consider chronologically and thematically the results of the project, new revelations, how these have changed our ideas about the development of the ancient landscapes of the region and what the implications are for future archaeological work, both with regards to aggregates extraction and the investigation of cropmark regimes of the region generally.

The Study Area

The study area focuses upon the 65km length of Magnesian Limestone outcrop that runs along the A1 corridor from Wetherby, West Yorkshire in the north to Dinnington, South Yorkshire in the south, flanked to the west by the lower foothills of the Pennines and to the east by low river floodplains. The staggered area is between 20km and 30km wide covering a total area of 1,525 square kilometres, the area of 61 O.S. 1:10 000 scale quarter sheets. The area occupies parts of several districts included in the study: Selby DC in North Yorkshire, the eastern parts of Leeds CC and Wakefield MDC in West Yorkshire, parts of the Metropolitan Boroughs of Doncaster, Rotherham and Barnsley in South Yorkshire, and the northern part of Bassetlaw DC in Nottinghamshire (Fig. 1.1).

In antiquity the limestone belt formed an intermediate geographical zone between the Pennines to the west and the lower wetland areas of the Vale of York and the Humberhead Levels to the east, a fact that resulted in its use as a corridor of north-south communication from the early prehistoric period. Whilst the well-drained soils of the Magnesian Limestone were attractive to Early Neolithic settlers, it was during the later Iron Age that the landscape was most extensively exploited for settlement and arable farming, and its topography later utilised by the Romans for their military road between the legionary forts at Lincoln and York. Subsequently, the same advantages have been exploited for the Great North Road and more recently the A1 motorway. Such good communications, coupled with the natural geological resources and the large conurbations of West and South Yorkshire, have made the area a focus for a growing aggregates extraction industry.

Geology

The solid and drift geology of the study area is both fundamental and influential to all aspects of this study. Geology has shaped the relief, drainage and soils influencing human exploitation and settlement in the area (Chapter 2), determined the nature, location and extent of mineral and aggregate extraction since historic times (Chapters 3 and 7) and, to an extent, affects the visibility and survival of cropmark evidence (Chapters 6 and 8). The description of the solid and drift geology is taken from the British Geological Survey 1:50,000 scale digital mapping (BGS 2006) and regional geological memoirs, as cited below. The study area extends over five areas of solid geology: the Carboniferous Millstone Grit and Coal Measures (26%), the Permian Magnesian Limestone (36%), the Permo-Triassic Sherwood Sandstones (37%) and the Triassic Mercia Mudstones (1%) (Fig. 1.2).

The Carboniferous strata are confined to the west of the study area where the Millstone Grit, comprising interbedded mudstone, siltstone and sandstone, outcrops to the west of Wetherby and south to Seacroft. Further south this is overlain by Coal Measures divided into Lower (Westphalian A), Middle (Westphalian B) and Upper (Westphalian C) formations. The Lower Coal Measures are restricted to the Leeds area, the Middle Coal Measures continue into Wakefield District, as far east as Castleford and Pontefract, and reappear further south in the districts of Barnsley and Rotherham. The Upper Coal Measures run from south of Pontefract to Dinnington on the southern edge of the study area. The Coal Measures formations have a similar lithology to the Millstone Grit, although the former commonly have thinner and finer sandstone beds and much more coal (Carroll *et al*. 1979).

The Carboniferous strata are separated from the later 'Magnesian Limestone' by deposits of aeolian desert sands that make up the Permian Yellow Sands Formation (formerly the Basal Permian Sands) outcropping in a thin band from Garforth southwards to Ledston, Castleford and Pontefract. These sands comprise less than 1% of the solid geology in the study area but have proved an important resource to the aggregates industry. By the late Permian, the study area sat at the western edge of a major enclosed sea depositing clayey dolomitic limestones and, during periods of retreat, desert-derived, lacustrine mudstones and siltstones or marls. To the west of the platform the basal Cadeby Formation (formerly Lower Magnesian Limestone) forms a broad outcrop of dolomite and dolomitic limestone between 30-70m thick (Cooper and Gibson 2003) exposed at Cadeby (Cat. no. 21), west of Doncaster, the type-site quarry for this material and now a Site of Special Scientific Interest.

The basal limestone deposits are overlain by the red mudstone and gypsum of the Edlington Formation (formerly Middle Permian Marl) and the fine-grain dolomites and dolomitic limestones of the Brotherton Formation (formerly Upper Magnesian Limestone), a sequence that is exposed at old workings at Park Balk Quarry (Cat. no. 6) and Darrington Quarries (Cat. no. 16) (Lake 1999). The final Permian deposit, the Roxby Formation (formerly Upper Permian Marl) overlays the Brotherton Formation along its eastern edge and is almost entirely covered by drift deposits of the Vale of York. Where it does outcrop, such as around Tickhill, it weathers to a heavy red-brown clay (Lake 1999).

The final regression of the sea that deposited the limestones (76%) and marls (24%) of the Permian platform was followed by the deposition of deep aeolian and fluvial sands, during Permo-Triassic desert conditions, that now make up the Sherwood Sandstone Group (formerly named Bunter Sandstone). A further periodic shallow sea developed in the later Triassic depositing thick mudstones and siltstones, the Mercia Mudstone Group (formerly Keuper Marl), that outcrop along the most easterly edge of the study area. Subsequent deposits of Jurassic, Cretaceous and Tertiary age, as appear further east, have been totally eroded from the study area following uplift and tilting of the land surface gradually exposing the Permian outcrop.

The following Quaternary period was characterised by dramatic climate fluctuations that caused repeated glaciation separated by temperate interglacial phases producing, in order of abundance: glaciolacustrine clays and silts, till (boulder clay), river terrace gravels, glaciofluvial sands and gravels and small quantities of morain, head and blown sand. These deposits, mainly from the most recent Devensian glaciation, together with later Flandrian deposits of alluvium and peat, form the drift geology that covers 50.5% of the study area, mainly confined to the east overlaying the Roxby marls and Sherwood Sandstone (Fig. 1.3).

During repeated glaciations, the Pennines were glaciated as far south as Leeds and a tongue of ice occupied the Vale of York, advancing as far south as Doncaster. The advancing ice formed a marginal belt of glaciofluvial sand and gravel and glacial till constituting 32.7% of drift deposits in the study area and are distributed on the Sherwood Sandstone in Doncaster, Armthorpe, Cantley and between Rossington and Bawtry, and further west on higher patches of the Magnesian Limestone outcrop (Eden *et al*. 1957). A patchy distribution of glacial till, comprising a stiff brown sandy clay with varying proportions of pebbles, cobbles and boulders, occurs the full length of the study area in a general north-west to south-east direction, outcropping between Wetherby and Barwick in Elmet, east of Garforth and Kippax, and between Pontefract and Criddling Stubbs. In South Yorkshire till outcrops north-east and south of Doncaster, south and east of Rossington and between Bawtry and Harworth.

The most recent ice advance blocked the Pennine drainage through the Humber gap causing much of the low-lying land to the east of the Permian outcrop to flood creating Lake Humber. The resulting glaciolacustrine deposits (33%), comprising laminated silts, clays and sands, are present in the east of the study area southwards from Church Fenton and between Knottingley, Doncaster and Thorne. The clayey stoneless drift also occurs in depressions in a triangle between Hatfield Moors, Doncaster and Austerfield, with associated sand deposits concentrated to the west where drainage entered the lake (Cooper and Gibson 2003), particularly south-east of Tadcaster. Lake Humber reached a maximum of *c*. 33m OD during its initial short-lived phase before dropping to below –4m OD and eventually stabilising at *c*. 9m OD. Samples from lake deposits identified during excavations at Ferrybridge Henge and submitted for optically stimulated luminescence dating returned dates of 16,500 +/- 1,100 (calendar) years, the 'best evidence available' for the age of the high level of Lake Humber (Gaunt *et al.* 2005). The lake is thought to have silted up gradually by

11,100 radiocarbon years ago, but may have been two or three millennia earlier (Gaunt 1994).

Throughout the Devensian, climatic change caused significant changes in sea level and successive phases of fluvial incision and aggradation. A final period of rapid incision followed the disappearance of Lake Humber, when the Pennine river systems re-established their courses and developed silty and sandy levees across existing lake sediments (Lake 1999). As sea levels rose during the Flandrian, silty or clayey alluvium, constituting 20.6% of the drift geology, was deposited along the courses of all the major rivers and tributaries in the study area and on the floodplain below 10m OD to the west of Cantley and Rossington. On the boundary of Doncaster and the East Riding, an area of artificially induced floodwarp (see below) is shown as alluvium on the geology maps (Gaunt 1994). Peat and peaty-clay occur beneath and within alluvium in some places, up to 7.7m deep and overlain by floodwarp in the former course of the River Went (Gaunt 1994). Surface peat, forming 7% of drift deposits, is confined to some of the lowest-lying areas such as the former course of Hampole Beck and along the course of the rivers Torn and Idle. The raised mire peat of Hatfield and Thorn Moors now only survives to a depth of between 0.5m and 1.5m, following intensive peat working.

Drainage

The west of the study area sits in the foothills of the Pennines where the low hills reach a maximum height of 140m OD only in the south-west and north-west dropping to 5m OD or less on the floodplains of the Humberhead Levels. Over 47.3% of the area is below 20m OD and only 5.6% is above 100m OD (Fig. 1.4). The major river systems flowing west to east from the Pennine uplands into the Humber basin have incised their routes through the Permian platform. In the north the River Wharfe enters the study area 3km west of Collingham from its source in the Yorkshire Dales. The river, incised into a deep gorge between Wetherby and Boston Spa, flows through Thorp Arch, Newton Kyme and Tadcaster and is then joined by the Skell before leaving the study area and becoming a tributary of the River Ouse near Selby. Further south, the River Aire flows east of Leeds through Castleford, Brotherton and north of Ferrybridge and Knottingley and then meanders east to the same destination as the Wharfe. Its tributary, the River Calder, originates in the Pennines of the southern half of West Yorkshire and enters the study area east of Wakefield, its historical navigable limit, to meet the Aire at a major confluence at Castleford.

Originating within the study area, the River Went begins at the confluence of Went Beck and Hessle Beck, draining the eastern half of Wakefield District. Presently, it runs along the northern edge of a flat valley bottom on a flood plain that probably served a much larger river judging from the alluvium spread and the extent to which the limestone has been incised where the river narrows between Wentbridge and Kirk Smeaton south of Pontefract. In South Yorkshire, the River Don is joined by one of its many tributaries, the River Dearne, at Conisborough before flowing through the gorge cut through the limestone between there and Sprotbrough, *c*. 5km downriver. The Don continues in a meander passed its tidal limit at Kirk Sandall, to cross the River Went north-east of Sykehouse and eventually joining the River Ouse near Goole. On the eastern side of the Permian outcrop the River Torne issues on the high ground near Harworth and flows north via Tickhill to enter the Humberhead Levels around Rossington. It bypasses the southern margin of Hatfield Moors and joins the River Idle outside the study area. The Idle itself flows through Nottinghamshire and briefly enters from the south where it meets its tributary, the River Ryton, before passing Bawtry and turning east, eventually entering the Trent near Misterton.

In addition to the main rivers that traverse the study area, a number of small rivulets are worthy of mention. In the north the Cock Beck starts west of Scholes and flows south-east turning north at Parlington before meandering through Aberford to join the River Wharfe south of Tadcaster. The Kippax Beck flows south-east from Austhorpe to the west of Garforth, Kippax and Ledston to join the River Aire north-west of Castleford. Further south, Hampole Beck/Dyke flows from South Elmsall east, its former course diverting north from Adwick le Street through Sutton Common to join the Went near Norton. Although these courses are insignificant today they undoubtedly had a more substantial function in the past as their juxtaposition with artefacts from as early as the Mesolithic period suggests (Berg 2001; Van de Noort and Ellis 1997).

Landscape Character

The topography of the area, following the underlying geology, shows considerable variation from east to west and falls within several of English Nature's 'Countryside Character' regions. The *Southern Magnesian Limestone* is flanked to the west by the *Nottinghamshire, Derbyshire and the Yorkshire Coalfield* and to the east by the *Humberhead Levels*. The far north of the area touches on the *Pennine Dales Fringe* and the *Vale of York* regions (Fig. 1.1).

The landscape of the Millstone Grits and Coal Measures in the west is characterised by generally low and modest but variable hills, escarpments and broad valleys. The undulating nature of the landscape is created by differential weathering and erosion of the geology forming broadly north-west to south-east orientated ridges on the alternate banding of wet shales and dry sandstones. Much of the area is dominated by extensive urban areas and industrial activity. Mills and factories tended to follow watercourses along the valleys whilst the underlying coal gave rise to a once active mining industry, the legacy of which are extensive, though now landscaped, spreads of spoil and mining waste. The Coal Measures give rise to mainly poor soils that have traditionally supported pasture, although today the pattern is more variable with more land coming under arable cultivation or improved grassland (NE38). Tree cover is generally low with pockets of broadleaved woodland surviving on poorer soils or steeper slopes. Some thick hedgerows, with oak and ash as hedgerow trees, exist in areas where older field patterns survive intact but most land boundaries are now marked with stone walling.

The Permian platform is shaped by the two escarpments of the Cadeby and Brotherton formations covering 36% of the study area, some 552km^2. Aligned slightly north-west/south-east the feature is not more than 13.5km wide in the north and 7km wide in the south. The western edge of the thicker Cadeby Formation forms a prominent scarp on average 30m high, near Cadeby, Barnburgh and north of Thorpe Audlin, but in places is less distinct or barely noticeable. The ridge slopes gently to the east eventually disappearing below the adjacent drift deposits of the Humberhead Levels. Even at this modest elevation parts of the ridge give extensive views of the lowlands to the east and south-east (NE30). The well-drained soils have always been a target for arable cultivation and the landscape is one of fertile farmland cut by numerous clayey valleys formed by the Edlington and Roxby marls. In the main river valleys of the Aire and Don there is widespread industrial influence including shale tips, mines, subsidence depressions and artificial *ings*, where sand and gravel have been extracted. Woodland is more abundant on the Permian than in adjacent areas, mainly because of the presence of a great number of large country houses and their managed estates, with their gardens and parklands such as Bramham, Ledston and Lotherton to the east of Leeds and Brodsworth, Cusworth and Melton Park near Doncaster. There are also a number of semi-natural, and in parts, ancient woodlands on the ridge (English Nature 2006) occurring on hilltops or steeper slopes and along small valleys and parish boundaries, areas less suitable for agriculture (NE30).

Most of the farming in the area is intensive and arable. The fields are usually large and geometric in pattern with long straight roads dating from relatively late planned enclosure. Elsewhere there are small or medium sized fields of irregular pattern dating from earlier periods of enclosure of open fields or common grazing. Field boundaries are usually low, thorn hedges with sparse occurrence of hedgerow trees, although stone walls occur in many places as estate boundaries or in or around villages (NE30). Small areas of pasture persist, especially on steeper slopes or narrow valley bottoms, but the overall extent of grassland is small.

The thick glacial deposits that cover the Sherwood Sandstones in the east of the area give a distinctive character to the landscape. With the exception of the north-east, where the hummocky terrain reflects the presence of glacial moraines, the flat broad floodplains of undulating low ground that make up the Humberhead Levels are commonly at or below mean high-water mark. Settlement tends to be strung out and sparse and has traditionally been located on available higher ground or followed roads on raised ridges where the Mercia Mudstone or Sherwood Sandstone outcrops (NE39), although this is more apparent further east outside the study area.

Large-scale drainage schemes and intensification of agriculture have resulted in the removal of many hedges, trees, small woods and remaining grasslands to make a traditional open landscape even more so with characteristic very large open fields divided by drainage dykes. There is, however, a surviving area of historic landscape around Fishlake and Sykehouse, north of Hatfield, where the traditional pattern of land use still remains. This includes small, thickly hedged fields, field ponds, some hay meadows, remnant ridge and furrow fields as well as parkland with old oak trees (NE39).

Ironically, these low-level 'wet' lands are, in terms of precipitation, relatively 'dry' as annual rainfall decreases rapidly from west to east across the study area (Faull and Moorhouse 1981, vol. 4 map 2). The high average annual rainfall in the Pennine uplands and foothills to the west of 1580mm is reduced to only 580mm in Doncaster (EA 2003), which sits in the 'rain shadow' of the Pennines. Mean annual infiltration rates are 180mm over the Sherwood Sandstone Group and only a slightly higher 200mm over the outcrops of the Cadeby and Brotherton formations (Lake 1999). In parts of the southern Coal Measures commercial forestry has never been a feature because of slow tree growth due to the relatively low rainfall (NE38). An annual mean temperature of 9-10 degrees centigrade in the east is some 2-4 degrees warmer than higher areas in the west (Van de Noort and Ellis 1997) where a reduced growing season, approximately 190-200 days per year, limits agricultural production to extensive livestock systems, compared to between 250 and 260 days in the east (MAFF 2000).

The low-lying land of the Humberhead Levels has probably changed more dramatically than either the Coal Measures or Permian limestone. A combination of drainage, river diversions and artificial silting (floodwarping) has resulted in the creation of arable farmland from extensive marshland and wet meadows. Gaunt (1994) has identified several man-made river diversions in the area. The stretch of the River Don between Thorne, north-east of Doncaster, northwards to the River Aire does not follow a natural course, and cuts across the lower course of the River Went at SE 6680 1878. The extant documentary and cartographic evidence indicates that the artificial waterway, formerly known as Turnbrigg Dyke, was constructed prior to 1410-1420 and later than 1360 (Gaunt 1975), although it has been suggested that the earliest diversion could have been of Roman construction (Buckland 1986; Gaunt 1975).

The first significant attempt at altering the drainage of the area was undertaken by Cornelius Vermuyden in the early 17th century (Gaunt 1994; Van de Noort and Ellis

1997). The original lower course of the River Don, that ran south-east across Hatfield Chase (Fig. 1.4), was beheaded at Thorne, diverting the entire flow into the artificial Turnbrigg Dyke and then to the River Aire. Vermuyden also diverted the northward flowing River Idle eastwards into the Trent, the former course running north to enter the former River Don in the study area. The River Torne, which previously joined the River Idle, was channelled into an artificial course, the New River Torne, before joining the River Trent.

Drainage schemes and river diversions continue to the present day and have increased and improved the amount of land suitable for arable cultivation, although not always successfully. The River Idle east of Bawtry, realigned by Vermuyden in the 1620s, had a major embankment constructed in 1958 and further straightening as recently as 1983 (Berg and Major 2006). The drainage improvements have led to agricultural intensification on the floodplain and, around Bawtry and Scaftworth, increased ploughing combined with a lower water table is causing desiccation of the peat and soil loss by wind erosion and exposure of buried archaeology (Van de Noort and Ellis 1997).

Soils

The soils of the study area have been identified from the 1:250,000 soil map of Northern England (Soil Survey of England and Wales 1983) and the descriptions of Carroll *et al.* (1979). The formation, character and distribution of soils are closely related to factors such as relief, slope and underlying geology. In many places the pattern is further complicated because of soil creep and hill wash and, in no small way, by human alteration. The thirty distinct soil types present within the confines of the study area have been grouped in a manner that allows direct comparison with data produced from the Humberhead Levels and Vale of York studies (Van de Noort and Ellis 1997; 1999), i.e. brown soils (40.5%), surface-water gley soils (31.0%), ground-water gley soils (10.6%) and peat soils (3.3%); the remaining 14.5% representing urban areas or unmapped man-made soils (Fig. 1.5). The drainage characteristics of the soil give a good indication of the nature of the landscape and despite four centuries of artificial drainage and soil improvement it remains that only 35.4% of the soils are described as freely draining, mainly over the Permian Magnesian Limestone, with 33.7% displaying either fully or partially impeded drainage, and 16.4% being naturally wet with a permanently high water table.

Within the brown soils group the majority are brown calcareous earths, in the main the permeable Aberford Series (511a) that cover the Permian Magnesian Limestone. The soil is well drained and easily worked but is usually shallow and today is most frequently used for growing cereals, wheat, barley, potatoes and peas. To the north and south of Barwick-in-Elmet, and as far south as Kirk Smeaton, areas of deeper drift deposits produce a loamy, clayey, weakly acid soil mapped only as Unit 46 (Carroll *et al*. 1979). Although clayey, the soil is freely drained due to the presence of fissures in the underlying limestone. On steeper convex slopes and ridges of the Magnesian Limestone a loamy brown rendzina of the Elmton series (Unit 39) occurs from Kirk Smeaton southwards, and particularly to the east and south of Maltby. Cultivation of this soil is hindered by shallow depth and stoniness with cropping restricted to cereals and grass, although the latter can suffer from wilting in dry years because of low available water capacity (Carroll *et al*. 1979, 95). In the north-east corner of South Yorkshire at 1-3m OD a man-made warp soil described as brown calcareous alluvial soil (532a) is mainly under arable cultivation. Non-calcareous brown earths of the Rivington series (541f/541g) occur in the west on sandstones of the Millstone Grit and Coal Measures. The freely draining slightly acid soils are mainly down to grass being limited by stoniness, shallowness, slope and low fertility. To the west of Castleford and between Rossington and Bawtry a non-calcareous brown earth (Wick 541r) overlays glacial sands and gravels and river terrace deposits. The stony subsoil is well drained and drought can be an issue with supplementary irrigation required in dry seasons, which may explain why this soil group displays such a high density of cropmarks. In the north, eastwards from Wetherby, the morainic drift and glacial tills support argillic brown earths of the Bishampton (572s) and Escrick (571q) series, the latter of these clayey soils having slightly better drainage but both having moderate to high fertility under arable and grassland. To the east of Knottingley, north-east of Armthorpe and spreading south into Nottinghamshire, areas of sandy loamy soil of the Newport series (551d) overlay glaciofluvial drift deposits. The soils are easily worked and permeable and used mainly for spring cereals. The main limitation is droughtiness, caused by the small available water capacity of the soil, and low rainfall. Windblown erosion of the topsoil can be an issue.

Surface-water gleys (stagnogleys) occur on both sides of the Permian outcrop on Carboniferous shales and sandstone, and over till and glaciolacustrine clays. These soils have low to medium natural fertility, impeded drainage and are neutral to acid under cultivation and this, together with poor subsurface structure, limits use to permanent grassland or where drainage has been improved, winter cereals. In the north, stagnogley soil of the Dunkeswick Series (711p) is most extensive down to Garforth in the west and east of Tadcaster whilst the more clayey Dale Series (712a), occurs in isolated pockets near Swillington, between Normanton and Pontefract and south of Conisborough. In between, on sandstone outcrops, the Bardsey series (713a) is similar, but stonier with less clay, stretching between the Magnesian Limestone and the urban outskirts of Leeds, Barnsley and Sheffield. The largest areas of surface-water gley soils lie in the east where flat glaciolacustrine clay land east of Sherburn in Elmet and north and north-east of Doncaster is covered by soils of the Foggathorpe series (712i). South of Doncaster a stagnogley soil (Brockhurst 711c) divides the well-drained Aberford brown earths overlaying the slowly permeable mudstones of the Edlington Formation that separates the Cadeby and Brotherton limestones.

Ground-water gley soils are found on low ground where the water table is naturally and constantly high. They occur mainly in the east of the area on alluvial soils of river floodplains (Conway 811b) and on stoneless glaciofluvial drift, particularly along the North Yorkshire/West Yorkshire border (Sessay 831b, Wigton Moor 831c, Enborne 811a). Some of these soils are productive and less waterlogged than in the past due to artificial drainage, ditches and the effects of old gravel workings. Others, such as the Blackwood series (821b) east of Doncaster, are limited despite additional drainage by high winter groundwater levels or are just too difficult to drain (Fladbury 813d) and remain under permanent pasture.

Peat forms a small but important component of the topography. Hatfield and Thorne Moors, east of Doncaster, are formed of *Sphagnum* peat (Longmoss 1011a) and are the remnants of a once extensive lowland raised mire occupying the Humberhead Levels. The moors form a nationally rare ecosystem and, although subjected to intensive commercial peat extraction since 1950 (Skinner 1998), now have SSSI status and are recognised for their ‘unparalleled’ palaeoenvironmental potential (Van de Noort and Ellis 1997, 220). Two other fen-carr peaty soils, Altcar 2 (1022b) and Adventurer's (1024a), are confined to small areas of flat, low-lying land near Armthorpe and Tickhill and are under arable crops where drained.

The Ministry of Agriculture, Fisheries and Food classify agricultural land in five grades from Grade 1 to 5, excellent to very poor (MAFF 1977). The grading system, which aids decisions within the planning system, is based on climate and site in addition to soil structure and as such does not always match the land potential assessed from soil lithology alone (Fig. 1.6). For example, the large area of surface-water gley soil (Foggathorpe 712i) in the eastern lowlands can be attributed to grades 2-4, depending on the extent of artificial drainage and the application of fertilisers. It is worthy of note that Riley recorded this as being devoid of cropmarks (1980, 59, fig. 8) but it does show a limited distribution around Swillington where it appears over Middle Coal Measure sandstones.

Within the extents of the study area a small proportion of Grade 1 high quality agricultural land (0.3%) falls within the East Riding on man-made warp soils. The distribution of Grade 2 land (36%) is closely associated with the Permian limestone, on till and moraine in the north-east, and on glaciolacustrine deposits and alluvium in the east. The minor limitations of this grade on arable cultivation are generally shallowness, stoniness and low fertility in each area respectively. The largest component is Grade 3 (43%), which reflects the poor drainage and low fertility of the acidic soils on the Carboniferous sandstones and shales west of the Permian outcrop. In the east the limitations are mainly low fertility on the glacial sands and gravels and river terrace deposits, but erosion and drought risk are also limiting factors on some lighter soils. North-east of Doncaster, poor quality agricultural land of Grade 4 (6%) is due principally to soil wetness and compaction problems while north-west of Castleford limitation is due to higher rainfall and poor drainage on clayey soils. Very poor agricultural land of Grade 5 (2%) occurs on the undrained peats of Hatfield and Thorne Moors.

The activities of man, particularly since the Industrial Revolution, have had a significant impact on the soils of the area and large expanses presently under arable cultivation would not have been available earlier, such as the clayey Foggathorpe Series mentioned above which was permanently waterlogged land until drainage improvements of the 18th century (Carroll *et al.* 1979). The practice of floodwarping in the Humerhead Levels was a method of improving a variety of soil conditions by raising land that was poorly drained, of reducing acidity of peaty soils or opening up compact clayey soils. The practice is recorded from the 1730s but may be older and was still in use up to 1947 (Gaunt 1994). The depth of 'alluvium' accumulated from floodwarping can vary from 0.48m to 1.6m (Van de Noort and Ellis 1997). The heavy clay soils on the Coal Measures were improved by the addition of lime, extracted near Knottingley where the Aire cuts through the Magnesian Limestone, and shipped west by canal (Carroll *et al.* 1979). It is estimated that over a metre of 'town manure' has been spread over the clayey land between Wakefield and Leeds (Carroll *et al.* 1979) producing deep man-made soils valued for the production of rhubarb since the end of the 18th century.

It is not only recent activity that has altered the nature of soils. Since the first forest clearances and subsequent working and cultivation, soils have been exposed to the processes of natural weathering, erosion and alteration. For example, two of the Bronze Age barrows excavated at Ferrybridge had been built on brown calcareous earths of the Aberford Series overlaying Magnesian Limestone, but are now surrounded by a shallow rendzina of the Elmton Series (Carter 2005) and buried soils exposed at Becca Banks and Roman Ridge contained pollen that indicate the presence of acidic soils and heath land not present locally today (Long and Tipping 2001). Similar changes over time in the North-east have led Van der Veen (1992) to conclude that the relationship between present-day soils and those prevailing in the Iron Age is very difficult to assess.

The study area can therefore be divided into three broad zones. The low hills and wide valleys of the Millstone Grit and Coal Measures were largely covered in acid soils that would have required heavy liming and manuring to maintain a fertile arable soil. This, together with their general poor drainage, would have made them more suitable for pastoral regimes, particularly on the higher ground further to the west. In contrast, the freely draining calcareous brown earths of the Magnesian Limestone were more suitable for arable farming, but probably not uniformly as in many places shallow topsoil and low rainfall would have been limiting factors. In the east, some better drained areas overlaying sands and gravels or outcrops of Sherwood Sandstone would have supported mixed farming regimes, but the majority of the flat low landscape was prone to seasonal or permanent wetness and sustained a habitat of flood meadows, reed beds, wet carr woodland and raised peat bogs.