TECHNICAL REPORT WA/90/14

Geology and land-use planning: Morpeth–Bedlington–Ashington

Part 1 LAND-USE PLANNING

I Jackson and D J D Lawrence

BRITISH GEOLOGICAL SURVEY

TECHNICAL REPORT WA/90/14

Onshore Geology Series

Geology and land-use planning: Morpeth–Bedlington–Ashington

Part 1 LAND-USE PLANNING

1:25 000 sheets NZ 28 and NZ 38

Parts of 1:50 000 geological sheets 9 (Rothbury), 10 (Newbiggin), 14 (Morpeth) and 15 (Tynemouth)

I Jackson and D J D Lawrence

This study was commissioned by the Department of the Environment, but the views expressed in it are not necessarily those of the Department

Maps and diagrams in this book use topography based on Ordnance Survey mapping

Geographical index

UK, England, Northumberland

Subject index

Land-use planning, thematic maps, resources, mining, engineering geology, Quaternary, Carboniferous

Bibliographic reference

Jackson, I, and Lawrence, D J D. 1990. Geology and land-use planning: Morpeth–Bedlington–Ashington. Part 1: Land-use planning. *British Geological Survey Technical Report* WA/90/14

Keyworth, Nottingham British Geological Survey 1990

BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available through the Sales Desks at Keyworth, Murchison House, Edinburgh, and at the BGS London Information Office in the Geological Museum. The adjacent Geological Museum bookshop stocks the more popular books for sale over the counter. Most BGS books and reports are listed in HMSO's Sectional List 45, and can be bought from HMSO and through HMSO agents and retailers. Maps are listed in the BGS Map Catalogue and the Ordnance Survey's Trade Catalogue, and can be bought from Ordnance Survey agents as well as from BGS.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Overseas Development Administration.

The British Geological Survey is a component body of the Natural Environment Research Council.

Keyworth, Nottingham NG12 5GG
☎ Plumtree (06077) 6111 Telex 378173 BGSKEY G
Fax 06077–6602

Murchison House, West Mains Road, Edinburgh EH9 3LA
☎ 031–667 1000 Telex 727343 SEISED G
Fax 031–668 2683

London Information Office at the Geological Museum, Exhibition Road, South Kensington, London SW7 2DE
☎ 071–589 4090 Fax 071–584 8270
☎ 071–938 9056/57

19 Grange Terrace, Edinburgh EH9 2LF
☎ 031–667 1000 Telex 727343 SEISED G

St Just, 30 Pennsylvania Road, Exeter EX4 6BX
☎ Exeter (0392) 78312 Fax 0392–437505

Bryn Eithyn Hall, Llanfarian, Aberystwyth, Dyfed SY23 4BY
☎ Aberystwyth (0970) 611038 Fax 0970–624822

Windsor Court, Windsor Terrace, Newcastle upon Tyne NE2 4HB
☎ 091–281 7088 Fax 091–281 9016

Geological Survey of Northern Ireland, 20 College Gardens, Belfast BT9 6BS
☎ Belfast (0232) 666595 Fax 0232–662835

Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB
☎ Wallingford (0491) 38800 Telex 849365 HYDROL G
Fax 0491–25338

Parent Body

Natural Environment Research Council

Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU
☎ Swindon (0793) 411500 Telex 444293 ENVRE G
Fax 0793–411501

Data used in preparing this report and associated maps are lodged at the Newcastle upon Tyne office of the British Geological Survey. Any enquiries concerning these documents should be directed to that office.

Reports are also available for the following 1:25 000 sheets:

NZ15: Chopwell, Rowlands Gill, Consett and Stanley NZ25: Kibblesworth, Birtley, Craghead and Chester-le-Street NZ27: Cramlington, Killingworth and Wide Open NZ17E & 18E: Ponteland-Morpeth

---

NOTES

All National Grid references in this report lie within the 100 km square NZ. Grid references are given to either eight figures (accurate to within 10m), or six figures for extensive locations.

Each borehole or shaft registered with BGS is identified by a four-element code (e.g. NZ 28 SE 58). The first elements define the 10 km square (of the National Grid) in which the borehole is situated; the third element defines the quadrant of that square, and the fourth is the accession number of that borehole. In the text of the report the borehole/shaft is normally referred to by the last three elements alone (e.g. 28 SE 58).

The word 'district' unqualified, in this account means the whole ground covered by NZ 28 NW, NE, SW, SE and NZ 38 NW and SW.

PREFACE

This report is one of two describing the results of a survey of the geology of the Morpeth-Bedlington-Ashington district. This volume, Part I, reviews the geological factors relevant to land-use planning and development. A second volume, Part II, describes the geology of the area in detail.

The district is covered by 1:10 000 sheets NZ 28 NW, NE, SW, SE and NZ 38 NW, SW and lies within 1:50 000 geological sheets 9 (Rothbury), 10 (Newbiggin), 14 (Morpeth) and 15 (Tynemouth). The district was first surveyed at the six-inch scale by H.H. Howell and W. Topley and published on Northumberland Old Meridian County maps between 1867 and 1879. A resurvey by G.A. Burnett, V.A. Eyles and A. Fowler between 1929 and 1950 was published on the New Meridian.

The present survey, which was funded jointly by the Department of the Environment and the British Geological Survey, revised the geological maps and prepared thematic maps designed for use by planners and developers. The survey was undertaken between 1986 and 1989 by I. Jackson (NZ 28 NE, SE, NZ 38 SW) and D.J.D. Lawrence (NZ 28 NW, SW, NZ 38 NW). R.A. Monkhouse, BGS Hydrogeology Research Group, provided information on groundwater resources and pollution while A. Forster and M.G. Culshaw of the BGS Engineering Research Group advised on the establishment of the geotechnical database and subsequent data analyses. The programme managers were Dr. D.J. Fettes (BGS) and Mr. H. Mallett (DOE).

F.G. Larminie, OBE, Director
British Geological Survey
Keyworth
Nottingham NG12 5GG

January 1990

CONTENTS

FIGURES

TABLES

MAPS

1:25 000 scale thematic maps [in folder]

1. Solid geology.
2. Drift geology.
3. Rockhead elevation.
4. Drift thickness.
5. Shallow mining.
6. Made and disturbed ground.
7. Borehole and shaft sites.
8. Engineering geology.
9. Mineral and water resources (excluding coal).
10. Geological factors for consideration in land-use planning.

1:10 000 scale standard geological maps [available separately]

NZ 28 NW Pegswood
NZ 28 NE Ashington
NZ 28 SW Nedderton
NZ 28 SE Bedlington
NZ 38 NW Newbiggin
NZ 38 SW Blyth

COVER PHOTOGRAPH

Woodhorn Colliery

Taken by Mr T Bain, BGS Photographic Unit

EXECUTIVE SUMMARY

INTRODUCTION

The Morpeth-Ashington-Bedlington area forms part of the Northumberland Coalfield. Coal mining and its decline has left a legacy of reclaimed and unreclaimed spoil heaps, uncharted old workings, subsidence and abandoned shafts. Large areas of variably restored opencast coal and brick clay workings are equally common. This has given rise to variable ground conditions which can pose problems for development and derelict land reclamation. When set against this background the need for comprehensive and up-to-date information on the geological environment is readily apparent.

This study was therefore undertaken to examine and upgrade the geological database and associated datasets and present the results in a form to aid planners, engineers and geologists. Two sets of maps and accompanying reports have been prepared:

1 (this report): A series of ten thematic maps at the 1:25 000 scale with an explanatory text.

2 (published separately, WA/90/19): A series of six geological maps at the 1:10 000 scale with an explanatory text.

The study was funded jointly by the Department of the Environment and the British Geological Survey (BGS). The work was carried out by BGS staff at the Newcastle upon Tyne office, with contributions from staff of the BGS Engineering Geology and Hydrogeology research groups at Keyworth and Wallingford.

OBJECTIVES

The detailed objectives of the study were:

a) To complete, where necessary, new basic field geological mapping of the study area and produce revised maps.

b) To collect, evaluate and interpret available information on geology, geotechnical properties, ground conditions, geomorphology, and hydrogeology.

c) To organise the information obtained into a data-base/ archive.

d) To present basic data and interpretations for selected parts of the study areas as thematic maps and accompanying reports in a form easily understood by planners and others not trained in geology, mining, civil engineering or related disciplines.

e) To identify the need for further investigations or specialist advice in relation to specific planning and development objectives and proposals.

METHODOLOGY

The work involved the collation and interpretation of data from many different sources:- a specially commissioned 1:10 000 scale field geological survey, coal exploration boreholes, deep mine and opencast coal abandonment plans, site investigation boreholes and reports, existing geological maps and memoirs and other archival material held by third parties. Computerised databases of borehole and geotechnical information were established.

CONCLUSIONS

1. The survey has collated and interpreted available geological data from all known sources. It is the most comprehensive study of the geology of the district for 50 years and has resulted in substantial revision of the geological maps. The ten 1:25 000 scale thematic maps, six new 1:10 000 scale geological standards, explanatory texts and the computerised databases provide a sound basis for the evaluation of geological issues in land-use planning decisions.

2. Almost all the district has been undermined for coal. Shallow mine

workings, present in many areas, are a potential cause of land instability, whereas it is reasonable to assume that subsidence caused by deep mining is generally complete. Over 240 disused shafts and adits have been located and others undoubtedly exist.

3. Below the top weathered zone, till, glacial sand and gravel and solid rock, which together cover a large part of the district, provide good foundation conditions. More variable conditions exist in the buried valleys, where deposits of laminated silt and clay may be present, and in the river valleys and estuaries, where alluvial clay, silt and peat possess relatively weak geotechnical properties.

4. Made ground and fill is extensive and of variable composition, consolidation and thickness. Many restored opencast coal sites exist but these are well documented; smaller disused and infilled clay pits and sandstone quarries may produce foundation problems if not identified prior to construction.

5. Slopes, especially those in drift sediments, may prove unstable and are liable to slip if oversteepened or undercut by rivers and the sea or disturbed by man.

6. Despite the long history of mining large resources of coal remain and, leaving aside planning and environmental constraints, there is considerable potential for opencast extraction.

7. Sand and gravel deposits occur extensively in the area east of Morpeth. Little detailed information on their thickness and composition exists but inadvertent sterilization by development prior to assessment should be avoided.

8. Larger sandstone units in the Coal Measures are the principal aquifers. Mining has caused significant modification to the natural hydrogeological regime and its effects need to be considered when evaluating potential leachate movement from landfill sites.

9. There is a remote risk of methane or oxygen-deficient air build-up in certain areas, especially those above unventilated old mine workings.

This study has collated and presented all available geological data **but is not a substitute for on site investigation**. Where mining is suspected the mine plans and shaft atlases maintained by British Coal should be consulted in the first instance.

1 INTRODUCTION

1.1 OBJECTIVES

This report describes the results of a research project funded jointly by the Department of the Environment and the BGS (Contract PECD 7/1/241). The objectives of the project were to provide an up-to-date geological database for the Morpeth, Bedlington and Ashington area as a foundation for land-use planning and development, effective future geological research and the safeguarding of mineral resources. The present study is the third DOE sponsored applied geological mapping project in south-east Northumberland, previous surveys have covered the Cramlington-Killingworth - NZ27 and Ponteland-Morpeth districts - NZ17E and 18E (see Figure 1). BGS has undertaken these studies as part of its programme to maintain its coverage of 1:10 000 scale geological maps of the UK.

1.2 GEOGRAPHICAL SETTING

The area described in this report lies to the north of Newcastle upon Tyne within the Blyth Valley, Castle Morpeth and Wansbeck districts of the County of Northumberland (Figure 1). The built-up areas of Blyth, Morpeth, Ashington, Bedlington, Newbiggin and Stakeford make up a significant proportion (c25%) of the land area but in the main the district is rural. The east coast rail line and the A1 trunk road cross the district in the west.

Coal mining was for centuries the dominant industry and has left its mark on the landscape in the form of colliery buildings and terraces, shafts, pit heaps and the effects of subsidence. Although underground mining is now confined to one small private mine, opencast coal mining continues and Butterwell, currently one of the largest sites in Europe, is situated in the north-west of the district. With the exception of opencast mining and the large aluminium smelting and electricity generating plants at Lynemouth and Blyth respectively, industry in the district is now chiefly based on small light units in and around the urban areas.

Topographically, the east of the district is a featureless till plain relieved only by the incised valleys of the rivers Blyth and Wansbeck and the low sandstone hills upon which Bedlington and North Seaton stand. In the west the ground is more undulating and south of Morpeth rises to over 85 m above sea level. The rivers Blyth and Wansbeck which drain the area, flow eastwards through gorges to meet the coast at Blyth and Cambois. At Cambois the coast is a dune-fringed sandy bay which separates the low rocky headlands of Newbiggin and North Blyth.

1.3 DATA SOURCES AND METHODOLOGY

Several centuries of coal mining and, in recent decades, an extensive search for coal seams which could be worked opencast have provided a wealth of geological data for the district. In compiling this report and accompanying maps data from the following sources were collated and interpreted:

* detailed geological field survey at 1:10 000 scale
* deep mine coal boreholes and shaft records
* deep mine coal abandonment plans
* opencast coal prospecting boreholes
* opencast coal completion plans
* site investigation boreholes, trial pits and reports
* existing geological maps
* aerial photographs
* Water Authority data
* Local Authority data
* geological reports and journals

The type, quantity, quality and limitations of each of these data sources is dealt with in Appendix A.

Computerised databases of borehole and geotechnical information comprising more than 40 600 records were established. Their structure and value, both current and potential, are described in Appendices B and C. Computer-aided and conventional techniques were used to produce the 1:10 000 scale standard geological maps, the 1:25 000 scale thematic maps and the accompanying reports.

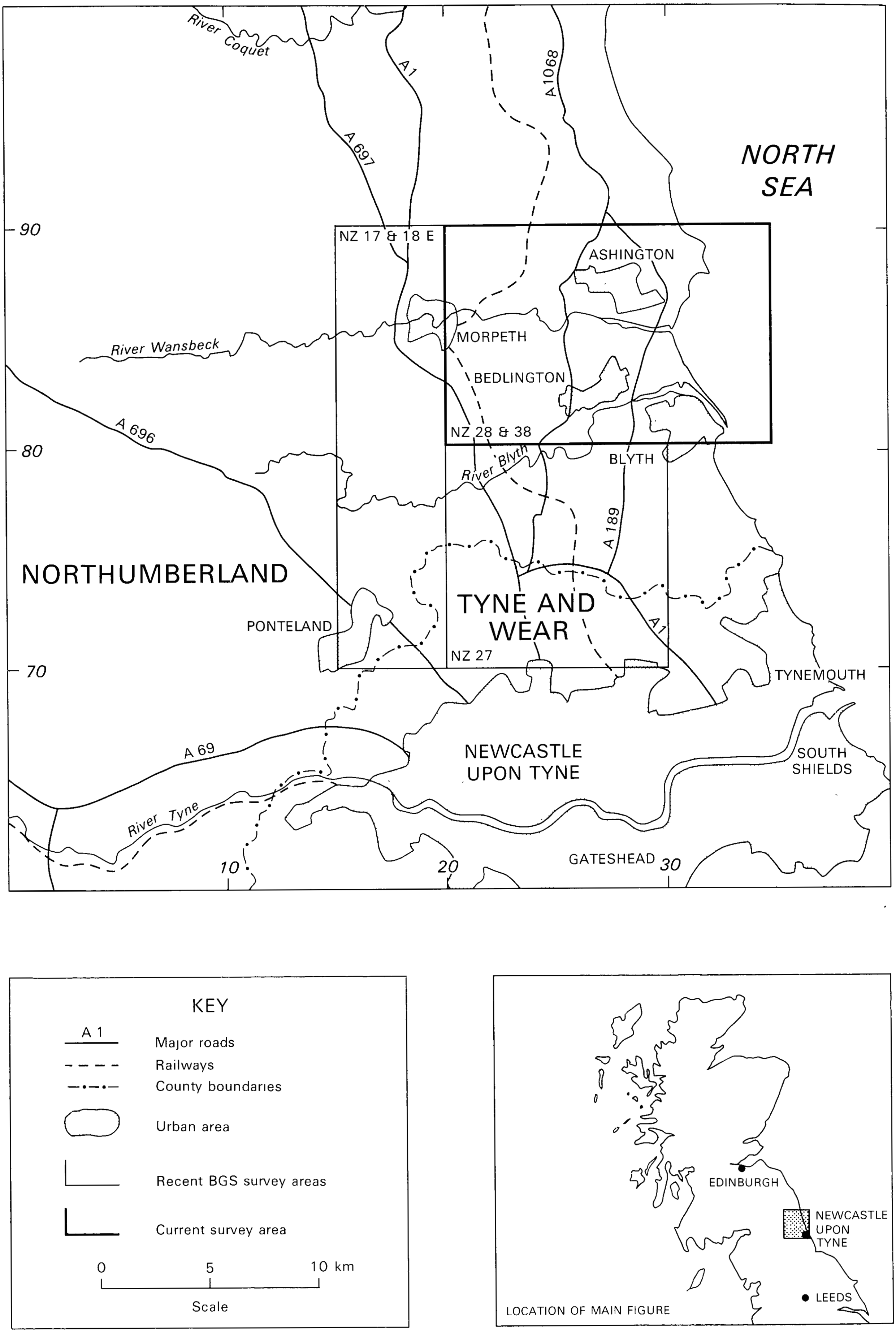


Figure 1. Location diagram

1.4 PRESENTATION OF RESULTS

The results of the study are detailed in Table 1.

1.5 LIMITATIONS

This report and accompanying maps have been produced by the collation and interpretation of geological, geotechnical and related data from a wide variety of sources. However extensive this research may seem the data are not comprehensive and do vary in quality. It is inevitable that this will be reflected in the documents presented; local features and conditions may not be represented and many boundaries may be only approximate.

The aim has been to produce a general description of the geological factors which are relevant to land-use planning and development. This report and associated documents can contribute to drafting and evaluating structure and local plan policies, they may alert planners, engineers and developers by highlighting particular aspects of the geology of the district but they *cannot and should not* replace site-specific surveys aimed at evaluating potential resources or hazards. Users must satisfy themselves by seeking appropriate professional advice and by carrying out ground surveys that conditions are suitable for any particular land-use or development.

The maps were constructed in May 1989, no information subsequent to that date has been taken into account.

1.6 CONFIDENTIALITY

Confidential data, chiefly British Coal Opencast Executive prospecting information, has been taken into account and used in a generalized way during the preparation of the geological maps, but details of specific boreholes are not individually quoted.

1.7 ACKNOWLEDGEMENTS

The help and cooperation of the following are gratefully acknowledged:

British Coal Deep Mines and Opencast Executive

Northumberland County Council

Northumbrian Water Authority

Landowners and tenants in the survey area.

Table 1. Presentation of Results

Part I: report with ten 1:25 000 scale maps listed below (This report)

MAP NUMBER	TITLE	DESCRIPTION
1	Solid geology	major rock units, named coals, faults.
2	Drift geology	Recent and glacial (superficial) deposits.
3	Rockhead elevation	Contours at 10m intervals on bedrock surface.
4	Drift thickness	Thickness of superficial deposits contoured at 10m intervals.
5	Shallow mining	Areas of known, probable and possible coal mining within 30 m of surface.
6	Made and disturbed ground	Differentiation of artificial ground, location of landfill sites.
7	Borehole and shaft sites	Location of shafts, boreholes, adits and trial pits.
8	Engineering geology	Surface rocks and soils classified in geotechnical terms.
9	Mineral and water resources (excluding coal)	Potential mineral deposits and sites of extraction
10	Geological factors for consideration in land-use planning	Significant elements from individual thematic maps presented together.

Part II: report describing six 1:10 000 scale standard geological maps listed below

MAP NUMBER	NAME
NZ 28 NW	Pegswood
NZ 28 NE	Ashington
NZ 28 SW	Nedderton
NZ 28 SE	Bedlington
NZ 38 NW	Newbiggin
NZ 38 SW	Blyth

2. GEOLOGICAL SUMMARY (MAPS 1-4)

2.0 INTRODUCTION

The following account is an introduction to the geology of the district; its purpose is to provide sufficient background to place in context the subsequent sections on land-use planning elements. A detailed description of the geology is given in a second report (Part II) which is published separately.

The district is underlain by geological deposits of two very different ages. Firstly, the solid rocks of the Upper Carboniferous period which were deposited 300-320 million years ago and comprise Coal Measures strata, underlain at depth by Millstone Grit (Figures 2, 3 and 4*). Secondly, Quaternary (Drift) deposits which are less than 18 000 years old and form an unconsolidated superficial layer which is generally between 5 and 20 m thick (Figures 5 and 7).

2.1 SOLID GEOLOGY (MAP 1)

2.1.1 **Carboniferous Rocks**

In Carboniferous times the area lay in a subsiding basin - the Northumberland Trough. Vast delta systems fed sediment from the surrounding land surfaces into the trough, accumulating a succession over 2 000 m thick. The succession comprises a series of cycles of sedimentation. Each of these cycles began with an abrupt change of relative sea level giving marine or near-marine conditions. The water shallowed as sediments built up to water level and the full cycle ended with the establishment of forests and swamps on the newly formed land. Each cycle gave a repeated sequence of rock types (cyclothem)** ideally starting with a basal marine mudstone and continuing upwards through non-marine mudstone, siltstone, sandstone and seatearth to coal. However the cycles are rarely complete and commonly die out or split laterally.

* The Figures reduced from the 1:25 000 scale maps are simplified portrayals. The appropriate map should always be consulted for detailed information.

** A short glossary of technical terms used in this report is presented on page 55.

The Coal Measures sequence includes the following lithologies:

Mudstone is the most dominant lithology and ranges in colour from light grey to dark grey. Although fossiliferous immediately above a coal seam, mudstones are generally devoid of organic remains elsewhere. The mudstones usually become increasingly silty upwards and grade into siltstones, or pass by intercalation and interlamination of sandy beds (striped-beds) into fine-grained sandstone.

Sandstone and Siltstone either form thin, widespread sheets, less than 5 m in thickness, or elongate channel deposits. 'Washouts' occur where such channel sandstones cut down into, and remove the coal seams; the sandstone containing pebbles and fragments of derived mudstone and coal ('scares'). Channel sandstones always have coarse bases although overall grain-size of sandstones decreases up the succession. Sandstones are usually pale grey or cream at depth, but near the surface they weather to rusty brown or, less commonly, white. They are generally well-cemented with quartz being the dominant component.

Seatearths (fireclay or ganister) underlie every coal seam and represent the soil accumulation on which vegetation flourished. There is no correlation between the thickness or character of a seatearth and that of the overlying coal. Seatearths are more persistent than their associated coals and grade from sandstone (ganister) to mudstone (fireclay). They are distinguished from underlying strata by the presence of rootlets and the absence, or extreme disruption, of bedding with abundant highly polished (listric) surfaces.

Coals are of bituminous rank and range in thickness from thin coal traces to about 2 m. All seams vary laterally in thickness; some thin and die out, although their position may be indicated by the associated and more persistent seatearth. Some seams are split by interdigitation of other sediment; splits may be on either a regional or a local scale. Many seams have 2 or 3 cm of cannel coal immediately above. The coal seams formed from vegetation which grew in swamps which were sufficiently de-oxygenated for the partial

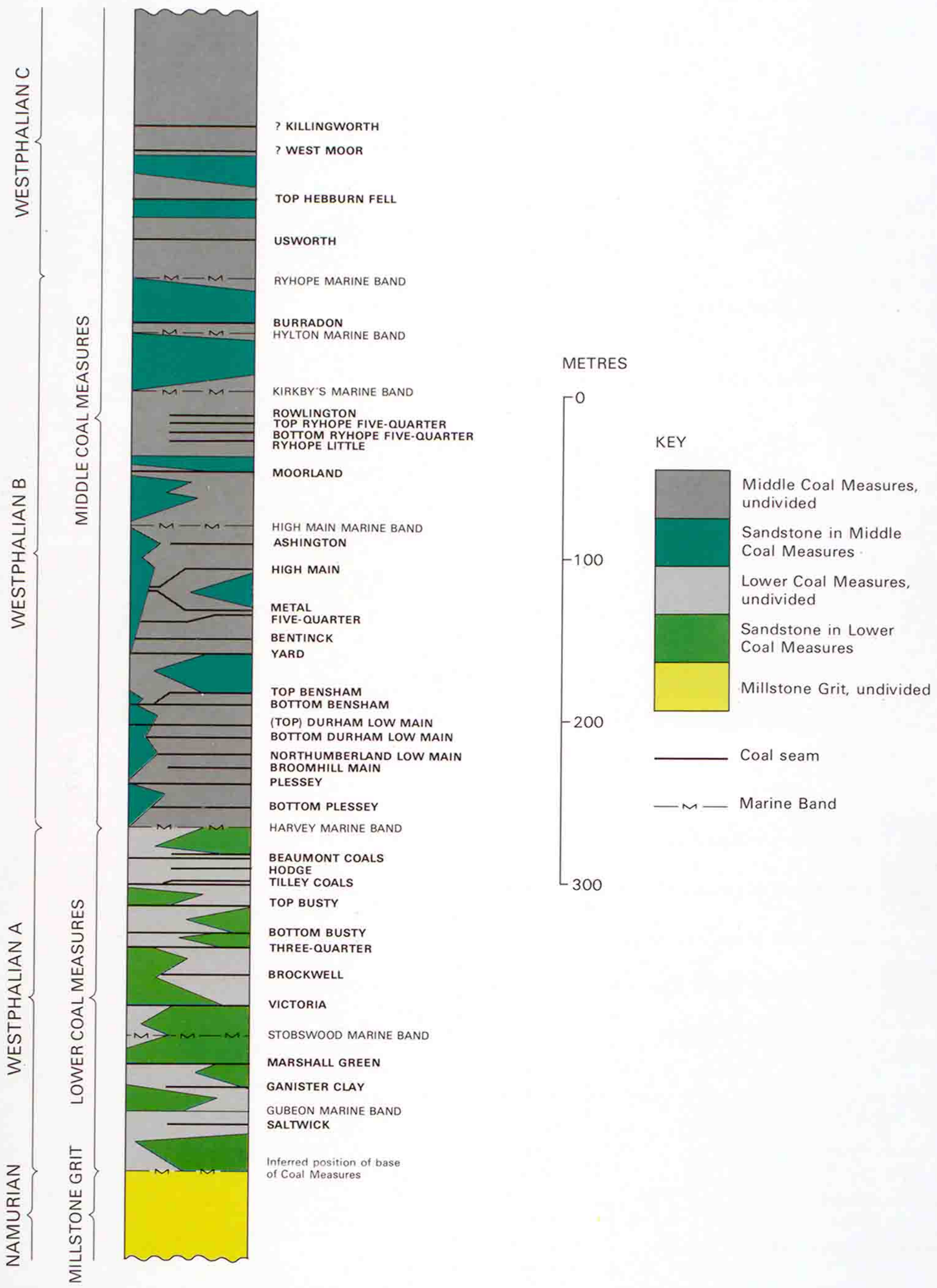
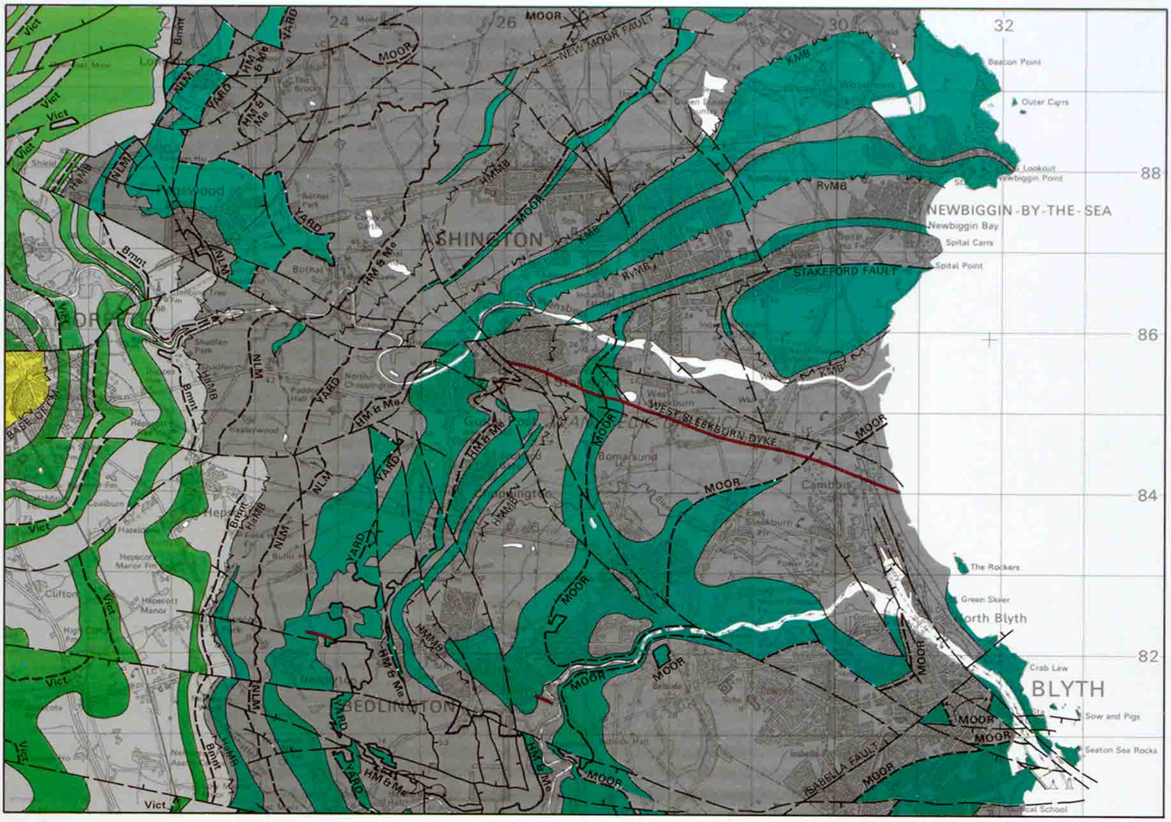


Figure 2. Generalized vertical section



KEY

- Middle Coal Measures, undivided
- Sandstone in Middle Coal Measures
- Lower Coal Measures, undivided
- Sandstone in Lower Coal Measures
- Millstone Grit, undivided
- Coal seam
- Fault
- Marine Band
- Dolerite dyke

RyMB	Ryhope Marine Band
KMB	Kirkby's Marine Band
MOOR	Moorland
HMMB	High Main Marine Band
HM & Me	High Main and Metal
YARD	Yard
NLM	Northumberland Low Main
HaMB	Harvey Marine Band
Bmnt	Beaumont
Vict	Victoria
CM	Coal Measures

Scale

0 1 2 3 km

Opencast extraction is taken into account, but limits of workings are not shown

This figure is a simplified portrayal of 1:25 000 scale map 1 which should be consulted for detailed information

Figure 3. Solid Geology

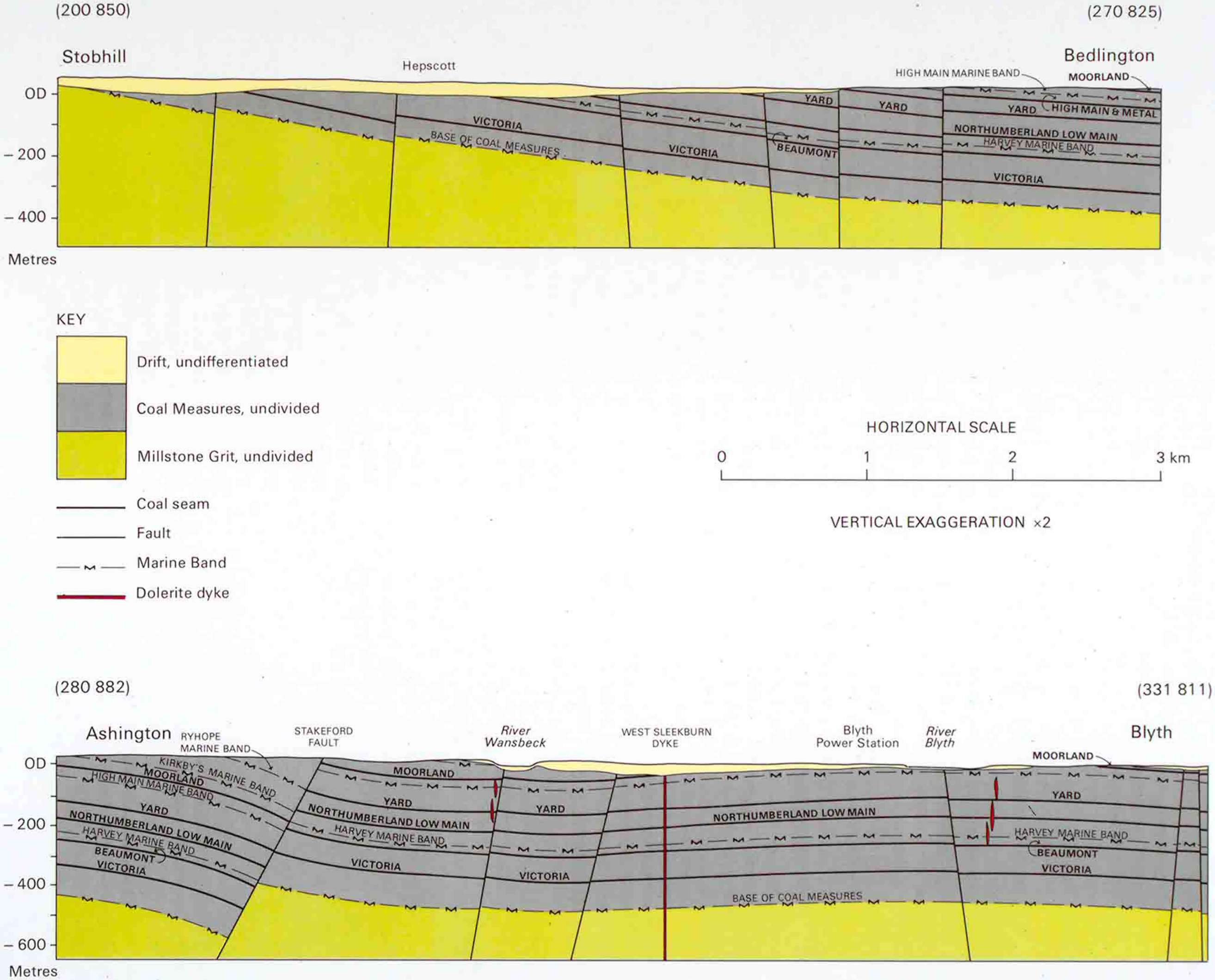


Figure 4. Horizontal sections

preservation of vegetable matter. The thickness to which a coal seam developed and the amount of splitting by other sediments was determined by the rate of subsidence of the original vegetation surface and its potential inundation.

There are approximately 35 named coal seams in the district, at least 22 of which have been mined. Despite (or perhaps because of) the long history of mining in the area, coal seam nomenclature suffers considerably from homonyms (different coal seams called the same name, e.g. High Main) and synonyms (the same coal seams called different names, e.g. Beaumont and Harvey); some due to mis-correlation, others introduced for commercial reasons. The seam names which appear on the geological maps and in this report are for the most part those adopted by Land (1974). Correlation has been made with the standard classification used by British Coal and the appropriate seam index letter has been included in the generalised vertical section of each 1:10 000 scale geological map, together with commonly occurring local names and Table 2 lists the more significant variations. A detailed description can be found in the Part II report.

Sideritic Ironstone (whin) is common, developed either as nodules, generally flattened parallel to bedding, or as layers. In the metre or so above coal seams it typically forms laterally continuous beds up to about 10 cm in thickness. Ferruginous concretions are common in seatearths.

2.1.2 Structure

The rocks were all folded and faulted during late Carboniferous times (about 280 million years ago). Subsequently, about 60 million years ago, they were tilted gently eastwards with some further faulting. The regional dip of the strata is to the east or south-east but there is considerable local variation (Figure 4). The estimated position of the larger faults is shown on the geological map (**MAP 1**).

2.1.3 Igneous Dykes

Several igneous dykes of Tertiary age have been recorded in mine workings in the district. These intrusions trend WNW-ESE, are generally less than 5 m wide and, in most cases, are both laterally and vertically discontinuous. Surface evidence of their presence is limited to sections in opencast coal workings, two possible quarries and a former exposure on the foreshore at Blyth [3185 8220].

2.2 DRIFT GEOLOGY (MAP 2)

Over much of the district the bedrock or rockhead surface is covered by Quaternary deposits (Figure 5). The form of the rockhead surface on which these deposits lie is illustrated by the rockhead elevation contours of Figure 6 and **MAP 3.** These show a major pre-glacial valley system entering the district from the west and south-west and declining to a depth well below present sea level at Cambois. In these valleys varied glacial sediments, a product of the last ice age, reach thicknesses in excess of 60 m (Figure 7 and **MAP 4**). In contrast the interfluvial areas generally have a thin (less than 10 m) drift covering consisting almost entirely of till (boulder clay). The youngest deposits (less than 12000 years old and therefore post-dating the last ice sheet) are the silts, muds, sands and gravels which flank the present rivers and coastline.

2.2.1 Till

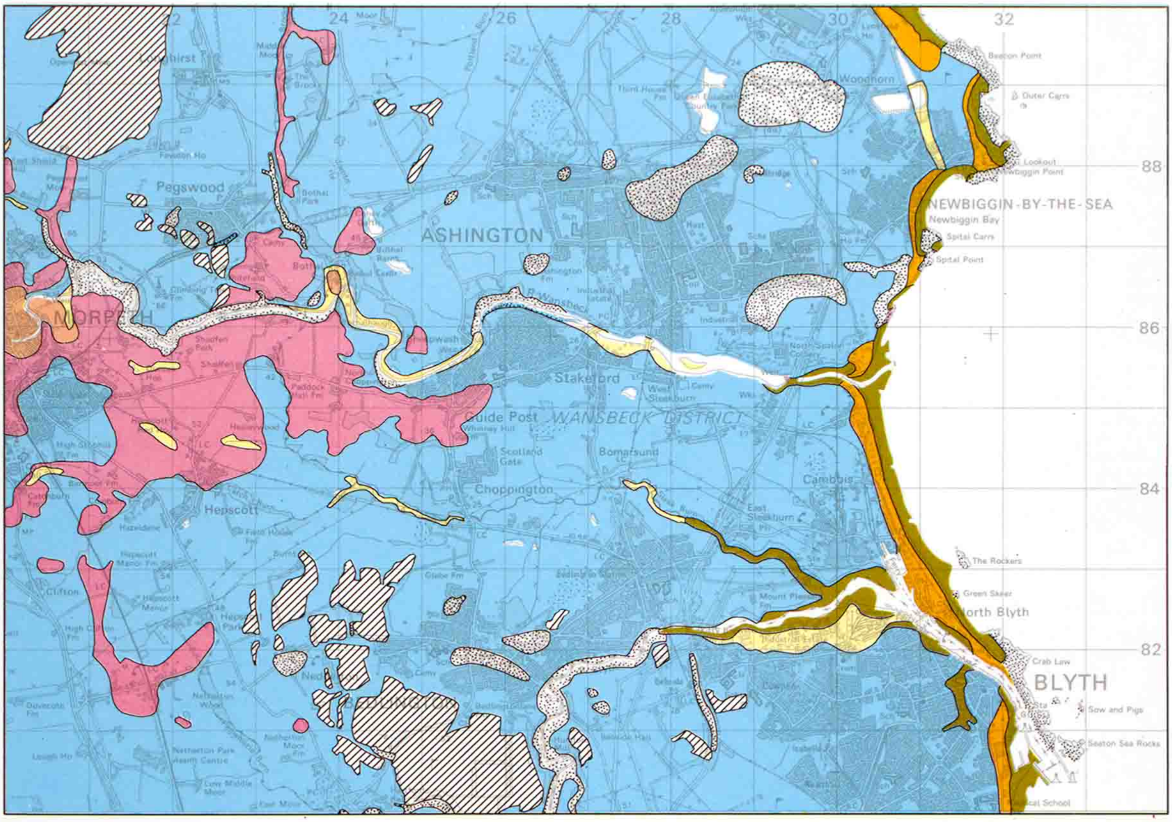
Till (Boulder Clay) is present over much of district. At depth, where it is unweathered, the till usually comprises a stiff grey to grey-brown silty, sandy, stony clay. Near surface however, in the first metre or so till is usually represented by a mottled orange-brown and pale grey silty, sandy and only sporadically stony clay. Till thicknesses of over 40m have been recorded in boreholes and may exceed 60m in the Stobhill and Stannington areas. Thin lenses and partings of sand and gravel and silt and clay are commonly found in the till and stones and boulders, while generally less than 100mm, may exceptionally reach several metres across.

2.2.2 Glacial Sand and Gravel

The most extensive deposit of glacial sand and gravel occurs in the west of the district around Park House, Shadfen, Hepscott and North Choppington to the south of the

Table 2 Coal seam nomenclature

This report	Local or county name(s)	British Coal Index Letter
Moorland	Blackclose	DE1
Ashington	High Main, Upper High Main, Ashington High Main	DE2
High Main	Diamond, Top Main, New Main	E
Metal	Top Main, Middle Main, Grey, Top Grey	F1
Five-quarter	Bottom Main, Bottom Grey	F2
Bentinck	Top Yard	G1
Top Bensham	Top Maudlin, Cowpen Bensham, Cambois Duke, Bensham	H1
Bottom Bensham	Bottom Maudlin, Stone, Cowpen Five-quarter, Cambois Five-quarter, Quarry, Six-quarter	H2
Durham Low Main	Five-quarter, Pegswood Band, Cowpen Brass Thill	J
Northumberland Low Main	Brass Thill, Pegswood Yard	K
Plessey	Hutton, Low Low Main	L
Bottom Plessey	Cheeveley, Lower Yard, Ruler	M
Beaumont	Harvey, Pegswood Tilley	N
Tilley	Widdrington Yard, Denton Low Main	P
Top Busty	Barmoor, Pegswood Harvey, Widdrington Five-quarter	Q1
Bottom Busty	Pegswood Top Busty, Splint, Old Man, Hepscott, Widdrington Main (or Top Main)	Q2
Three-quarter	Widdrington Main (or Bottom Main), Little, Pegswood Bottom Busty	R
Brockwell	Bandy	S
Victoria	Choppington Brockwell	T
Marshall Green	Choppington Victoria	U



KEY

- Blown Sand
- Alluvium
- Marine Beach and Tidal Flat
- River Terrace Deposits, undifferentiated
- Glacial Sand and Gravel
- Till (boulder clay) and glacial drift, undifferentiated

- Solid rock at surface

- Worked-out opencast coal seam area

Areas of made ground omitted for clarity

0 1 2 3km
Scale

This figure is a simplified portrayal of 1:25 000 scale map 2 which should be consulted for detailed information

Figure 5. Drift geology

River Wansbeck. It consists of brown and grey medium-grained sand and sandy silt ranging up to 18m in thickness. Elsewhere boreholes record apparently less persistent deposits at varying levels within the glacial sequence.

2.2.3 **Laminated Silt and Clay**

This deposit has not been differentiated at surface but is known from borehole evidence and clay pit workings to be most prevalent in the buried valley between Choppington and Cambois. the deposits are usually finely laminated and virtually stone-free and may be intercalated with fine-grained sand partings and thin till units.

2.2.4 **River Terrace Deposits**

These are developed along the Wansbeck where they comprise sand and gravel which is hard-packed towards the base and up to 4 m thick. Very few other details are available.

2.2.5 **Alluvium**

Sediment deposited by rivers and streams flanks many of the watercourses in the district and is a variable deposit of sand/silt/clay/gravel often containing organic debris.

2.2.6 **Marine or Estuarine Alluvium**

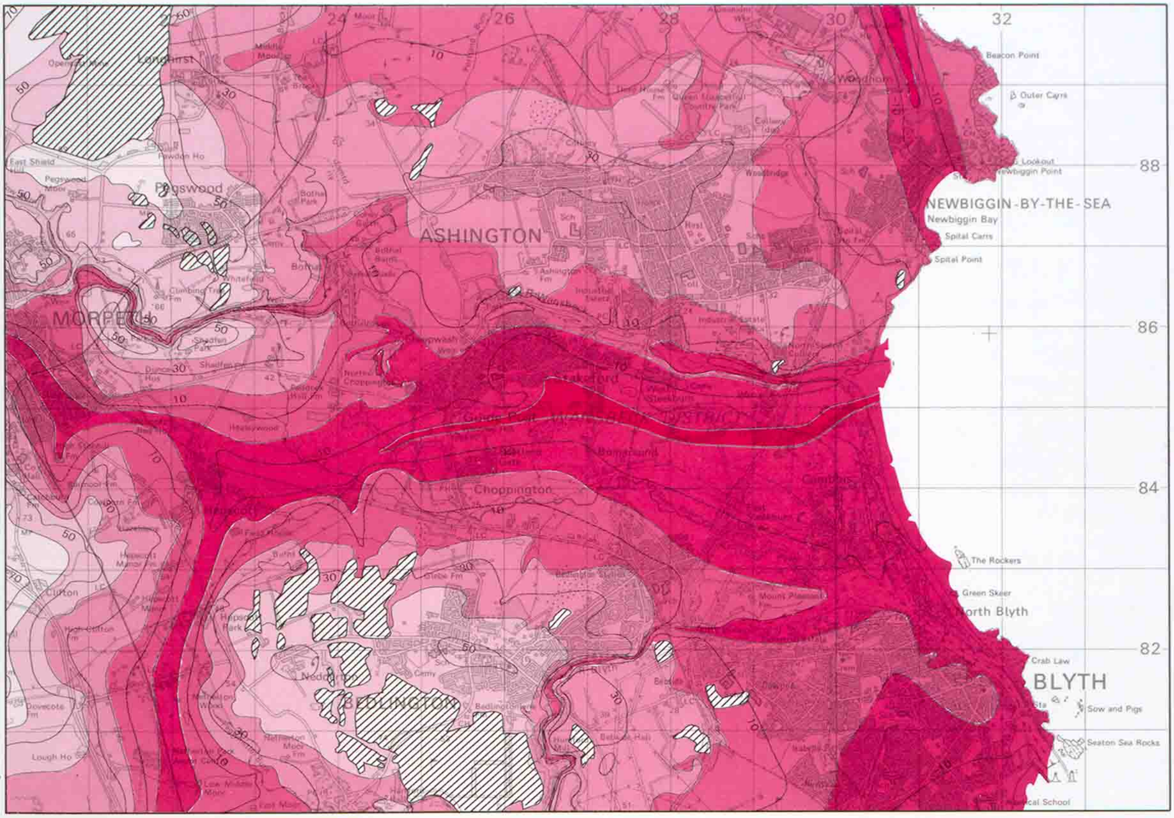
These sediments occur below the Normal Tidal Limit. The most extensive spread has been mapped on the south bank of the Blyth Estuary [290 822], where it consists of beds of silty, pebbly clay and sand and gravel. The deposit also occurs beneath the tidal flats of the river Wansbeck but here comprises up to 11.6m of sand and gravel.

2.2.7 **Marine Beach and Tidal Flat**

The beaches are chiefly of sand with subordinate shingle. Tidal flats of mud and silt occur in the Blyth and Wansbeck estuaries. All of these deposits are in a dynamic situation (likely to be affected by the action of the rivers and the sea) and are therefore subject to changes of extent, thickness and composition over a very short timescale.

2.2.8 **Blown Sand**

These wind-transported sediments fringe the coast as dunes, the inland edge of which are generally indistinct. Like the deposits above they may change their extent and thickness in a relatively short period of time.



KEY

80
70
60
50
40
30
20
10
OD
−10
−20
<−20

Metres relative to OD.

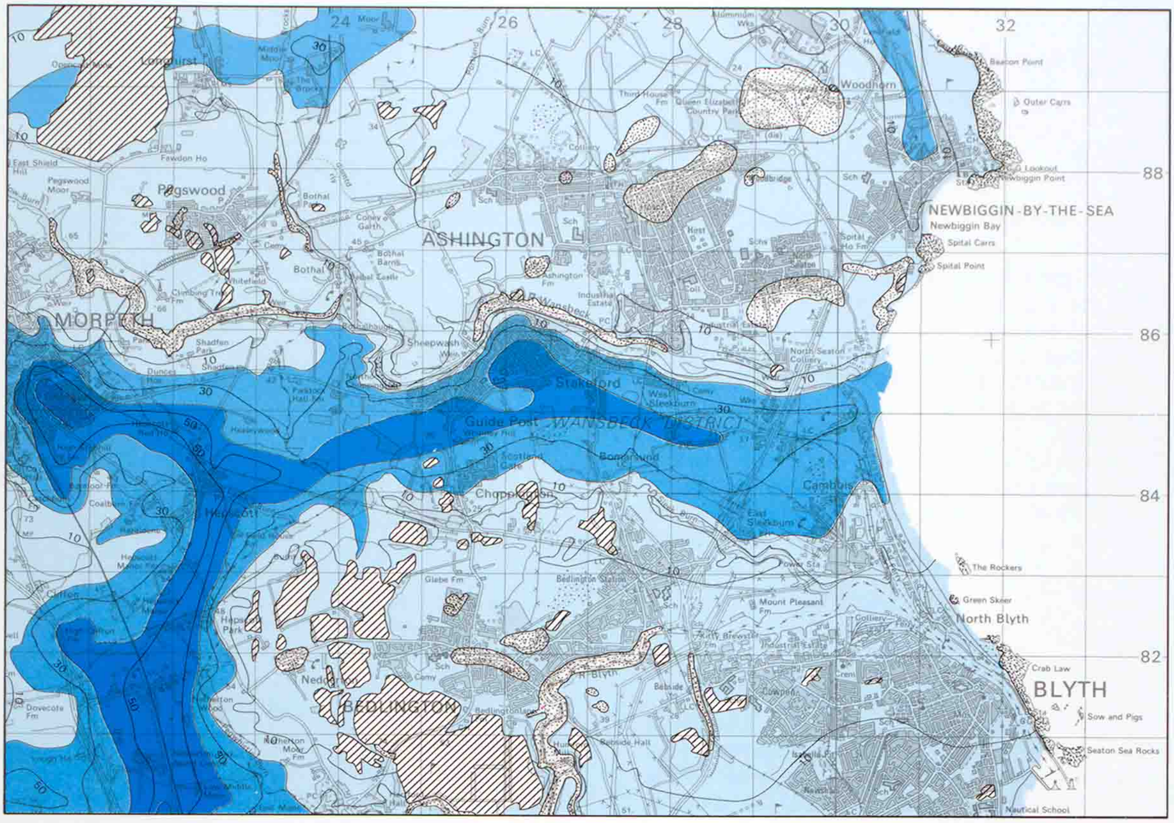
Worked-out opencast coal and quarry sites.

The contours relate to natural rockhead surface only.

0 1 2 3km
Scale

This figure is a simplified portrayal of 1:25 000 scale map 3 which should be consulted for detailed information

Figure 6. Rockhead elevation



KEY

Solid rock at surface
0
10
20
30
40
50
60
>60

Drift thickness in metres

Worked-out opencast coal, quarry and pit sites.

The contours relate to drift deposits only and do not take into account made ground.

0 1 2 3km
Scale

This figure is a simplified portrayal of 1:25 000 scale map 4 which should be consulted for detailed information

Figure 7. Drift thickness

3 LAND STABILITY AND GROUND CONDITIONS (MAPS 5-8)

3.0 INTRODUCTION

This section describes factors which may affect ground conditions and stability and therefore have important implications for planning and development. *Coal Mining* is likely to be the principal cause of potential ground instability in this district and mining methods and the stability problems associated with them are reviewed. **MAP 5** indicates areas which are thought to be underlain by shallow mining and locates shafts and adits know to BGS and British Coal. The particular hazards posed by shafts and adits are also detailed below.

Under *Engineering Geology* the rocks and superficial deposits are described in a geotechnical context, and the essentially qualitative descriptions are supplemented by information from a database created during the project. **MAP 8** classifies the deposits exposed at surface in engineering terms and indicates the sites of those boreholes with geotechnical test results. Made ground, depicted on **MAP 8**, is also the subject of a separate map, **MAP 6**, where the extent of disturbed or landscaped ground is additionally shown and made ground is subdivided on the basis of composition.

MAP 7 illustrates the sites of all non-confidential boreholes, shafts, adits and trial pits held by BGS and for which further information is available. *Slope movement* may cause foundation problems, therefore areas of steep slopes have been delineated on Figure 11 and known landslips are shown in more detail on **MAP 8.** Data on *flooding*, actual and potential, was provided by the Northumbrian Water Authority and this has been supplemented by information from the BGS field survey (Figure 12). Brief reviews of the effects of *coal mining on the local hydrogeology* and the potential problems of *methane and deoxygenated air* conclude the section.

3.1 COAL MINING

Almost all the district has been undermined and, in general, the number of seams which have been removed increases to the east (Table 3). However, with the closure of Ashington Colliery in 1988, large scale deep mining of coal in the district ceased. The presence of such extensive underground workings poses two questions which should always be asked prior to any development.

These are:

1) *"Has the area been undermined?"*

2) If so, *"at what depth and by what method?*

The last question is fundamental because the depth and style of any mining is directly linked to the subsequent stability of the ground surface. For this reason, a history of mining methods in the Northumberland coalfield is outlined below.

3.1.1 History of Mining Methods

Coal was probably worked in this region by the Romans, but the earliest documented working is from the year 1236 when the monks of Newminster, near Morpeth, were granted mining rights near Blyth (Galloway, 1882). The first workings were likely to have been at outcrop, either on the coastal cliffs or in the valley sides. By the end of 13th century coal was being extracted from shallow drifts or adits and from bell-pits. The latter consisted of a shaft, usually about 1 m across sunk through the overlying strata to the coal at a maximum depth of about 12 m. The coal was then worked all around the shaft until the unsupported roof became unsafe. Another pit was then sunk adjacent to the first and the process repeated. The excavated area of coal was roughly circular and no more than 20 m across. Although crude, with careful management, the system recovered a high percentage of the seam. Because of the depth limitation, only narrow strips close to the outcrop could be mined and the potential reserves were accordingly small. No positive examples of bell pits have been noted in the district.

It is of more than academic interest that almost every major industrial dispute in the mining industry (including the 1984 strike) has seen a return to these primitive methods

Table 3 Former collieries with a take within the district

Colliery	Approximate Grid Reference of Mine Entrance	Date workings abandoned
Ashington	266 880	1988
Barmoor	217 840	1911
Barrington	265 237	1938
Bates	306 823	1986
Bedlington A	274 830	1971
Bedlington D (or Doctor)	260 822	1968
Bedlington E (or West Sleekburn)	281 848	1962
Bedlington F (or Bomarsund)	270 847	1968
Bessie Grey (New)	210 865	1937
Bothal Park	232 878	1961
Cambois	303 847	1968
Catchburn	203 831	1921
Choppington A	250 841	1966
Choppington B (or High)	242 848	1966
Choppington North	242 848	?
Clifton	203 827	1899
Clifton West	199 832	1947
Cottingwood West	205 873	1918
Cowpen	306 815	1946
Ewart Hill	246 807	1954
Hartford	269 794	1961
Hepscott	239 838	1924
Horton Grange (or Bebside)	281 813	1962
Howburn	208 868	1962
Isabella (or Cowpen Isabella)	300 807	1966
Lilly	209 814	1926
Longhirst	238 890	1961
Longhirst Drift	233 887	1969
Longhirst Grange	215 881	1901
Mill (or Crofton Mill)	316 811	1969
Morpeth Banks	215 875	?
Morpeth Moor	211 870	1917
Netherton (or Hartley West)	233 819	1974
Netherton Hall	231 837	1943
Newbiggin	309 885	1967
Newsham (or New Delaval)	292 802	1955
North Seaton	290 858	1966
Park House	214 861	1931
Pegswood	228 872	1969
Woodhorn	289 884	1981

Note: other small coal workings exist throughout the district

Table 4 Opencast coal sites

Site	Grid Reference	Date coaling completed	Coal seam(s) worked	Coal recovered Mg (tonnes)
Active				
Butterwell	211 810	-	Victoria to ?Durham Low Main	-
Cowpen Road	286 814	-	Moorland	-
Abandoned				
Abyssinia I+IIA	250 885	1955	High Main and Metal	18 860*
Acorn Bank + Extensions	255 805	1966	High Main, Metal, Five-Quarter, Bentinck, Yard	6 871 830
Bebside (Furnance Bank)	278 820	1985	Moorland	?
Bebside (Hathery Lane)	284 808	1970	Ryhope Five-Quarter, Ryhope Little	42 837
Bedlington Reclamation Heap	266 824	1983	Moorland	11 794
Climbing Tree	226 868	1957	Bensham, Durham Low Main, Northumberland Low Main, Plessey, Bottom Plessey	140 545
Ewart Hill and Ewart Hill Deep	250 812	1954	High Main, Metal, Five-Quarter	2 263 083
Fawdon House	217 872	1945	Durham Low Main	31 620
Netherton I+II	230 825	1948	Top Durham Low Main, Northumberland Low Main	166 132
Pegswood Moor	223 871	1945	Bensham, Durham Low Main, Northumberland Low Main	118 500*
Stepping Stones	269 808	1958	Moorland	101 349

* estimated tonnage

of working with little attempt to reinstate shafts or workings afterwards.

In medieval times deeper resources of coal were worked by driving headings from a shaft through the coal seams with cross cuts at irregular intervals. Adequate ventilation was usually the limiting factor to the extent of the workings. This mining style progressively developed a regular pattern with roadways intersecting at right angles and unmined pillars of coal left supporting the roof - a method known as pillar and stall or bord and pillar. It became the established system of mining in the Northumberland and Durham Coalfield, with initial extraction rates of 40-50% commonly increased by the practise of removing the pillars on retreating. Most seams mined in this district have been worked at some point by the pillar and stall method. Occasionally the early irregular mining is revealed when opencast workings cut into in shallow seams, (e.g. Cowpen Road, Bebside [286 815]).

Although a mechanized version of pillar and stall mining is still used today at Ellington Colliery just north of the district, by the beginning of the 19th century, many collieries were working larger areas of coal by the shortwall or panel method. This system extracted coal from a broad face with the roof supported by wooden props, leaving a space which was subsequently packed with debris and small coal allowing the roof to settle down steadily. Extraction rates of up to 80% were achieved and the method was sometimes used in conjunction with, or used to rework, areas of pillar and stall.

Longwall mining developed from this method and in its mechanized form was the last system of mining to be used in the district. Two parallel headings, typically about 200 m apart, are driven from a main development road. Between these headings the coal was excavated. As the face was advanced the roof behind the working face was allowed to collapse.

In the twentieth century, the development of mechanical earth-movers made large-scale opencast mining practical. The initial sites developed during the early 1940s were seldom excavated deeper than 20 m, but since then the economic limit to excavation has increased to more than 100 m. One of the largest opencast sites in Europe is situated at Butterwell to the north-east of Morpeth [210 890]. A list of the opencast sites within the district is given in Table 4.

3.1.2 Stability Problems caused by Mining

The most serious hazard which the early methods of working present to a planner or developer is that in most cases they are not documented and any plans which do exist are likely to be inaccurate.

Although this survey did not encounter ancient bell pit workings it cannot be assumed that they do not exist, or that they have necessarily collapsed and are now satisfactorily compacted. It is known from other areas that bell pits were commonly only partly backfilled and the state of compaction was not good. If any are present they are likely to occur within the 30m limits shown on **MAP 5**. Shallow drifts associated with outcrop workings (including those worked during strikes) may also be left in poor condition.

Shallow pillar and stall workings have been identified at a number of locations and are probably present elsewhere within the district. Near surface they can pose particular problems. They do not collapse when mining has ceased since earth pressures, at shallow depths were not sufficient. However, the roof becomes weaker with time and sudden failure, particularly through loading by new construction, may occur.

Site investigations need to be properly designed and executed to identify this type of working as much of the coal is left undisturbed in pillars and, if too few boreholes are drilled or if they are drilled on a regular grid, they may only find the pillars and miss the voids.

Additionally, because packing of workings with rock was not necessary, and where roof measures have subsided to rest on the seatearth with slight disturbance, the only evidence in borehole cores may be a little powdered coal on a stained, slightly weathered and perhaps rusty seatearth. It is, therefore important that in any site investigation the potential problems associated with pillar and stall working are allowed for and a comprehensive geotechnical and mining report commissioned.

Piggott and Eynon (1978) noted three principal mechanisms of failure of pillar and stall workings:-

i) collapse of roof beds spanning adjacent pillars

ii) pillar failure

iii) squeeze of floor or roof strata

Sudden collapse of the beds spanning the stalls is the major cause of ground instability problems. The void propagates upwards under the combined influences of gravity and weathering, until the whole void becomes choke-filled with debris, or more competent beds are reached. If the void reaches the surface, it forms a crown hole (pitfall). A whole series of these depressions occur west of the Ashington-Ellington Road [260 886] where shallow workings in the Ashington Seam have collapsed. Piggott and Eynon (1978) showed empirically that the maximum height of collapse in British Coal measures is commonly up to 6 times the height of the mine void but may, exceptionally exceed 10 times the height. This relationship is also considered valid by Garrard and Taylor (1988) although they have reservations about the bulking theory and regard arching as the dominant void-arresting mechanism; stating that up to 70% of the old workings in their study were likely to suffer some further collapse if disturbed, (for instance by additional loading). However, as Carter (1984) has noted, 'safe-depth' rules are often broken in real-life situations.

It is possible that the deterioration of pillars may take place after many years but generally pillar failure is rare in shallow coal working, provided that the original pillar geometry was sufficient to support the roof. Piggott and Eynon (1978) commented that the pillars left by ancient mining were usually much greater in cross-section than was required to support the over-lying strata. However, failure may occur where pillars are very small or have been robbed at a later date. Pillars may also collapse long after mining has ceased when piles associated with modern construction, create highly concentrated loads.

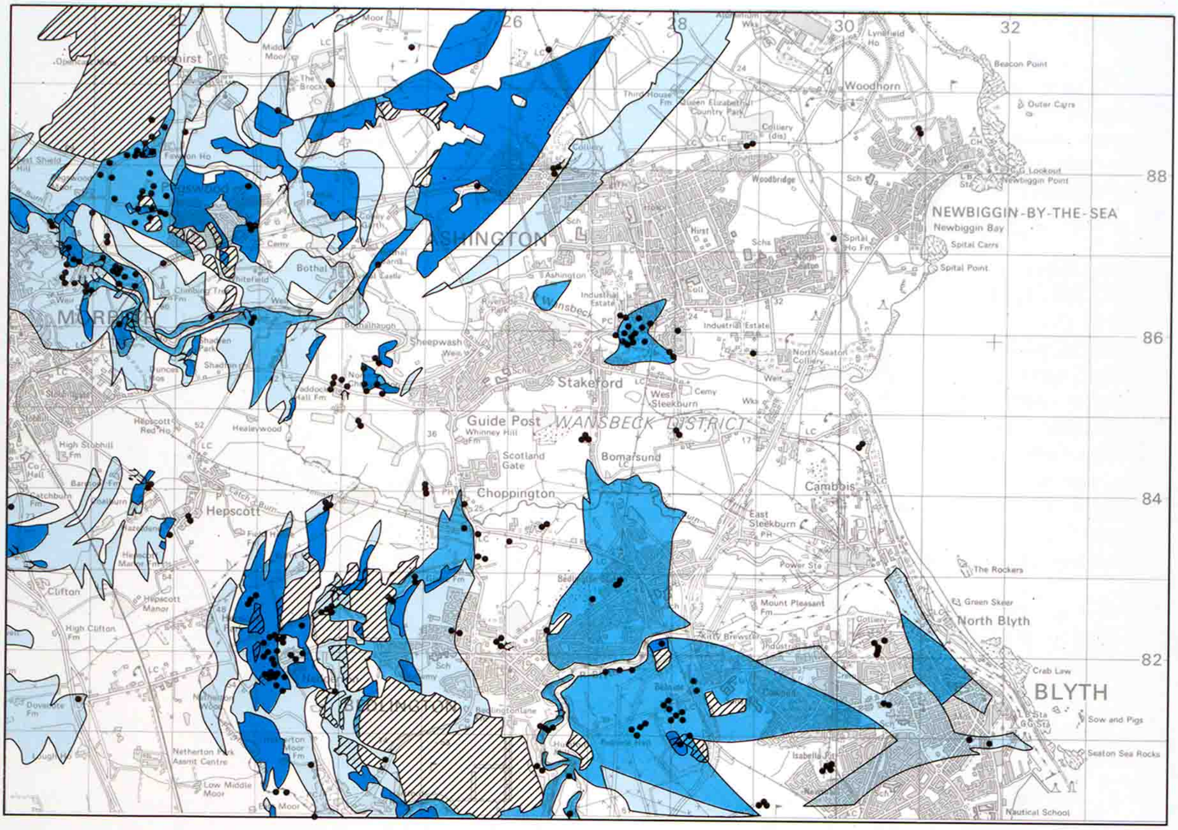
Piggott and Eynon (1978) identified the squeeze of floor or roof strata as a common cause of failure of shallow coal workings. In such cases, the strength of the coal pillars is such that the earth pressures are transferred to the floor or roof strata and their bearing capacity becomes a critical factor. If the pillar is strong enough to carry the load, it will be 'punched' into the roof or floor measures, particularly where low strength seatearths underlie the coal or where former workings are flooded. The last situation may become more significant as mine water levels rise as a result of the cessation of pumping (see 3.5).

Much has been published on subsidence induced by longwall mining (see Bell *et al.*, 1988). Generally the amount of subsidence is a function of depth, the width of the panel mined and the thickness of strata removed. Subsidence occurs rapidly after mining and is usually complete about a year after extraction, although a small amount of residual subsidence may occur over the next few years. Consequently while this method may cause problems for existing developments it poses few problems for subsequent development of the land.

Subsidence caused by all of these mining methods will usually extend beyond the limit of working (the draw zone) and may be influenced by natural faulting (2.1.2) which is often reactivated by mining.

3.1.3 Shallow Mining (MAP 5)

Shallow coal workings are shown on Figure 8 and **MAP 5** where an attempt has been made to delimit areas of known, inferred and possible mining at depths of less than 30 m from surface. The areas delineated are generalized and do not take into account subsidence draw zones which will extend beyond the limits shown. *In considering particular sites it is essential to consult the original documents* (held by British Coal Mining Records Office, Mine Service Centre, Tursdale, Co. Durham, DH6 5NT) from which much of the information has been abstracted. Workings known from mine plans can be anticipated but the areas of inferred or possible working shown on **MAP 5** are much less certain. *It is important to remember that ancient, unrecorded workings may occur at*



KEY

Mine workings within 30 metres of ground surface

- Workings recorded on plans
- Some evidence for mining from surface features or borehole data
- Local workings possible
- Workings probably absent within 30 metres of surface
- Worked-out opencast coal seam area
- • Pit or mine shaft, abandoned
- Adit or mine mouth, showing direction of entry (majority abandoned; see map 5 for status).

0 1 2 3km
Scale

This figure is a simplified portrayal of 1:25 000 scale map 5 which should be consulted for detailed information

Figure 8. Shallow mining

shallow depth in any area where a coal thick enough to be worked lies near the surface (see individual 1:10 000 scale geological standards for detailed information on coal positions).

3.1.4 **Shafts and adits**

The sites of shafts and adits are shown on **MAPS 1, 5, 7 and 10** and also on the 1:10 000 scale geological standards. All shafts and adits known to BGS and British Coal have been plotted but their positions in some cases may be inaccurate and it is not claimed that all have been traced. Particular care should be taken in those areas where the Moorland (or Blackclose) seam lies at shallow depth, for example at and around Blyth and Bedlington and north-east of Stakeford Bridge.

The location and condition of disused shafts clearly affects the safety of any proposed development and poses the following specific hazards.

1. *Accidental Entry*

   A fall down a shaft results almost inevitably in serious injury or death. Apart from a fall, there is danger of drowning, suffocation or poisoning by gas. In an adit there is also a danger from falls of roof strata.

2. *Movement or collapse of ground*

   The surface near a shaft may subside or collapse. If the shaft lining has deteriorated, the collapse may not be confined to the diameter of the shaft but may spread to form a crater. The diameter of the crater is a function of the depth to competent strata and the angle of repose of the incompetent strata that collapses. Collapses may also occur beneath competent strata in a shaft; these may not immediately affect the surface but the collapse may reduce the load-bearing capacity of the ground around the shaft.

   Old mine shafts may collapse because of changes in ground water levels, additional surface loadings due to new structures or tipping, vibration from traffic, mining subsidence or blasting. The collapse of one shaft may cause nearby shafts, linked by underground workings, to become unstable.

3. *Presence of gas*

   Various gases may be found in unventilated old workings. These include carbon dioxide and nitrogen (blackdamp), which may create an oxygen-deficient atmosphere and cause asphyxiation; methane (firedamp), which is explosive in a mixture of 5 - 15% with air and finally carbon monoxide and hydrogen sulphide (stinkdamp), both of which are poisonous even at low concentrations. The escape of oxygen-deficient air during periods of low atmospheric pressure has proved a particular problem in the Cramlington and Seaton Delaval areas immediately south of the district.

4. *Pollution of water supplies*

   Old shafts provide artificial channels allowing water to pass from one aquifer to another. If one aquifer becomes polluted, a shaft can act as a path for spreading the pollution to other aquifers (see section on Effects of Coal Mining on Hydrogeology; 3.5).

Much of this section has been drawn from National Coal Board publication "The Treatment of Disused Mine Shafts and Adits" (1982); this handbook contains useful information about the location and treatment of disused shafts and adits and is commended to planners and developers who may encounter unsuspected old workings.

3.2 ENGINEERING GEOLOGY (MAP 8)

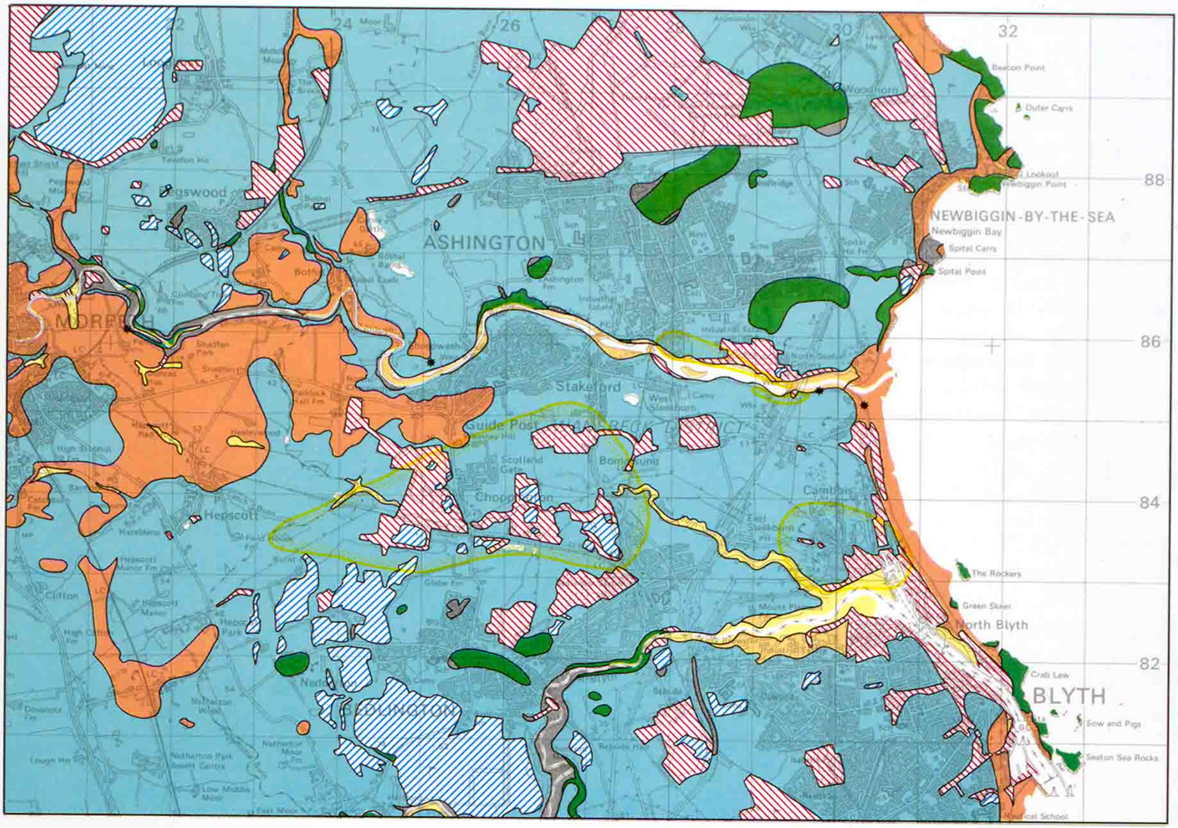
The geological materials of the district have been allocated to five principal groups on the basis of their predicted behaviour in an engineering context; in certain cases the engineering divisions split or combine geological units (Table 5). With the exception of laminated silt and clay, **MAP 8** (Figure 9) shows the nature of only the topmost material likely to be encountered during development or investigation. The 5 m drift thickness contour is delineated on the map as an indication of the areas in which some foundations or trenches for services may encounter solid rock; outside this area, **MAPS 3 and 4** (Figures 6 and 7) should be consulted for an indication of likely drift thickness or rockhead elevation. The geotechnical properties and behaviour of the engineering divisions and their constituent geological units are discussed below according to their engineering geology classification.

Table 6 summarises the geotechnical properties values and their variation, obtained from a simple statistical analysis of the geotechnical database established for the project (see Appendix C). Apart from simple visual checks of scatterplots and histograms, no attempt was made to validate individual test results or to take account of the depth or location of samples, so that all are equally 'weighted'. For most samples only a few geotechnical tests had been carried out and rarely was a full range of test results available for a particular lithological/geotechnical unit within one borehole. In most cases, the difference between the maximum and minimum values is large. *The information should only be used, therefore, as a guide when planning a site investigation and not as a substitute for a sampling and testing programme.*

Details of the tests and the methods of applying them in site investigations can be found in publications of the British Standards Institution, B.S. 1377 and B.S. 5930. A summary of the tests and their applications is given in Appendix C.

Table 5 Engineering Geology Divisions

Description	Lithology	Geological Formation
ROCKS	Sandstone, siltstone, mudstone, coal seatearth	Coal Measures and Millstone Grit
SOILS		
Normally consolidated cohesive	Clays and silts	Alluvium Marine Beach and Tidal Flat Marine and Estuarine Alluvium Laminated Silt and Clay
Overconsolidated cohesive	Clay	Till
Non-cohesive	Sand and gravel	Blown Sand Alluvium Marine Beach and Tidal Flat Marine and Estuarine Alluvium Glacial Sand and Gravel
Fill, made ground	Highly variable	Made Ground



KEY

SOLID ROCKS

- Sandstone
- Undivided solid

SUPERFICIAL DEPOSITS

- Normally consolidated cohesive soils, at the surface
- Normally consolidated cohesive soils, concealed
- Overconsolidated soils
- Non-cohesive soils
- Mixed normally consolidated cohesive and non-cohesive soils

FILL AND MADE GROUND

- Quarry, pit or opencast infill
- Artificial deposits on natural landsurface (Made Ground)
- * Landslip

Scale

0 1 2 3 km

This figure is a simplified portrayal of 1:25 000 scale map 8 which should be consulted for detailed information

Figure 9. Engineering geology

3.2.1 **Rock**

Rock generally has adequate bearing capacity for domestic and light industrial structures using normal foundations. However the weathering process commonly reduces the strength of a rock and weaker material may be encountered where rock crops out, or at rockhead where drift covers an old weathered surface. Consequently ease of excavation in the rock generally varies with the degree of weathering. Geological faults, or displacement, within the solid rocks may have produced broken rock or juxtaposed rocks of varying type and strength. Undermining may have widened joints in overlying rocks and loosened blocks, particularly of sandstone, so that they are unstable in excavations or above tunnels and may require special support.

Few test results are available for the solid rocks in the district. It should be noted that on weathering the rocks gradually change into soils *in situ* and that the summary values given in Table 5 include a range of weathered to unweathered samples.

Sandstones vary from fine- to coarse-grained. Some of the coarser-grained sandstones are gritty and highly abrasive, others are quartz-cemented and extremely hard. Ganister, a variety of sandstone seatearth found beneath some coals is a particularly tough rock. Excavation and tunnelling in sandstones generally presents few support problems, with the possible exception of undermined areas (see above). Near rockhead weathered sandstones will probably be rippable, but explosives may be required to break up unweathered rock to facilitate excavations. The depth of weathering varies and probably exceeds 6 m in places. It can be extremely difficult in boreholes to differentiate between basal drift deposits containing sand and weathered sandstone bedrock, especially where recovery is incomplete. Such differentiation is, however, extremely important as sandstones commonly weather irregularly to produce an uneven rockhead surface. Loose sand from weathering can be adjacent to virtually unweathered rock and the different bearing capacities of the adjacent materials must be allowed for in foundation design, particularly where major structures such as bridge piers are concerned. Chemical tests indicate that no special precautions need be taken against sulphate attack on concrete buried within sandstone.

Mudstones and Siltstones range from weak to strong, strength decreasing with increasing weathering. Their clay minerals are stable, but mudstones weather rapidly on exposure and expand on contact with water, making them liable to heave, so that excavations should be protected as far as is possible against wetting and will usually need support. Explosives are not generally required in surface excavations; weathered mudstones are diggable, but they may need ripping when fresh. As weathered material has a lower bearing capacity than unweathered it may be necessary to place foundations (e.g. footings or piles) beneath the weathered materials. The weathered zone has been recorded in boreholes up to about 4 m thick, for completely weathered rock, but the degree of weathering decreases beneath this depth. Weathering is greater where drift cover is less. The few sulphate determinations on the materials place them in classes 1 and 2 of the BRE classifiction (Building Research Establishment, 1983). However, disseminated pyrite may be present within the rocks, rapid weathering of which leads to ground water of high acidity (pH<4) in which abundant sulphate ions may be present so that the possibility of attack on buried concrete must be considered. Trenching in mudstones is generally relatively easy, but tunnelling at depths of 12 m or less presents substantial support problems. A recent useful discussion of the properties of Coal Measures mudrocks is given by Taylor (1988).

Seatearth mudstones are probably the commonest lithology immediately underlying coal seams though locally they may occur unaccompanied by a coal. They are strikingly different from the sandstone seatearths (or ganisters) noted above and typically consist of readily-weathered clay minerals and abundant random internal polished ("listric") surfaces, which make them potentialy unstable both in excavations and under load. Disseminated pyrite may also be present and comments made above concerning the weathering of this mineral in mudstones apply here too.

SUPERFICIAL DEPOSITS

ENGINEERING GEOLOGY DESCRIPTION	LITHOSTRATIGRAPHICAL UNIT	STANDARD PENETRATION TEST N	BULK DENSITY Mg/m³	DRY DENSITY Mg/m³	MOISTURE CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	PLASTICITY INDEX %	UNDRAINED (APPARENT) COHESION kPa	ANGLE OF SHEARING RESISTANCE (°)
COHESIVE	PEAT				1 99.9				3 12 7-19	3 0
COHESIVE	ALLUVIUM (mainly clay)	4 6 3-9	8 1.94 1.79-1.99		9 30.9 18.7-80	5 52 23-113	5 35 20-89	5 16 2-25	10 41(34) 10-130	6 1.3 0-8
COHESIVE	MARINE AND ESTUARINE ALLUVIUM (mainly clay)	3 21 13-34	63 1.89(0.19) 1.25-2.29		65 33(17) 6.5-99.9				46 52(64) 0-317	46 2.4(7.2) 0-28
COHESIVE	SUPERFICIAL MOTTLED CLAY (weathered till)	8 22(14) 4-48	268 2.03(0.11) 1.52-2.27	8 1.76(0.07) 1.67-1.86	312 20.9(4.0) 8.0-40.2	82 45(8) 27-63	82 20(4) 13-32	82 25(7) 10-43	263 108(56) 0-379	222 1.9(5.4) 0-32
COHESIVE	TILL	90 52(46) 6-195	2082 2.12(0.12) 1.51-2.93	162 1.87(0.17) 1.45-2.21	2083 17.3(4.9) 1.2-38.2	222 40(8) 5-61	220 17(4) 9-30	220 23(7) 0-45	1859 132(62) 0-455	1653 1.0(3.9) 0-40
COHESIVE	LAMINATED CLAY	33 62(42) 9-138	36 1.98(0.83) 1.77-2.21	2 1.59 1.58-1.61	41 25.7(5.3) 13.7-36.9	5 48 28-72	5 20 15-27	5 28 10-45	40 71(30) 20-134	35 1.5(5.8) 0-32
NON-COHESIVE	ALLUVIUM (mainly sand and gravel)	7 13 2-28								
NON-COHESIVE	MARINE AND ESTURINE ALLUVIUM (mainly sand and gravel)	65 22(32) 1-170	1 2.24		1 5.7					
NON-COHESIVE	MARINE BEACH AND TIDAL FLAT (mainly sand and gravel)	41 40(14) 13-66								
NON-COHESIVE	GLACIAL SAND AND GRAVEL	226 18(14) 1-60	4 2.00 1.95-2.07	1 1.79	29 17.5(0.6) 7.9-27.6					
MIXED	MADE GROUND	214 19(19) 2-200	44 1.95(0.17) 1.43-2.24	16 1.65(0.2) 1.06-1.95	79 28.5(13.0) 9.0-99.9					

SOLID ROCKS

ROCK	SANDSTONE	52 132(121) 6-500			5 14.0 7.9-19.7					
ROCK	MUDSTONE AND SILTSTONE	74 99(83) 10-480	26 2.12(0.14) 1.81-2.48	5 1.72(0.18) 1.47-1.89	40 15(5) 4-25	7 43 33-53	7 18 16-24	7 24 17-35	32 129(94) 3-469	25 7.1(10.6) 0-34

Number of values → 74
Mean value → 99(83) ← Standard Deviation of values, given where at least 10 values are present.
10-480 ← Range of values

* see Appendix C for explanation of classes used to describe the results of consolidation and sulphate tests. The superscript after class value indicates the number of samples with that value.

VANE TEST	COEFFICIENT OF VOLUME COMPRESSIBILITY Mv CLASS *	COEFFICIENT OF CONSOLIDATION Cv CLASS*	COMPACTION MAXIMUM DRY DENSITY Mg/m³	COMPACTION OPTIMUM MOISTURE CONTENT %	CALIFORNIA BEARING RATIO %	CLAY %	SILT %	SAND %	GRAVEL %	pH	SULPHATE CLASS *
										1 7.0	1 1
	2 $2^{1}3^{1}$		2 1.57 1.39-1.74	2 20 14-25						4 6.2 5.5-6.9	4 1
16 13(4) 7-21	6 $3^{5}4^{1}$	6 $3^{3}4^{3}$				2 34 23-45	2 60 51-69			3 6.7 6.4-7.0	1 1
16 109(21) 85-143	16 $2^{2}3^{13}4^{1}$	16 3	17 1.77(0.15) 1.53-2.01	17 15(4) 10-22	42 10(9) 3-60	3 39 7-96	5 17 4-35	4 67 48-80	4 5 1-13	46 7.3(0.5) 6.0-8.8	64 $1^{61}2^{3}$
83 106(37) 9-182	157 $2^{85}3^{69}4^{3}$	144 $2^{7}3^{102}4^{35}$	52 1.86(0.13) 1.54-2.08	52 14(7) 8-56	82 9(8) 2-45	8 4 1-6	16 31(22) 3-72	17 44(25) 5-94	16 27(24) 4-95	87 7.1(0.5) 5.0-8.1	100 $1^{85}2^{11}$ $3^{3}4^{1}$
	7 $2^{4}3^{3}$	7 $3^{1}4^{6}$	1 1.67	1 16	7 6 2-19					4 7.4	5 $1^{3}2^{2}$
							3 5	3 34 13-50	3 51 43-55	2 7.0	2 1
						7 8 4-12	37 10(11) 1-54	45 73(25) 8-99	41 20(23) 1-75	5 6.8 6.5-7.5	5 1
								9 83 45-100	8 19 2-55		
1 71	2 3	3 3	21 1.73(0.08) 1.60-1.91	21 14(2) 11-17	5 11 1-32	13 8(8) 2-29	40 19(15) 2-60	45 60(28) 2-98	27 34(35) 1-98	17 7.1(0.6) 5.5-8.1	26 $1^{25}2^{1}$
4 73 36-96	1 3	1 3	13 1.81(0.26) 1.25-2.08	13 13(5) 8-22	13 33(35) 1-99	11 7(5) 1-16	40 11(8) 1-31	63 57(26) 10-99	63 35(25) 1-87	40 6.7(1.3) 3.3-9.0	69 $1^{35}2^{28}$ $3^{1}4^{1}5^{4}$

			1 1.72	1 14	1 24		4 13 6-20	4 58 28-77	4 29 9-62	7 7.1 6.8-7.4	8 $1^{2}2^{3}3^{3}$
1 114	5 2	5 $3^{4}4^{1}$	3 1.96 1.92-1.99	3 9 8-10	2 5 3-7	2 4 3-4	2 47 40-53	2 41 36-46	2 9 8-10	3 7.5 7.0-8.0	3 $1^{2}2^{1}$

The values given for geotechnical parameters are the result of an interpretation of data obtained from site investigation reports. Sampling was not done in a statistically valid way and the mean and standard deviation are therefore not statistically valid. However, they do give a useful indication of values and spread of the geotechnical properties. It must be emphasised that many of the lithostatigraphical units are variable laterally and vertically and that some sands may occur in predominantly clay units and clays may occur in predominantly sand units.

3.2.2 Normally Consolidated Cohesive Soils

These soils are commonly very soft to soft, are highly compressible and are of low bearing capacity. Even lightweight structures will commonly require special foundations to spread the load or piles to transfer the load to deeper, stronger foundations. The deposits can vary laterally in composition, leading to possible differential settlement where structures cross compositional boundaries. Gravel layers within them may locally provide better foundation conditions. However, the thickness of the gravel and nature of the deposits underlying it must be determined.

Laminated silt and clay consists of blue-grey, brown weathering finely laminated clay, silt and silty clay. It is of soft to stiff consistency with intermediate plasticity, low to moderate compressibility and medium to fairly fast rate of consolidation (owing to the drainage effect of the silty laminae). **MAP 8** indicates the areas in which it may be present within other glacial deposits; these areas are based on an interpretation of information derived from boreholes and former exposures. A maximum known thickness of 12 m is recorded from the former Foggos Brickworks [250 835]. Laminated clay and silt have a low safe angle of rest and excavations need close support.

Peat has not been mapped at surface, but is known to be present within alluvial deposits, usually associated with soft grey organic clays, and beneath sand dunes (e.g. at North Blyth). Geotechnical data for peat is available for only 3 boreholes within the district. It is essentially highly compressible with a very low bearing capacity. In excavations it may either stand well without support, or flow and require close boarding. Its properties are described in detail in Hobbs (1986).

Clay-rich *alluvium* is present along the flanks of the rivers Blyth and Wansbeck and their tributaries above the Normal Tidal Limit and also occurs commonly as peaty flats on the surface of the glacial sand and gravel. From the few geotechnical data available, the alluvium is believed to be a variable material with low bearing capacity and generally high compressibility.

The grey or grey-brown clay of the *Marine and Estuarine alluvium* varies from very soft to stiff, but is generally firm with medium compressibility and a medium to fairly rapid rate of consolidation. Hydrostatic pressures in the estuarine alluvium may fluctuate because of tidal influence. Groundwater control for excavations, together with shoring are usually required.

3.2.3 Overconsolidated Cohesive Soils

Glacial till (boulder clay) is the only deposit in this category within the district. It is the most widespread surface deposit and is the material on which most development has taken place, consequently it has yielded more geotechnical test data than other deposits (**MAPS 2 and 8**, Table 6). The till usually has a distinct weathered upper layer, generally weaker, less dense, more plastic and with a higher moisture content than the underlying unweathered material. This weathered layer was identified as a distinct unit in several site investigation reports, although it was not mapped as a separate unit. Its test results have been entered into the geotechnical database under the heading of 'Superficial Mottled Clay'. It is a red-brown or mottled grey-brown and orange-brown sandy or silty clay with pebbles. The depth to which the till has been affected by weathering varies. It is commonly weathered to 3 or 4 m, a depth within which most normal foundations would be placed and extends to at least 8 m in Northumberland (Eyles and Sladen, 1981).

Locally the undrained shear strength of the Superficial Mottled Clay may be increased near the surface where the clays are dry or where secondary effects have led to unusual compaction. Lower parts can be soft and plastic, particularly where in contact with underlying water-bearing strata (e.g. glacial sands and gravels), such as was observed to the south of Morpeth. The reversed strength gradient which thus can be induced must be taken fully into account in foundation design. It is an especial hazard in open excavations which are reasonably stable where the clays are dry, but dangerously unstable where lower parts of the profile are wet. Sub-vertical joints are a major source of weakness in such situations and also lead to instability on natural slopes, in particular where superficial stony clay overlies plastic laminated clay.

Unweathered till is primarily a stiff grey stony clay of low to intermediate plasticity, low to medium compressibility and with medium to slow rate of consolidation. Thin lenses of sand, gravel and laminated, stone-free silt and clay are also present and lateral variation in lithology leads to variation in bearing capacity across the deposit.

Water-bearing deposits of granular materials in the till are prone to running or piping and may cause high inflow of water during excavation. Laminated or stone-free clay layers in the till may soften rapidly on wetting leading to poor trafficability on site and unstable pit or trench walls.

Generally till provides satisfactory support for lightweight structures with normal foundation design, although lateral variation in bearing capacity on a site-scale may cause differential settlements. The possible presence within the till of large boulders, or even of large bodies of detached bedrock, should also be considered. The failure to recognise such occurrences may lead to a misinterpretation of site investigation data and subsequent problems in executing foundation design. Sulphate determinations indicate that generally no special precautions are required to prevent sulphate attack on buried concrete, the majority of the samples falling in Class 1 of the BRE classification (Building Research Establishment, 1983). However, it should be noted that over 10% of determinations were BRE Class 2, and four others in Classes 3 and 4. These higher values probably result from local groundwater contamination (see made and disturbed ground below), but emphasise the need for careful investigation to determine the geological and geotechnical variability in three dimensions at the scale of any particular site prior to development.

3.2.4 **Non-Cohesive Soils**

These granular materials are composed of variable amounts of sand and gravel and commonly contain clayey or silty layers. Where dense or very dense, the deposits provide an adequate bearing capacity for most domestic or light industrial purposes using normal foundations. Where loose they have lower bearing capacities. Excavations even in dense material, usually require support and "running" conditions are likely, such that below the water table de-watering may, therefore, be needed. Cuttings through these deposits require drainage measures to remove water from perched water tables and relieve high water pressures in confined aquifers (sands and gravels overlain by less permeable clays) to avoid heaving or sagging on excavation.

Glacial Sand and Gravel occurs widely in the western half of the district (see **MAP 2** and Figure 5), both as large irregular spreads with recorded thicknesses in excess of 18 m, and as smaller accumulations or beds within the till. It is commonly associated with laminated silt and clay in the major drift-filled channels. It is a heterogeneous deposit, but consists predominantly of loose to medium dense, fine-to medium-grained brown sand with subordinate sandy silt and, generally well-sorted, sand and gravel layers. No special precautions against sulphate attack on buried concrete are indicated by the test data.

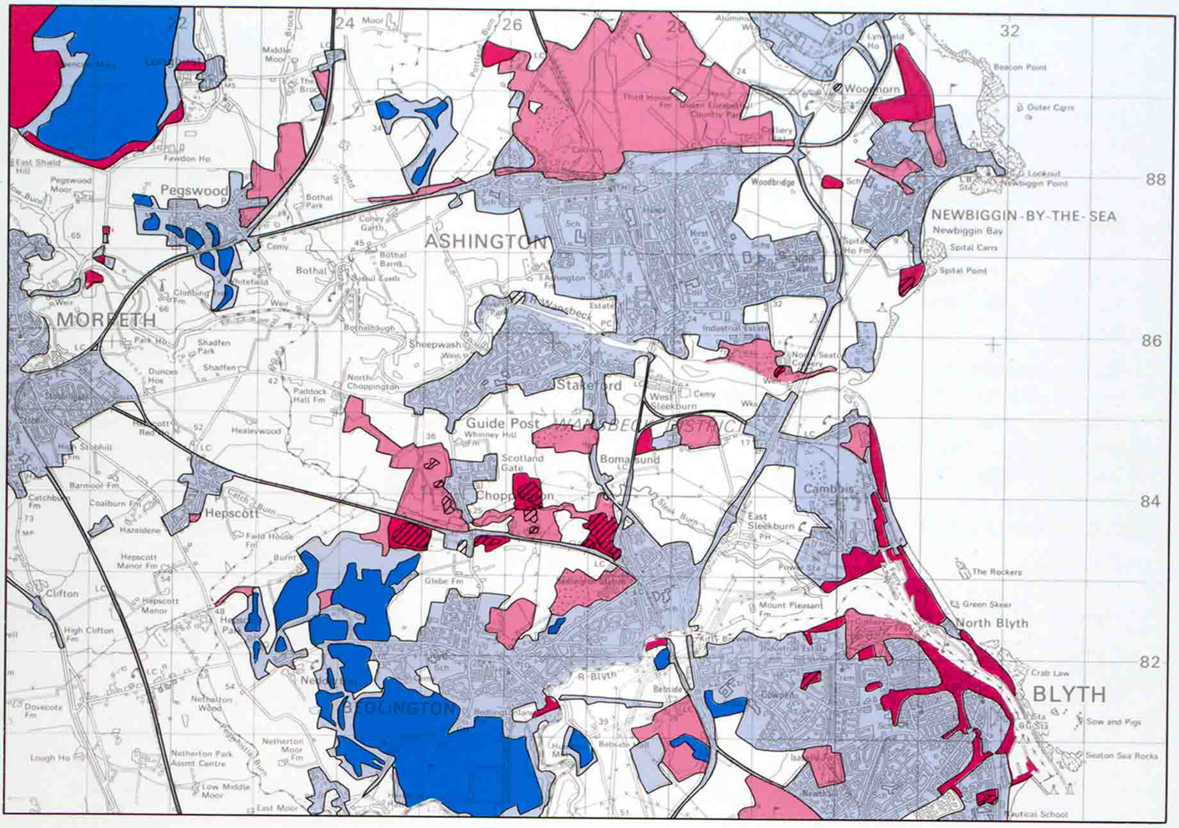
No geotechnical data are available for *blown sand* from within the district. The sand is generally fine-grained and uniformly graded. It is expected to be of loose relative density.

Marine Beach and Tidal Flat Deposits comprise the surface deposits fringing the coast and extending up the rivers Wansbeck, Blyth and Sleekburn. The beach deposits are mainly of sand in the bays and shingle around and immediately south of the headlands. The tidal flat deposits and the mouths of the rivers consist of a thin layer of grey silt and clay. Standard penetration test data for the sands indicate that they are generally medium dense to dense.

The *alluvium* along the flanks of the river Wansbeck between Bothal and the Normal Tidal Limit consists mainly of non-cohesive sand and gravel. In the river Wansbeck, *marine and estuarine alluvium* consists of up to 11.6 m of gravel and medium dense sand. The few standard penetration test data available for these deposits show them to range from very loose to dense.

3.2.5 **Made and Disturbed Ground**

Materials in this category exhibit a wide



KEY

Worked-out opencast coal seam area

Miscellaneous waste

Colliery waste

Landscaped and disturbed ground

Approximate area of excavation in former quarry or pit, excluding opencast coal seam areas

0 1 2 3km

Scale

This figure is a simplified portrayal of 1:25 000 scale map 6 which should be consulted for detailed information

Figure 10. Made and disturbed ground

range of geotechnical properties summarised in Table 6. **MAP 8** (Figure 9) indicates their disposition separated into two main types:

(i) *Fill* placed in quarries, pits and other excavations,

(ii) *Made Ground*, artificial deposits which have been spread over the natural land surface. The recognition of such areas is important in an engineering context, because of the variable foundation conditions which may exist within adjacent tipped materials and their contrast with those of bordering natural deposits.

Additionally, the possible presence of voids, methane-generating and hazardous components and the potential of leachate to contaminate areas outside the spread of made ground may have consequences on health or lead to chemical attack on buried concrete and structures. Careful attention should be given to site investigation in order to take into account the problems outlined above when areas of made ground are included within the boundaries of any proposed developments.

MAP 6 (Figure 10) should be consulted for further information on the nature and composition of areas of made ground. The following description of engineering properties uses the categories illustrated on that map.

(i) Worked-out opencast coal-seam areas.

(ii) Miscellaneous waste.

(iii) Colliery waste.

(iv) Landscaped and disturbed ground.

Worked-out Opencast Coal-Seam Areas

These areas occur chiefly to the south-west of Bedlington and north-east of Morpeth (Table 4). Two of them, Butterwell (currently active) and Acorn Bank (restored in 1966), are extremely large in area (137 and 342 hectares respectively) whilst the remainder are generally less than 40 hectares. All the sites now restored and landscaped have been filled with the overburden which was originally removed from them, the composition of the fill is, therefore, likely to be relatively uniform. Although settlement and compaction of the fill must be expected in the years immediately following restoration, the position and former depth of the excavations is well documented and because of this can be taken into account prior to any development. Engineering problems are likely to be mainly due to settlement; differential settlement may be a problem at the margins of a site should development straddle the fill and undisturbed ground.

Miscellaneous Waste

This category includes domestic, agricultural, building, industrial and quarry waste. All waste disposal sites known to Northumberland County Council are shown on **MAP 6** and a list of the waste materials which may have been placed in them is given (Table 7). Some sites may not have been located (two possible sites occur near Willow Bridge [253 833] and Stakeford Bridge [273 857]). Domestic, agricultural and industrial refuse is likely to be highly variable in composition and geotechnical properties. Problems of methane-production, voids, differential settlement, toxic leachate or toxic solids, may be anticipated in association with this material.

Restored and partially restored old clay pits are common in the Choppington area and small disused and infilled sandstone quarries are scattered throughout the district. Where known the approximate limit of the excavations is shown on **MAP 6**. Commonly there are no clear surface indications of their true extent (or in a few areas their presence) and in most instances their location and limits have been derived from old topographic or geological maps. The latter however, do not provide any indication of the nature of the fill material.

Large parts of the town of Blyth are underlain by made ground. In the town centre a sizeable tidal creek has been infilled and adjacent to the river large quantities of ships' ballast (chiefly flint gravel from the Thames estuary) were tipped at the height of the coal trade. Immediately to the north of the town parts of both banks of the estuary have been reclaimed and softer estuarine deposits may occur below the fill which must be taken into account when designing site

Table 7 Made Ground

A: Miscellaneous waste: known landfill sites

Site Name	Grid Reference	Licence or Resolution Number	Classes of waste	Status
Alcan (UK) Ltd	299 896	1	12	Closed
Spital House Farm	299 878	2	6,11	Closed
Quarry Woods	210 866	4	6,11	Closed
Barrington	263 383	11	6,9,11	Active
Pegswood Colliery	231 878	19	6	Closed
North Blyth	312 828	22	6	Closed
Links Quarry, Newbiggin	308 866	24	6,9,11	Closed
Alcan (UK) Ash Lagoons, Stage 2	308 888	25	9	Closed
Alcan (UK) Pot Linings Site 2	304 890	32	12,14	Active
Alcan (UK) Ash Lagoons, Stage 3	307 892	38	9	Active
Links Quarry (East)	309 867	45	6	Closed
Choppington Old Brickfields	248 834	51	1,2,3, 4,6,10	Active
Bothal Barns Farm	246 869	56	6	Active
Ellington Road	260 893	R22	1,2,6,7	Active
Stakeford	278 861	R23	1,6,7, 10,11,12	Closed
Bomarsund	267 847	R28	1,6,7, 10,11,12	Closed

Waste Classification

1. Domestic and commercial waste (including street sweepings, litter, market refuse and gully contents but not wasts falling into the following categories) - untreated
2. Domestic and commercial waste (as above) - pulverised/composted
3. Domestic and commercial waste (as above)-baled.
4. Sewage sludge and pail closet contents.
5. Incinerator residues.
6. Waste from construction or demolition.
7. Medical, surgical and veterinary waste.
8. Old cars, vehicles and trailers.
9. Pulverised fuel ash.
10. Non-hazardous industrial waste - potentially combustible.
11. Non-hazardous industrial waste - inert and non-flammable.
12. Difficult waste. This will generally be notifiable waste or waste contaminated with hazardous quantities or concentrations of notifiable waste, but also includes certain categories of waste which may not be notifiable but which would cause difficulties in certain circumstances.
13. Water treatment sludge.
14. Farm wastes.

Compiled from information provided by Northumberland County Council updated May 1988.

B: Miscellaneous waste: fill unknown

Locality	Grid Reference	Excavation (if any)
Bebside	278 822	-
Bedlington	272 835	clay pits
Bedlington	2648 8260	-
Bedlington	2805 8235	-
Blyth	3044 8170	clay pit
Blyth	3075 8230	sandstone quarry
Blyth	3076 8200	sandstone quarry
Blyth	315 817	-
Blyth	318 806	clay pit
Blyth	3188 8050	clay pit
Blyth	3184 8032	clay pit
Bomarsund	276 847	-
Bothal Park	237 875	clay pit
Cambois	305 843	-
Cambois	305 837	-
Cambois	2960 8345	-
Cambois	298 834	-
Cambois	303 832	-
Choppington	254 834	clay pit
Cowpen	297 818	clay pit
Coney Garth	2515 8730	clay pit
Fawdon House	2176 8833	sandstone quarry
Morpeth	2076 8644	-
Morpeth	2112 8658	sandstone quarry
North Blyth	310 829	-
North Blyth	317 820	-
Pegswood	2181 8786	sandstone quarry
Pegswood	2193 8768	sandstone quarry
Pegswood	2156 8779	-
Woodhorn	2995 8906	sandstone quarry
Stobhillgate	2019 8502	clay pit

C: Colliery Spoil

Locality	Grid Reference	Condition
Ashington/Woodhorn Collieries	270 890	Partially restored
Barrington	265 836	Partially restored
Bates Pit, Blyth	306 823	Unrestored
Bedlington A	270 829	Restored
Bedlington Doctor	260 823	Restored
Bomarsund	267 847	Restored
Cambois	303 847	Restored
Choppington	250 840	Restored
Coney Garth	250 877	Restored
Cowpen South Pit, Blyth	306 815	Restored
Ellington Road, Ashington	261 894	Restored
Horton Grange	281 813	Partially restored
Hepscott	223 837	Restored
Isabella Pit, Blyth	300 807	Partially restored
Longhirst	238 891	Partially restored
Mill Pit, Blyth	316 808	Restored
Newsham	292 802	Restored
Netherton	238 827	Restored
Netherton	229 827	Partially restored
Netherton	232 822	Unrestored
Newbiggin	311 884	Restored
Newbiggin	306 880	Restored
North Seaton	290 857	Restored
Pegswood	232 879	Restored
Pegswood	212 872	Partially restored
West Sleekburn	263 847	Restored

investigations prior to development and in the design of the development itself.

Colliery Waste

Until recent years conspicuous mounds of colliery spoil were a common feature of the local landscape; almost all have now been restored (Table 7). Whilst some are still distinct artificial mounds, the reclamation of others has involved the redistribution of the spoil over large areas and dressing the surface with soil and sub-soil. In such areas, e.g. around Third House Farm [280 890], the thickness of the spoil is highly variable and the limits of the artificial ground difficult to fix.

Colliery waste is largely composed of rock fragments whose properties are well established (Taylor, 1978), but there may be substantial quantities of carbonaceous and pyritous material which may cause spontaneous combustion and the production of toxic gases. In the past most colliery heaps in the area were subject to periodic self ignition and some burned for considerable periods. During the reclamation of the heaps it has been the practice to identify hot spots by drilling and special procedures have been adopted (exposure, cooling and compaction) to ensure that the possibility of any future ignition is remote. However problems caused by swelling of the mudstone (shale) fragments causing ground heave must be addressed in foundation design if development takes place. High sulphate levels may require sulphate-resisting mixes to be used in buried concrete.

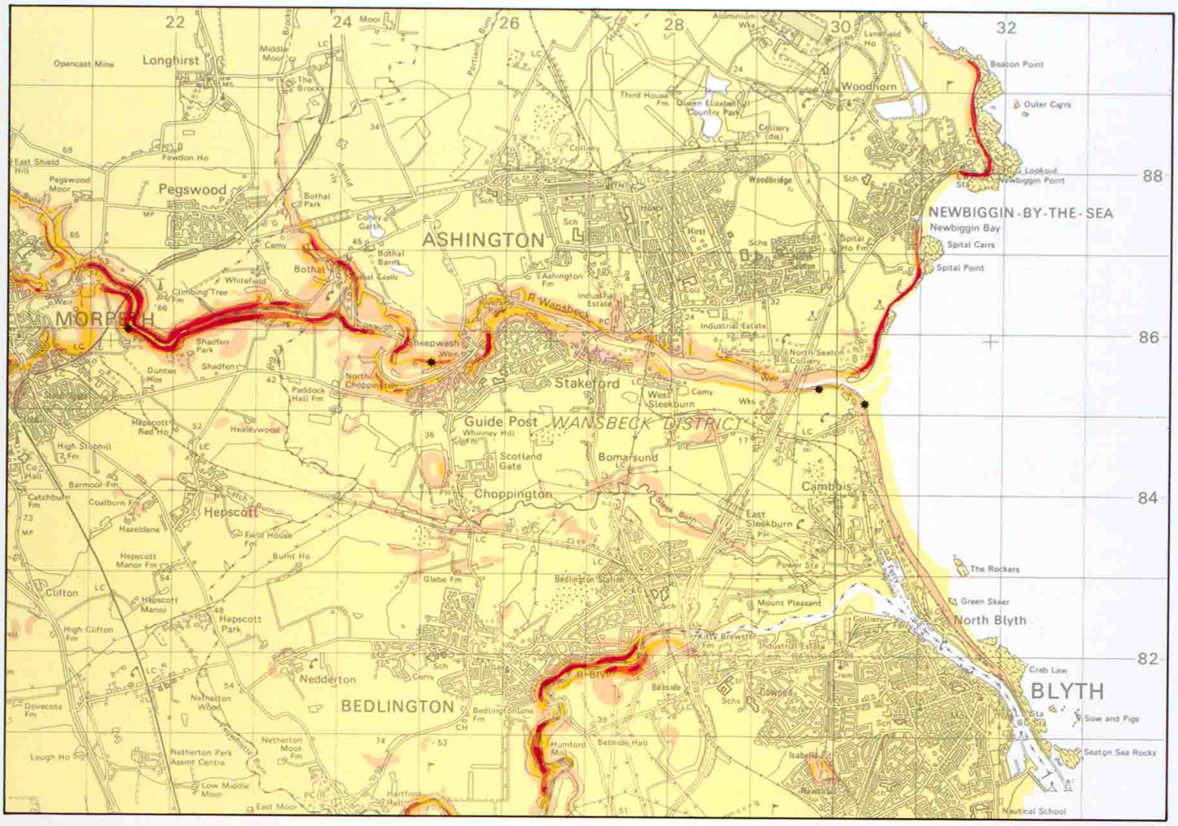
Landscaped and Disturbed Ground

This category includes the extensive veneer of man-made ground within urban areas, landscaped recreation and industrial areas, major road and rail lines, coal stockpiles and the restored areas on the perimeter of opencast excavations. In general the cover of landscaped or disturbed ground in the built-up areas is patchy and usually less than 2 m thick. It is virtually impossible to accurately determine the distribution of such deposits without a highly detailed investigation. Fill placed for road or rail lines or as part of associated engineering projects will usually be of known geotechnical properties, deposited in a controlled manner and compacted to a specified density.

3.3 SLOPE STEEPNESS AND STABILITY

Figure 11 illustrates the slopes of the district classified by the degree of steepness. The figure was produced digitally by computer using 1:25 000 scale Ordnance Survey contour information. Because the contours do not show detailed variations in slope angle or direction, a small scale generalized portrayal of slope steepness was judged appropriate. From Figure 11 it can be appreciated that the terrain is relatively subdued and that steep slopes occur only along the incised river valleys and on the coast. Slope steepness should not be viewed in isolation as a guide to slope stability , but considered in conjunction with rock/soil composition and attitude and hydrogeology.

Landslips and rockfalls occur naturally in areas where the land surface has been oversteepened or undercut by rivers or the sea. In this district examples were noted on the sides of the Wansbeck Valley at Parkhouse [215 860], Sheepwash [251 856] and North Seaton [297 854] and on the coast between Cambois [306 840] and Newbiggin [310 870] (see **MAP 8** and Figures 9 and 11) where active marine erosion is taking place and rock falls and slips occur in the sandstone and low boulder clay cliffs. Coastal defence measures, including the emplacement of rock cubes and concrete sea walls, have been adopted at both Cambois and North Blyth. Landslips may also occur where the ground has been artificially oversteepened, in cuttings, or by removing material from the foot of a slope or by loading slopes during embankment construction.



KEY

SLOPE CATEGORY DEGREES	GRADIENT RATIO	PERCENTAGE
> 15°	> 1:4	> 27%
11°–15°	1:5–1:4	20%–27%
7°–11°	1:8–1:5	13%–20%
3°–7°	1:20–1:8	6%–13%
< 3°	< 1:20	< 6%

Figures are approximate

* Landslip

Scale

0 1 2 3 km

Figure 11 Slope steepness

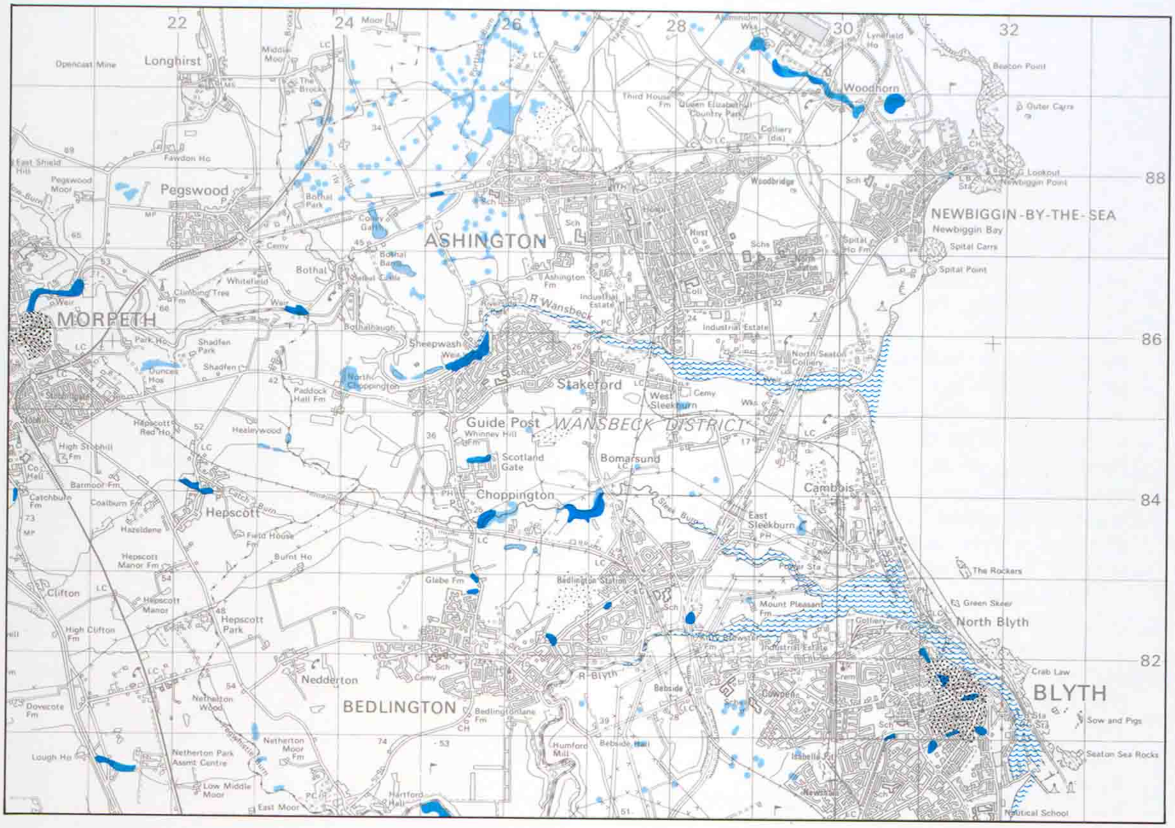
3.4 FLOODING

Figure 12, Flooding, was compiled from data provided by the Northumbrian Water Authority but, additionally, indicates the location of areas of waterlogged or flooded ground noted during the BGS field survey and thought to be due in the main to recent mining subsidence.

The Northumbrian Water Authority have subdivided their information on flooding into four categories.

1. Areas which have been flooded.
2. Areas which could potentially flood.
3. Areas subject to tidal flooding.
4. Areas now protected by floodbanks which were once potentially liable to flood.

Areas in the first category include the floodplain of the Wansbeck at Morpeth, Bothal and Sheepwash, small tracts along Woodhorn, Hepscott and Sleek burns and isolated areas of low-lying ground at Bedlington and Blyth. Included in the second category are parts of the Woodhorn Burn and Blyth Valley. The areas identified as subject to tidal flooding are the Wansbeck and Blyth river courses up to the Normal Tide Limit and a small part of Newbiggin town. The construction of an amenity weir at North Seaton has reduced the prospect of tidal flooding in the lower Wansbeck Valley and, similarly, flood protection measures at Morpeth and Blyth have removed the threat of flooding in those areas.



KEY

NORTHUMBRIAN WATER AUTHORITY DATA

Areas which have been flooded

Areas subject to tidal flooding

Areas which could potentially flood

Areas now protected by flood banks which were potentially liable to flood

BGS FIELD OBSERVATIONS

Wet or ponded depressions

Small area of wet ground

Scale

0 1 2 3 km

Figure 12. Flooding

3.5 THE EFFECTS OF COAL MINING ON HYDROGEOLOGY

Coal mining has caused two significant modifications to the local hydrogeology. The first change is in the development of vertical connections between water-bearing units by fracturing due to subsidence and by shafts sunk for the purpose of mining. Lateral movement of groundwater has also been greatly facilitated by the connection between workings instigated by a policy of passing mine drainage water from one mine to another towards the coast where it was finally pumped to the sea. As a result, any contaminant entering an old working, whether an open pit or underground, may disperse widely and rapidly. Leachate from landfill waste disposal sites is one example of a source of such contaminants. While this appears to pose a potential problem, the volume of groundwater in storage within the old mine workings is very large, and the consequent dilution of the contaminant is considered by Northumbrian Water Authority to be reduced to undetectable levels. However, Aldous *et al.* (1986) concluded that problems may occur if drainage is free and transmission rapid and moreover, that it is relatively difficult to predict the probable effects of waste disposal on particular groundwater discharges. Certainly if water abstraction boreholes were to be constructed near the source of such contamination dilution would be insufficient.

The second effect of coal mining on the local hydrogeology is in the lowering of groundwater levels. Dewatering operations in the coal mines caused a general depression of groundwater head often amounting to many metres. Some of the dewatering took place through adits between adjacent mines. The result was to establish base drainage levels at a lower altitude than the natural level. With the cessation of large-scale mining activity and therefore pumping, groundwater levels have risen (and may still be rising) although over most of the district it is unlikely that they will attain the levels of pre-mining days. There are, at present therefore, considerable voids (comprising old workings as well as joints, fissures and pores within the rock) present beneath the ground surface and above the present water table which may act as reservoirs for gases (see 3.6). If, in places, groundwater levels recover sufficiently there are possible implications both for the release of these gases and the geotechnical properties of currently unsaturated rocks and deposits.

3.6 NATURAL DISCHARGE OF METHANE AND DEOXYGENATED AIR

A potential hazard which should be considered in this district is the possibility of a build-up of naturally occurring methane and/or oxygen-deficient air, in excavations, basements, tunnels and other underground space. The up-to-date information contained in **MAPS 1, 4 and 5** may be used to evaluate geological structure, thickness of cover and presence of old workings and shafts should the problem arise.

Strata containing hydrocarbons such as coal tend to give off methane as well as other gases. Normal oxidation processes also tend to generate carbon dioxide and, during climatic periods when atmospheric pressure is high, air may be drawn down into pore spaces or voids such as old workings and become de-oxygenated. In places these gases may become trapped beneath impermeable cover (such as till) and may escape where this is thin, or breached (e.g. by shafts, fissures/faults, foundations, cellars), especially during periods of low atmospheric pressure.

Where there is no continuous, impermeable cover the discharge of gases still takes place. However, unless concentrated by some means, the discharge is over a wide area, dilution with the air is rapid, and no particular risk is present. Nonetheless, the construction of boreholes, sewers and water pipelines can form paths through which gases can readily pass and in which they may collect. Even house cellars, shallow wells and similar excavations can pose some risk. Adequate precautions to ventilate such works and to disperse the gases are essential. Local problems in the Cramlington area and the disastrous explosion at Abbeystead in Lancashire in 1983 (HMFI, 1985) where methane was ignited in a subsurface chamber with consequent fatalities, emphasises these dangers.

4. MINERAL AND WATER RESOURCES (MAP 9)

4.0 INTRODUCTION

Nine different mineral products have been extracted from the district. They are described briefly below and the sites of extraction and, where appropriate, the location of the deposits are delineated on **MAP 9** (Figure 13). Coal was, and is, by far the most important mineral in the region but within this particular district brick clay and sandstone were also significant. A brief discussion of groundwater resources is included in this section, but pollution and the effects of mining are considered elsewhere (3.5).

4.1 COAL

Deep-mined coal is no longer worked in the district by British Coal, the last pit, Ashington, closed in 1988 but a small shallow private drift mine is still operated at Shadfen Park [222 857]. Substantial quantities of coal remain at depth but these resources are currently regarded by British Coal as uneconomic and further deep mining appears unlikely. Opencast mining, introduced in the 1940's, is still active both on a small and large scale and, at the time of writing, further large exploration programmes are underway.

Leaving aside any planning and/or environmental contraints, there are considerable coal resources in much of the area with potential for opencast extraction. The general location of these resources can be deduced from study of the maps in this report, the 1:10,000 geological maps and the Part II Report.

However, the potential for opencast extraction is dependent, not only on the location of coal seams, but also on the number, thickness and quality of individual seams in any given area, the thickness of overburden and the extent to which the coal seams have already been removed by erosion or by underground mining, or disturbed by faulting.

A full description of coal seam distribution, thickness and mining is given in the Part II Report.

4.2 SANDSTONE

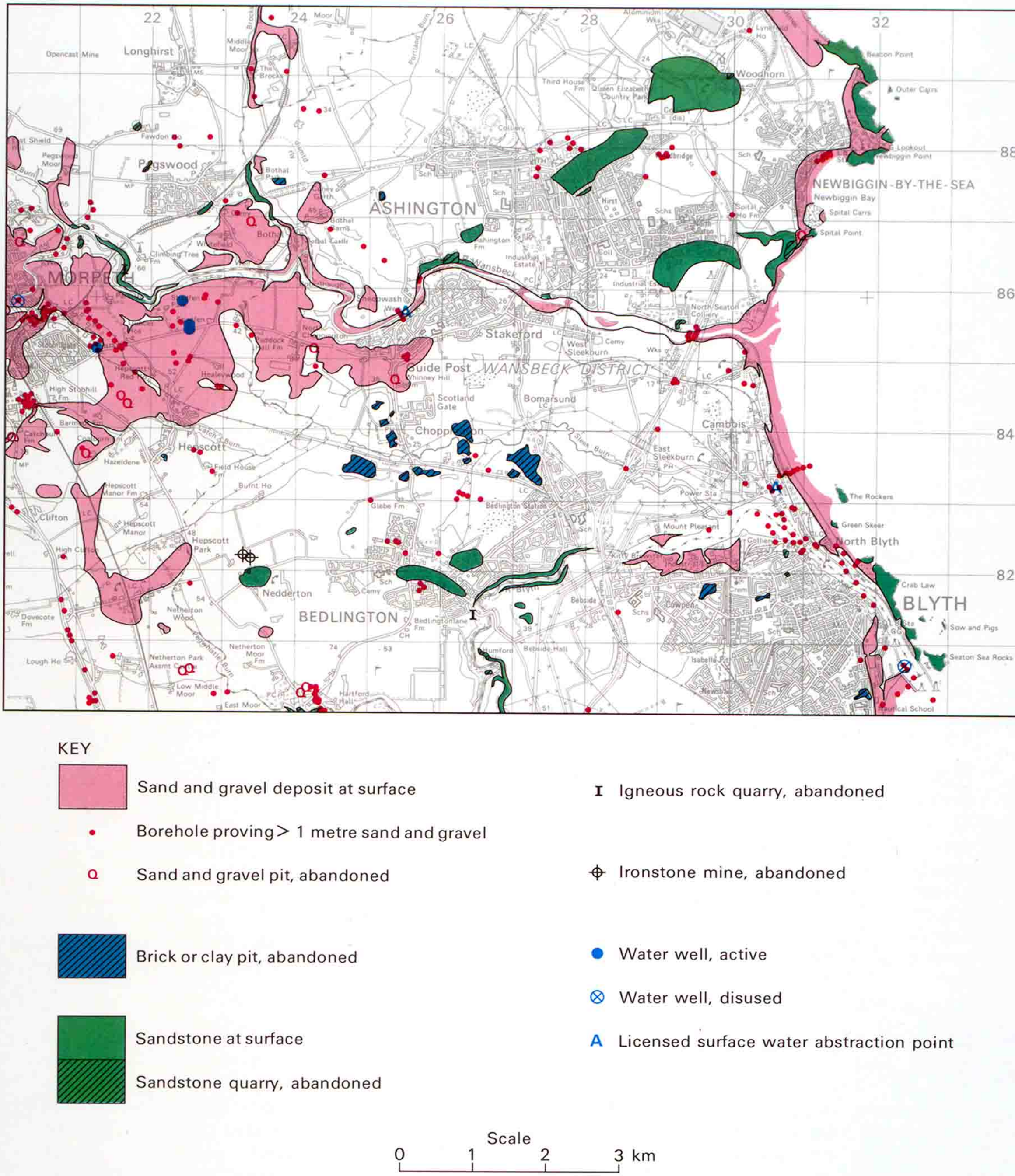
Sandstone was formerly quarried on a small scale at many localities throughout the district (see **MAP 9**, Figure 13 and Table 8). It was chiefly used as a local building stone, but one quarry at Hartford [241 800] is reported to have supplied stone for the repair of the Houses of Parliament and two London Bridges. A thick sandstone above the Kirkby's Marine Band - the North Seaton or Woodhorn Sandstone - has been particularly widely worked, for grindstones (shipped mostly to Norway and Sweden), and for facings for buildings. Considerable resources of sandstone remain of varying hue and grain-size, both in the thicker persistent units like the Woodhorn Sandstone, and in the relatively thin discontinuous beds.

4.3 MUDSTONE AND SILTSTONE

These rock-types (often described as shale) are common throughout the Coal Measures sequence and resources are substantial. Shale has been quarried for use in brick-making elsewhere in Northumberland, but no such quarries have been identified within the district. The shale (or 'brat') roof of the Northumberland Low Main was formerly mined and extensively employed in brick-making both at Ashington and Pegswood collieries, the latter was producing 40 000 bricks per week in 1935 (Fowler, 1936).

4.4 IRONSTONE

Sideritic ironstone is commonly developed as nodules or layers above a number of coal seams. Although they have been worked in the past these deposits contain too little iron and are too thin or discontinuous to be considered economically viable today. At least two former ironstone mines are recorded from the Netherton area of the district [233 823] where beds above the Northumberland Low Main Coal were worked. These mines supplied ore to the Bedlington Iron and Engine Works which was situated near Furnace Bridge beside the River Blyth [278 821]. This works, now demolished, played a seminal role in the national and international development of early railroads and locomotives and is closely associated with the names of Stephenson and Longridge. Curiously, although its original situation is said to be



This figure is a simplified portrayal of 1:25 000 scale map 9 which should be consulted for detailed information

Figure 13. Mineral and water resources and extraction (excluding coal)

based on the presence of wood, water, coal and iron nearby, the part of the coal measures sequence exposed near the works is not noted for significant quantities of ironstone.

4.5 SEATEARTH

The fireclays below the High Main and Five-Quarter coals were formerly taken at Ashington Colliery for brick-making. The Seggar clay below the Northumberland Low Main Coal is also reported to have been mined locally in the Netherton area [230 827].

4.6 IGNEOUS ROCK

Several dykes are recorded in mine workings in the district but they are generally narrow (usually less than 5 m) and with one exception, the West Sleekburn Dyke, discontinous both vertically and laterally. Small quarries south of Bedlington [264 815] and on the east bank of the river Wansbeck [2127 8612] probably worked a valley side exposure of tholeiitic dolerite from the Netherton-South Blyth Dyke.

4.7 METALLIFEROUS MINERALS

Mineral veins of pyrite, galena, sphalerite, calcite, ankerite and baryte occur throughout the district but as they rarely exceed 2 mm in width they are of only academic interest. However, there is an exception, at Choppington 'B' or High Pit where, "lead ore in considerable quantity was found in a fault (and was) worked for some time in 1948" (Martin).

4.8 SAND AND GRAVEL

Sand and gravel occurs within blown sand, glacial and river terrace deposits and alluvium. The thickest and most extensive development of sand and gravel is within the glacial deposits flanking the river Wansbeck in the west of the area, where it has been worked in several small pits. Boreholes have also shown sand and gravel to be present beneath varying thicknesses of till overburden elsewhere in the district, but there is little or no available information on its grade or quality. Blown sand was worked locally in a small pit at Spital Point, Newbiggin [309 868].

4.9 GLACIAL CLAYS

Small disused pits and brickfields which formerly worked till or laminated clay have been identified at many localities across the district (see **MAP 9** and Table 9) and it is probable that several other smaller workings have not been located. Clay pits are most prevalent on the flanks of the Sleek Burn between Scotland Gate [250 840] and Red Row [273 838] and records indicate brick and tile making taking place as early as the 18th century. The pits in this area appear to have worked lenses ("seams") of relatively stone-free (and probably laminated) clay within the more complex glacial sequence of the buried valley (see 2.2). Although many of these pits closed because their particular seam of clay was exhausted, it is likely that considerable resources still exist elsewhere in the buried valley.

4.10 GROUNDWATER

Under natural conditions, the Coal Measures in this district form a multi-layered aquifer. Groundwater is stored in, and flows through, fissures in the sandstone beds and in the coals. Groundwater movement within the enclosing mudstones and shales is slow, amounting only to seepage. The larger sandstone units can potentially support useful well yields, but faulting tends to divide these units into discrete areal blocks to which natural replenishment may be slow. Consequently, yields which initially may be good tend to diminish with time as the aquifer storage is depleted. Natural discharge is to the valleys of the river Blyth and the Wansbeck where the boulder clay cover is absent.

Recorded yields of boreholes constructed into the Coal Measures vary widely, usually ranging from less than 70 cubic metres per day (m^3/d) to more than 2000 m^3/d. A few boreholes have yielded only negligible amounts. The large yields are from boreholes of more than 100 m depth, but drawdowns tend to increase with depth so that the specific capacity (yield divided by drawdown) actually decreases with depth. The number of abstraction boreholes in the district is too small to permit a useful analysis of performance (see **MAP 9**), but it would appear that a borehole of 100 m depth would have a specific capacity of the order of 35% less than one of 50 metres.

The quality of groundwater in undisturbed Coal Measures strata is rather variable, with the total dissolved solids generally less than 1000 milligrammes per litre (mg/l) in the west of the district, and rising towards 20 000 mg/l near the coast. The chloride ion concentration follows a similar pattern with less than 50 mg/l (as Cl) in the west and more than 5 000 mg/l in the east. The sulphate ion concentration follows a rather different pattern, rising from less than 250 mg/l (as SO_4) in the western outcrop to more than 500 mg/l centrally, and then tending to fall towards the coast. Total hardness (as $CaCO_3$) also appears to increase eastwards to values above 1000 mg/l in parallel with the increase in sulphate concentration.

Groundwater pumped from coal mines is generally more mineralised. At the Bates Colliery No. 3 shaft [310 823], the mean of the total hardness between 1978 and 1984 of the pumped water was over 6000 mg/l of which only some 300 mg/l was carbonate hardness (information provided by the Northumbrian Water Authority) . Although sulphate was not monitored over this period, it probably accounts for the high non-carbonate hardness.

Discontinuous lenses of sand and gravel within the boulder clay, and rather more extensive granular deposits on its surface, form small and unimportant aquifers which may, in the past, have been exploited by a few small wells as formerly on the northern margin of the district at Broomhill Farm [215 902]. No data on quality is available.

For details of the relationship between mineworkings, pollution and groundwater the section of the report on the effects of coal mining on hydrogeology should be consulted (3.5).

Table 8 Former sandstone quarries

Locality	Grid Reference	Lithology[1]	Sandstone name or position
Ashington	2615 8646	"Brown, micaceous".	Woodhorn/North Seaton Sandstone
Bebside Wood	2662 8082	"Massive, yellow".	Below Moorland Coal
Bedlington	2638 8096	Fine with medium-grained yellow-brown.	Below Moorland Coal
Blyth	3075 8230	-	Below Moorland Coal
Blyth	3076 8200	-	Below Moorland Coal
Fawdon House	2176 8827	"grey and brown, micaceous, bedded and shaley".	Above Bensham Coal
Hartford	2408 8001	-	Above Durham Low Main Coal
Humford Mill	2666 8058	Fine-medium-grained, yellow-brown.	Below Moorland Coal
Humford Mill	2678 8049	-	Below Moorland Coal
Morpeth	2100 8666	-	Above Three-quarter Coal
Morpeth	2112 8658	-	Above Three-quarter Coal
Netherton	2332 8196	"Massive bedded, coarse-grained"	Above Bensham Coal
Newbiggin	3143 8943	"Red and grey bedded"	Woodhorn Sandstone
Newbiggin	3165 8937	"Red and greyish white, micaceous in partings". "Medium grain to fine grain".	Woodhorn Sandstone
North Seaton	3073 8680	"fine brown"	North Seaton Sandstone
North Seaton	308 866	"Medium grained, sparingly micaceous".	North Seaton Sandstone
North Seaton	2926 8555	"Massive".	North Seaton Sandstone
Pegswood	2181 8786	"Grey and greenish grey".	Above Bensham Coal
Pegswood	2193 8768	"Micaceous sandstone".	Above Bensham Coal
Woodhorn	2974 8918	"Brownish yellow, reddish, very micaceous in partings".	Woodhorn Sandstone
Woodhorn	2995 8906	"Brown, reddish in places, sparingly micaecous fine-grained".	Woodhorn Sandstone
Stakeford	2604 8630	Massive, medium-grained, yellow-brown.	Above Burradon Coal

Note: 1. Descriptions in quotes = former exposures

2. Several small sandstone quarries are also recorded south of Front Street, Bedlington.

Table 9 Former clay pits worked for brick and tile making

Site	Grid Reference	Site	Grid Reference
Barrington	263 840	Choppington	253 849
Barrington	2630 8375	Choppington	249 835
Barrington	2636 8358	Choppington	254 834
Bedlington	272 835	Choppington	2575 8340
Bedlington	2700 8340	Coney Garth	2515 8730
Blyth	3044 8170	Cowpen	897 818
Blyth	318 806	Hepscott	2223 8370
Blyth	3188 8050	Hepscott	2217 8358
Blyth	3184 8032	Hepscott Burn	235 837
Bothal Park	237 875	Howard House	2394 8270
Choppington	2510 8435	Morpeth	2076 8644
Choppington	2530 8424	Newbiggin	3107 8914
Choppington	252 841	Stobhillgate	2019 8502

5. SUMMARY OF GEOLOGICAL FACTORS FOR CONSIDERATION IN LAND-USE PLANNING (MAP 10)

MAP 10 is a graphic summary - it brings together specific elements from individual thematic maps which are considered to have a significant bearing on planning and development. Such a compilation allows the identification of areas where difficulties may arise and, conversely, where problems are less likely. However, it is important to realise that only selected aspects have been abstracted and that difficult geotechnical conditions may exist elsewhere. **MAP 10** should be used therefore as a guide to the relevant single theme maps which should be consulted for context and detail. *The need for properly designed and executed site-specific investigations cannot be overstated.*

In the following section each of the elements which may constrain development and which appear on **MAP 10** (and Figure 14) are briefly summarised.

5.1 SHALLOW MINING

Almost all of the district has been undermined for coal but, whereas subsidence related to longwall deep mining is probably complete, shallow workings, present in many areas, are a potential cause of land instability. Areas where shallow mining is known from plans or for which there is other evidence are delineated on **MAP 10**, which also shows the location of 240 shafts and adits known to exist. Where mining is suspected a careful study of the detailed mine plans and shaft atlases held by British Coal should always be made.

5.2 SOFT GROUND

Soft ground is associated mainly with recent alluvial and marine sediments of the river valleys, estuaries and coast. The variable sands, silts, clays and peats of which these deposits consist possess relatively weak geotechnical properties. Additionally beds of laminated silt and clay occur within the glacial sequence in the Choppington - Stakeford - Cambois area and may provide lower bearing capacities than overlying deposits.

5.3 FILL AND ARTIFICIAL DEPOSITS (MADE GROUND)

These deposits are extensive and have a variable composition, rate of consolidation and thickness. Many restored opencast coal sites exist but they are well documented; smaller disused and infilled clay pits and sandstone quarries (which may have been used as 'unofficial tips') may produce foundation problems if not identified prior to construction. The possibility of hazardous or methane-generating components within fill should always be considered.

5.4 LANDSLIPS

A small number of landslips have been noted. They occur chiefly where thick drift sediments are undercut or oversteepened by the River Wansbeck, but have also been identified on the coast.

5.5 SAND AND GRAVEL RESOURCES

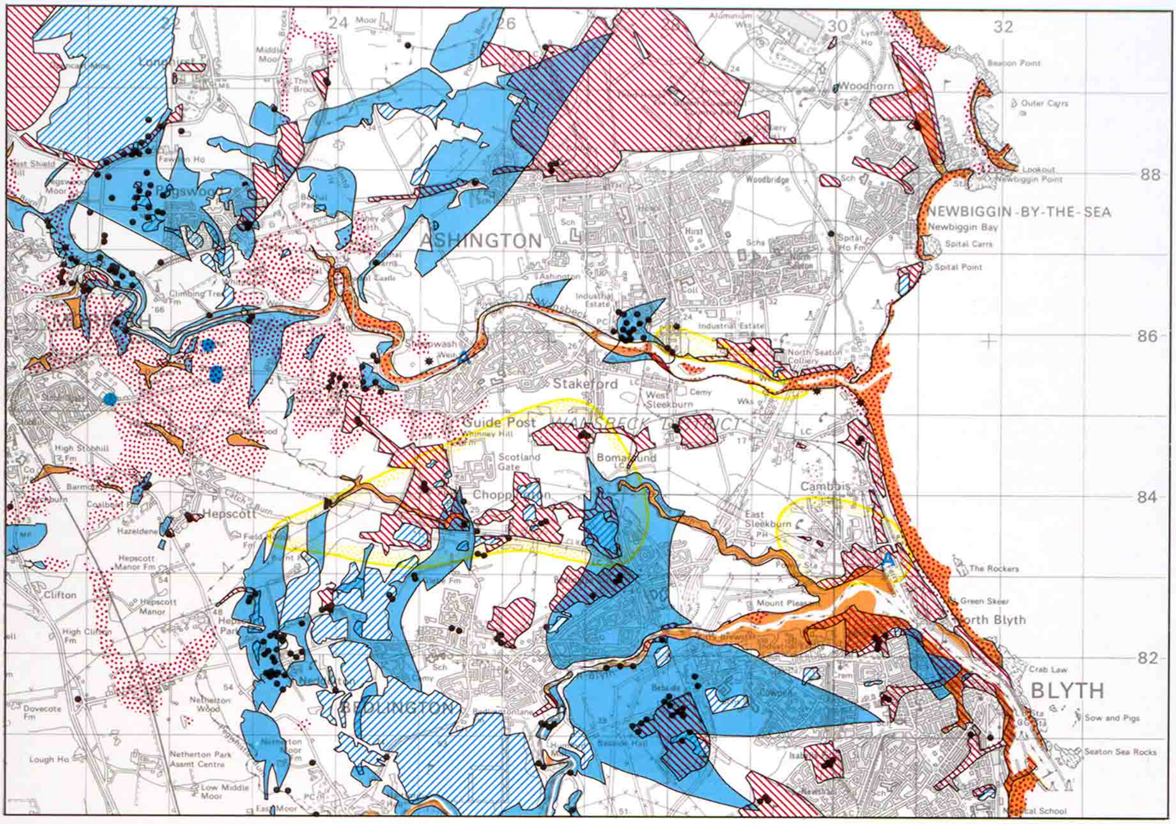
Sand and gravel commonly occurs within variable thicknesses of fluvial and marine sediments but it is the glacial deposits, which are widespread in the west of the district, which may have potential as a source of aggregate. It is recommended that in order to avoid sterilization an assessment of the true extent and quality of any resource should be made prior to extensive development.

5.6 WATER RESOURCES

The four active wells and two licensed surface water abstraction points are located on **MAP 10**. Large sandstone units in the Coal Measures are the principal natural aquifers but coal mining has caused significant modification to the hydrogeological regime and its affects should always be considered when evaluating potential leachate movement from landfill sites.

5.7 NOTE

Leaving aside any planning and/or environmental constraints, there are considerable coal resources in much of the area with potential for opencast extraction. The general location of these resources can be deduced from study of the maps in this report, the 1:10,000 geological maps and the Part II Report.



KEY

LAND STABILITY

- Soft ground; at the surface
- Soft ground; concealed
- Quarry, pit or opencast infill
- Artificial deposits on natural landsurface
- Mine workings likely to be present within 30 metres of ground surface
- • Pit or mine shaft, abandoned
- Adit or mine mouth, showing direction of entry (majority abandoned; see map 5 for status)
- ✱ Landslip

MINERAL AND WATER RESOURCES

- Sand and gravel deposit at surface (excluding built up areas)
- ● Water well active
- A Licensed surface water abstraction point

Scale

0 1 2 3 km

This figure is a simplified portrayal of 1:25 000 scale map 10 which should be consulted for detailed information

Note: Land outside the above areas is not known to be subject to significant physical constraints but still requires proper site investigation before development

Figure 14. Geological factors for consideration in land-use planning

SELECTED BIBLIOGRAPHY

ALDOUS, P.J., SMART, P.L. and BLACK, J.A. 1986. Groundwater management problems in abandoned coal-mined aquifers: a case study of the Forest of Dean, England. *Quarterly Journal of Engineering Geology*, Vol. 19, 375 - 388.

ANON, 1982. The treatment of disused mine shafts and adits. *National Coal Board Mining Department.*

BELL, F.G., CRIPPS, J.C., CULSHAW, M.G., LOVELL, M.A. 1988. A review of ground movements due to civil and mining engineering operations. *In* Engineering Geology of Underground Movements. 23rd Annual Conference of the Engineering Group of the Geological Society. (Eds. BELL, F.G., CULSHAW, M.G. and CRIPPS, J.C., LOVELL, M.A.) (London: *Geological Society Engineering Geology Special Publication.* No. 5.

BORINGS AND SINKINGS, 1878-1910. Council of the North of England Institute of Mining and Mechanical Engineers. *An account of the strata of Northumberland and Durham as proved by borings and sinkings.* 7 volumes in 4 books. Newcastle upon Tyne.

BUILDING RESEARCH ESTABLISHMENT, 1983. Concrete in sulphate - bearing soils and groundwater. *Digest 250 H.M.S.O.*, London.

CARTER, P.G. 1984. Case Histories which break the rules. *In:* Mineworkings 84. *Proceedings of the International Conference on Construction in areas of abandoned mineworkings.* (Eds. FORDE, M.C., TOPPING, B.H.V. and WHITTINGTON, H.W.). Engineering Technics Press, 20-29.

EYLES, N. and SLADEN, J.A. 1981. Stratigraphy and geotechnical properties of weathered lodgement till in Northumberland, England. *Quarterly Journal of Engineering Geology, Vol. 14*, 129-141.

FOWLER, A. 1936. The geology of the country around Rothbury, Amble and Ashington. *Memoirs of the Geological Survey of Great Britain* Sheets 9 and 10.

GALLOWAY, R.L. 1882. *A history of coal mining in Great Britain*, London.

__________ 1898. *Annals of Coal Mining and the Coal Trade.* London. (First Series).

__________ 1904. *Annals of Coal Mining and the Coal Trade.* London. (Second Series).

GARRARD, G.F.G. and TAYLOR, R.K. 1988. Collapse mechanisms of shallow coal-mine workings from field measurements. *In:* Engineering Geology of Underground Movements. 23rd Annual Conference of the Engineering Group of the Geological Society. (Eds. BELL, F.G., CULSHAW, M.G., CRIPPS, J.C., LOVELL, M.A.) (London: *Geological Society Engineering Group Special Publication* No 5, 181-192.

HER MAJESTY'S FACTORY INSPECTORATE, 1985. The Abbeystead Explosion: A report on the investigation by the Health and Safety Executive into the explosion on 23 May 1984 at the valve house of the Lune/Wyre Transfer Scheme at Abbeystead. *HMSO.*

HOBBS, N.B. 1986. Mire morphology and the properties and behaviour of some British and foreign peats. *Quarterly Journal of Engineering Geology*, Vol. 19, 7-80.

JACKSON, I., LAWRENCE, D.J.D. and FROST, D.V. 1985. Geological notes and local details for Sheet NZ27. Cramlington, Killingworth and Wide Open (SE Northumberland). *Open File Report, British Geological Survey.*

LAND, D.H. 1974. Geology of the Tynemouth District. *Memoirs of the Geological Survey of Great Britain* Sheet 15.

LAWRENCE, D.J.D. and JACKSON, I. 1986. Geology of the Ponteland-Morpeth district. *Research Report of the British Geological Survey.*

__________ 1990. Geology and land-use planning: Morpeth - Bedlington - Ashington. Part II: Geology *British Geological Survey Technical Report* WA/90/19.

MARTIN, E.S.B. 1974. Bedlington Iron and Engine Works (1736-1867). A New History. *Northern History Booklets.* No 52.

MARTIN, S.B. dates unknown. Bedlingtonshire Village History Series, "Bedlington", West Sleekburn", "Bomarsund and Stakeford", "Choppington Township", "Sleekburn", "Netherton".

ORCHARD, R.J. 1964. Partial extraction and subsidence. *Transactions of the Institute of Mining Engineering*, Vol. 123, 417-427.

PIGGOTT, R.J. and EYNON, P. 1978. Ground movements arising from the presence of shallow abandoned mine workings. *In:* Large ground movements and structures. *Proceedings of the Conference held at the University of Wales Institute of Science and Technology* (Ed. GEDDES, J.D.), Cardiff 1977. Pentech Press, London, 749-780.

TAYLOR, B.J., BURGESS, I.C., LAND, D.H., MILLS, D.A.C., SMITH, D.B. and WARREN, P.T. 1971. Northern England. *British Regional Geology* (4th Edition) HMSO.

TAYLOR, R.K. 1968. Site investigations in coalfields: the problem of shallow mine workings. *Quarterly Journal of Engineering Geology*, Vol 1, 115-133.

________ 1978. Properties of Mining Waste with respect to foundations. In: *Foundation Engineering in Difficult Ground* (Ed. BELL, F.G.) (Newnes-Bullerworths London) 175-203.

________ 1988. Coal Measures mudrocks: composition, classification and weathering processes. *Quarterly Journal of Engineering Geology, Vol 21, 85 - 89.*

GLOSSARY

ADIT Horizontal passage from the surface into a mine.

AQUIFER Body of rock or sediment sufficiently permeable to conduct groundwater and yield significant quantities of water to wells and springs.

BED Basic unit of rock or sediment.

CANNEL Usually impure coal with glassy fracture.

CARBONACEOUS Rock or sediment rich in carbon.

COMPETENT Able to withstand force.

CYCLOTHEM Series of beds deposited in a cycle.

DETAIC Laid down in a delta.

DRAWDOWN Lowering of water level in a well due to water withdrawal.

DRIFT Unconsolidated sediments deposited during the Quaternary.

GEOLOGICAL STANDARD 1:10 000 scale map of field geologist's interpretation of all available data for a particular area intended for public examination.

HYDROGEOLOGY Groundwater geology.

HYDROSTATIC PRESSURE Pressure exerted by water at any given point in a body of water at rest.

INCISED Describes river or stream which has cut down into the land surface.

INTERFLUVIAL Describes higher ground between streams or rivers.

LEACHATE Solution produced by water passing through a substance.

LITHOLOGY Physical character of a rock.

OVERBURDEN Material overlying a mineral deposit.

PYRITOUS Containing iron-sulphides.

RANK Degree of metamorphism in coal; is the basis of coal classification.

RESOURCE Total amount of potentially workable mineral.

ROCKHEAD Bedrock surface.

SIDERITIC Containing ferrous carbonate.

TILL Sediment deposited by a glacier; commonly a stiff stony clay.

APPENDIX A: DATA SOURCES

1. Field survey

Undertaken at the 1:10 000 scale by a geologist on foot. It involves the examination, recording and interpretation of surface morphology and natural and man-made exposures. It attempts to delimit solid and drift deposits and checks for the existence of old shafts, adits, underground workings and abandoned and active pits and quarries. The amount of detail identifiable is heavily dependent on the degree of exposure and the nature of the landforms. In a largely drift covered area like the current district there is often little evidence of the solid rocks. Mapping of the natural drift deposits is made difficult by the extensive built-up and man-made areas.

2. Deep-mined coal boreholes and shaft records

These provide a log of strata encountered down a borehole or shaft. They may start at ground level or from an underground position. The method of drilling the boreholes may be either open-hole or cored. The earliest borehole for which BGS holds a record was drilled in 1731 and boreholes were still being drilled up until the closure of the last colliery in 1988. Boreholes and shafts are lodged in the BGS archive as text but are conventionally converted to graphic form at a standard scale (1:480) for correlation. 233 shafts and 1 011 deep-mined coal exploration boreholes are held for this district. The records are of variable quality and the absence or inadequacy of certain details, for example surface level, location, strata record, is common. They are however the main source of information about lithological variation across the district.

3. Deep-mined coal abandonment plans

These are a record of underground working in individual coal seams and, ideally, will show the extent, date and depth of the working, coal thicknesses, faulting, presence of water and the location of shafts and drifts transecting the seam. Initially their scale varied but became established at 2 chains to the inch and subsequently 1:2 500. They may be large old linen documents or modern plastic plans covering a ground area of 2 km^2. Coal mines prior to 1850 are only patchily recorded and even after 1872, when the keeping of accurate plans became mandatory, plans frequently only showed the extent of the working and are often difficult to register with surface topography. After 1947 the plans are considered to be fully reliable and comprehensive (however these are often plans of the lower, deeper seams and therefore those which the planner/developer is least concerned). Almost all coal mine plans are held by the Mines Record Office of British Coal; a list of those plans within the survey area is given in the Geology report (Part II).

4. British Coal Opencast Executive prospecting boreholes

These date from the early 1940's to the present day and were drilled in selected prospecting areas, usually at a close spacing. They are largely openhole and many of the older boreholes are very poorly logged; however, a small number of diamond (cored) boreholes were put down to control the stratigraphy. Early sites were not usually deep (<20 m) and therefore the prospecting boreholes were also shallow and often difficult to correlate. With time progressively deeper seams were exploited and boreholes in excess of 50 m drilled. Prospecting by British Coal is now a much more structured exercise but the majority of holes are still not cored and are only logged geophysically. Private licensed operators have a varied approach to exploration and, because of their commercial sensitivity, the boreholes are rarely deposited with BGS. All the British Coal Opencast Executive borehole data are confidential.

5. Opencast coal completion plans

Following completion of coaling at a British Coal opencast site a plan is routinely produced at 1:2 500 scale showing limit of working, surveyed coal-base contours, faulting, typical sections and coal and overburden thickness at specified points. They also indicate the tonnage extracted from each seam and dates of working and restoration. These documents represent the results of a "measured survey" and are therefore a good datum if seam correlation is known, although inevitably some of the early plans are lacking in vital detail. Completion plans from private sites tend to be much less comprehensive.

6. **Site investigation boreholes, trial pits and reports**

In the past boreholes were only rarely put down to investigate ground conditions prior to construction; the exceptions were structures like bridge foundations or harbour works. Today almost every development, from minor residential to major civil, is preceded by some form of site survey, that is, trial pit, or boreholes or probe. BGS holds records of 1 454 boreholes and trial pits drilled for this purpose in the district and undoubtedly many more exist. They are usually only shallow explorations, with an average depth of less than 10 m; they therefore tend to be restricted to the drift sequence and use a method appropriate to those deposits, that is shell and auger rig or mechanical excavator. Initially poor recording of the sediments has improved greatly but there is an engineering rather than a geological bias. Samples are usually taken for subsequent laboratory testing and the results of this together with an interpretive section and the borehole results make up the conventional geotechnical report.

7. **Existing geological maps**

There have been two previous full surveys of the district, the first undertaken between 1860 and 1880 and a second between 1929 and 1950. These produced field slips and published six-inch geological maps on the Northumberland Old Meridian County Series and New Meridian County Series respectively. In addition a largely desk-based revision of the south-eastern part of the district took place between 1957-1961. The working maps (mostly mining slips) for this revision were based on New Meridian County Series but the results were published on National Grid six-inch sheets. The BGS archive also contains *ad hoc* desk interpretations of mining and borehole information. Although the older surveys were undertaken without the benefit of much of the borehole, opencast and mining data available to the current revision a significant factor in their favour was the lack of urban development and landscaping. They therefore had much more natural exposure and this is reflected in the amount of observed detail on their fieldslips. They did not, unfortunately, delimit areas of made ground.

8. **Aerial photographs**

BGS holds no coverage for this region but was able to borrow stereographically paired photographs taken in 1971 for Northumberland County Council and a second set flown in 1981 and held by the Department of the Environment. Although the 1971 series were at an appropriate scale (approximately 1:10 560) their usefulness was reduced by their age. The 1981 photographs were, unfortunately, at too small a scale (1:25 000) to allow accurate identification or delineation of salient features.

9. **Water authority data**

The Northumbrian Water Authority provided information on flooding and water abstraction and quality. Additionally discussions took place between the Authority and BGS on the subject of mine water and leachate dilution.

10. **Local authority data**

Northumberland County Council Waste Disposal section provided information on the location of known landfill sites and composition of deposited waste. The Land Reclamation Section of the County Council gave access to data on the extent of reclamation schemes and the procedure for restoring colliery waste. General and site specific discussions have taken place between the County Soils Engineer and BGS, and his department has also provided a large quantity of site investigation data. Information on mineral extraction within Northumberland was obtained from the Mineral Planning section. The highways departments of Blyth Valley and

Wansbeck district councils have provided copies of relevant site investigation reports. (See also aerial photographs.)

11. Geological reports and journals

The bibliography contains a selection of those documents consulted during the study, they range from memoirs describing the geology of the region to academic papers concerning specific subjects.

APPENDIX B: THE BOREHOLE DATABASE

BGS holds an extensive collection of paper records which describe the strata encountered during the sinking of boreholes, mineshafts and trial pits, and in sections measured by BGS geologists (see Appendix A). These records represent a major source of factual data, in some parts the only source, for geological investigations and interpretations within the coalfield. The paper borehole record is considered to be the authoritative primary record and there has been no attempt to replicate it on the computer. A computerised database for the project area was seen as a way of utilising the data held in the paper archive to maximum effect by allowing rapid and flexible retrieval of a wide range of information.

All borehole and shaft records in the project area have been coded following a format which has been developed within BGS. This work has resulted in the establishment of a simple system by which borehole information can be assigned to two tables of data, on the basis of the following criteria:

a) All data which describes a feature of the borehole itself, for example, its name, its location by National grid reference, the date it was drilled, height above (or below) sea level.

b) All information relating to samples taken from point depths below the surface for that borehole.

A complete list of fields in each of these tables within the borehole database is given below.

The data is currently held in an ORACLE relational database management system running on a VAX 6410 computer at BGS Edinburgh. It can be interrogated by menu or specifically by using a query language (SQL). It may be used as an index to available records or for detailed geological analysis. Retrieved data may be manipulated and displayed using a number of statistical and graphic application packages and it is possible to automatically produce graphic vertical sections, scatter plots, contour maps and three-dimensional diagrams. Several elements within the thematic maps were produced by retrievals from the database and most of the figures in the accompanying geological report (Part II) were directly generated by computer.

List of fields in the BGS Newcastle borehole database

a) Index table

O.S.1:10000 sheet number*	Reliability
Accession number and suffix*	Start point
National grid reference and accuracy	Inclination
Borehole name	Drilling date
Comments	Geologist
Other borehole number	Drilling method
Surface level and accuracy	Borehole diameter
Confidentiality	Consulting engineer
Purpose	Drilling contractor
Originator	Water strike

b) Lithological table

O.S.1:10,000 sheet number*	Stratigraphy
Accession number and suffix*	Reliability
Depth	Workings
Lithology	Comments
Base of bed	

* "the primary key index"

APPENDIX C: THE GEOTECHNICAL DATABASE

The classification of the geological formations into groups or units of similar engineering properties was carried out using geotechnical data extracted from site investigation reports on sites within the area of the project. Data was abstracted, coded onto a specially designed form and entered into an ORACLE relational database management system maintained on a VAX 6410 computer in BGS Edinburgh.

Geotechnical data were obtained for over 14 000 individual tests [a single Standard Penetration Test (SPT) counting as one test] from 913 boreholes. The location of each test was identified by both the Primary key index (see Appendix B) of the borehole from which it came and the depth of the tested sample in that borehole, thus enabling cross-referencing with all other stratigraphical, lithological and location data held in the computerised borehole database. The sites of non-confidential boreholes with geotechnical test samples are shown on **MAP 8.**

The results of the following geotechnical tests and measurements (laboratory and *in situ*) were abstracted and entered into the database:

1. Standard penetration test (SPT).
2. Bulk density.
3. Dry density.
4. Moisture content.
5. Liquid limit.
6. Plastic limit.
7. Plasticity Index.
8. Triaxial test (drained and undrained).
9. Consolidation.
10. Compaction.
11. Particle size analysis (PSA).
12. California bearing ratio (CBR).
13. pH.
14. Sulphate content.
15. Rock quality designation (RQD).

A brief description of the tests and their applications is given below. The following British Standards Institution publications should be consulted for further information:

ANON, 1975. *Methods of test for soils for civil engineering purposes,* BS 1377. British Standards Insititution, London.

ANON, 1981. *British Standard code of practice for site investigation,* BS 5930. British Standards Institution, London.

The *Standard penetration test (SPT)* is a dynamic test carried out at intervals during the drilling of a borehole, widely used to give an indication of the relative density of granular soils (very loose to very dense), and the consistency of cohesive soils (very soft to hard). Correlations have also been made between SPT and the bearing capacity of a soil.

Density of a soil, that is the mass per unit volume, may be measured in various ways. The total or *bulk density* is the mass of the entire soil element (solids + water) divided by the volume of the entire element. The *dry density* is the mass of dry solids divided by the volume of the entire soil element. Soil density measurements may be used to assess various earth loads such as soil mass, overburden pressure, surcharge pressure and earth pressure on retaining walls.

The *moisture content* of a soil sample is defined as the ratio of the weight of water in the sample to the weight of solids, normally expressed as a percentage. It is a basic soil property and influences soil behaviour with regard to compaction, plasticity, consolidation and shear strength characteristics. As moisture is removed from a fine-grained soil it passes through a series of states, that is liquid, plastic, semi-solid and solid. the moisture contents of a soil at the points where it passes from one state to the next are known as 'consistency limits'.

The *plastic limit (PL)* is the minimum moisture content at which the soil can be rolled into a thread 3 mm diameter without breaking up.

The *Liquid Limit (LL)* is the minimum moisture content at which the soil flows under its own weight. The range of moisture content over which the soil is plastic is known as the *plasticity index (PI)*, such that $PI = LL - PL$.

The factors controlling the behaviour of the soil with regard to consistency are: the nature of the clay minerals present, their relative proportions, and the amount and proportions of silt, fine clay and organic material. A soil may be classified in terms of its plastic behaviour by plotting plasticity index against liquid limit on a standard plasticity (or Casagrande) chart. The consistency charts also give an indication of soil strength and compressibility.

The triaxial compression test is the most widely used test for determining the shear strength of cohesive soils, and a number of different methods may be used depending on the application of the results. The test may be carried out with the sample either drained or undrained and the type of test will depend upon the site conditions and type of engineering works being undertaken.

Graphical interpretation of the results enables the shear strength of the soil to be determined in terms of its cohesive and frictional components: *undrained (apparent) cohesion, C,* and angle of *shearing resistance (internal friction), Ú.*

The *vane test* is used for soft materials that would be difficult to sample and prepare for other strength tests. The test enables the undrained shear strength of the soil to be calculated and the residual shear strength to be measured. The undisturbed and remoulded strengths of the soil will give a measure of its sensitivity.

If saturated cohesive soil is subjected to an increase in loading the pressure of the water in the pore spaces will increase by the same amount as the applied stress. The water will therefore tend to flow towards areas of lower pressure at a rate controlled by the soil permeability. The removal of water causes a decrease in volume of the soil, a process known as consolidation. The *coefficient of volume compressibility Mv* (m^2/MN), is a measure of the amount of volume decrease that will take place for a given increase in stress. The *coefficient of consolidation, Cv* (m^2/year) is a measure of the rate at which the volume change will take place for a given increase in stress. The results of consolidation tests give Mv Cv at a number of increasing loads. To enable this range of values to be used in the database the ranges are converted to classes using the tables which have been taken from: HEAD, K.H., 1982. *Manual of Soil laboratory testing*. Pentach Press London and LAMBE, T.W. and WHITMAN, R.V., 1979. *Soil Mechanics (S.I. Version).* Wiley, New York.

The assignment to a class is mainly based on the mid-range values obtained during progressive testing.

Coefficient of volume compressibility (Mv) Class

m^2/MN		
> 1.5	5	Very High
0.3 - 1.5	4	High
0.1 - 0.3	3	Medium
O.05 - 0.1	2	Low
< 0.01	1	Very Low
m^2/yr		
< 0.01	1	
0.1 - 1	2	
1 - 10	3	
10 - 100	4	
> 100	5	

Consolidation test results are important for foundation design and calculating the likely settlements that will take place during and after construction. The test results also enable the planning of phased construction stages to allow full consolidation settlement (dissipation of pore pressure) to take place prior to successive load stages.

The compaction test determines the *'optimum' moisture content* at which a soil may be compacted to its maximum dry density. The *dry density* of the compacted soil is plotted against its moisture content and the moisture content at which maximum compacted density may be achieved is read from the curve. The results of the compaction test are used to determine the optimum moisture conditions at which to place a given soil as general or embankment fill.

The *California Bearing Ratio* test is an empirical test carried out in the laboratory, or in the field, which compares the resistance of a soil to penetration by a standard plunger to the resistance to penetration shown by a standard crushed stone:

CBR = *Measured force*
'Standard Force'

The CBR value of recompacted soil is very sensitive to variations in moisture content and dry density. The results of the CBR test are used to assess the suitability of soils for use as base, sub-base and sub-grade in road construction.

Particle size distribution is used for classifying soil in engineering terms. Particle size distribution curves will give an indication of soil behaviour with regard to permeability, susceptibility to frost heave or liquefaction and will give some indication of strength properties. Particle size analysis does not, however, indicate structure. For example a sandy clay and a laminated sand and clay which may behave very differently *in situ*, may show similar particle size distribution in bulk test sample.

The *pH* of soil or groundwater is important when designing concrete structures below ground surface. Ordinary Portland cement is not recommended in situtions with a pH below 6, high alumina cement can be used down to pH 4 and supersulphated cement has been used to pH 3.5. Acidic groundwaters can also cause corrosion in buried iron pipes.

It is also important that the *sulphate content* of groundwater and soil is known as ordinary Portland cement deteriorates in the presence of sulphate. *Building Research Establishment Digest* No. 250 (1983) discusses the factors responsible for sulphate attack on concrete below ground level, and recommends what can be done, by suitable selection of cement type and concrete quality, to resist attack by naturally occurring sulphates.

Part of the appropriate table is reproduced below, the document should be consulted for further information.

Allocation to sulphate class in concentrations of sulphate expressed as SO_3

	Concentrations of sulphates expressed as SO_3		
	in soil	in groundwater	
Class	Total SO_3 (%)	SO_3 in 2.1 water: soil extract g/l	g/l
1	<0.2	<1.0	<0.3
2	0.2 to 0.5	1.0 to 1.9	0.3 to 1.2
3	0.5 to 1.0	1.9 to 3.1	1.2 to 2.5
4	1.0 to 2.0	3.1 to 5.6	2.5 to 5.0
5	>2	>5.6	>5.0

Rock quality designation (RQD) was introduced to give an indication of rock quality in relation to the degree of fracturing from drill cores. It is defined as a sum of the core sticks in excess of 100 mm in length expressed as a percentage of the total length of core drilled. RQD has been used with uniaxial compressive strength to give an indication of excavatibility, and as one input for the classification of rock masses to assist in the design of tunnel support systems.

For further information see: DEERE, D. K., 1964. Technical description of rock cores for engineering purposes. *Rock Mechanics and Engineering Geology*, 1, 1, 17-22.

BRITISH GEOLOGICAL SURVEY / DEPARTMENT OF THE ENVIRONMENT

THEMATIC GEOLOGICAL MAPPING

MORPETH – BEDLINGTON – ASHINGTON

NZ 28/38

MAP 7 BOREHOLE AND SHAFT SITES

Scale 1:25 000

KEY

- ○ Borehole terminated within drift
- ● Borehole proving solid rock
- ●U Underground borehole
- □ Trial pit terminated within drift
- ⌖ Pit or mine shaft, abandoned
- Adit or mine mouth, showing direction of entry
- Adit or mine mouth, abandoned, showing direction of entry
- [1] Approximate limit of area prospected by British Coal Opencast Executive. (Information from these areas has been used in the compilation of the geological map, but details of the boreholes are confidential).The number refers to the list of opencast sites.

ONLY NON-CONFIDENTIAL BOREHOLES ARE SHOWN

DETAILS OF BOREHOLES, EXCEPT THOSE WHICH ARE CONFIDENTIAL, MAY BE CONSULTED ON APPLICATION TO THE OFFICER-IN-CHARGE,BRITISH GEOLOGICAL SURVEY, WINDSOR COURT, WINDSOR TERRACE, NEWCASTLE-UPON-TYNE, NE2 4HB.

Whilst efforts have been made to trace the sites of shafts and adits it is not claimed that all have been located.
For information on the exact position of mine shafts and adits, application should be made to British Coal.
Where boreholes and shafts are very closely spaced, some may have been omitted for clarity.

LIST OF BRITISH COAL OPENCAST PROSPECTING AREAS

BGS 1:10 000 SHEET REFERENCE NUMBER		BRITISH COAL SITE NAME
NZ 28 NW/	1	East Shield Hill I
	2	Butterwell
	3	Fawdon House
	4	Pegswood Moor
	4A	Pegswood I
	4B	Pegswood II
	5	Abyssinia I
	5A	Abyssinia II
	5B	Abyssinia IIA
	5C	Abyssinia IIB
	5D	Abyssinia III
	6	Climbing Tree
	7	Sheepwash
	8	Jubilee
	9	Longhirst Lane
	10	Watch House
	11	Stonyflat
	12	North Choppington
	13	South Lodge
	14	Longhirst I
	14A	Longhirst II
	14B	Longhirst III
	14C	Longhirst IV
	14D	Longhirst V
	15	Morpeth I
	15A	Morpeth II
	15B	Morpeth III
	16	Bothal I
	16A	Bothal II
	17	Cabin Hill
	18	East Shield Hill II
	19	Bothal Burn includes Longhirst II, Abyssinia III, Bothal II
NZ 28 NE/	1	Third House includes Woodhorn II
	2	Lemoor
	3	Woodhorn I

BGS 1:10 000 SHEET REFERENCE NUMBER		BRITISH COAL SITE NAME
NZ 28 SW/	1	Netherton
	1A	Netherton II
	1B	Netherton III
	2A	Poland
	2B	Warsaw
	3	Ewart Hill Deep includes Bedlington, Hartford Road, Ewart Hill North, Ewart Hill South
	4	Red House
	5	Howard House includes Meadow Dale
	5A	Howard includes Howard Row, Howard House Ext.
	6	Francis
	7	The Lodge
	8	Diamond Hill
	9	Netherton IV
	10	Clifton Row
	11	Hazelton
	12	Clifton Lane
	13	Field House
NZ 28 SE/	1	Acorn Bank
	2	Hathery Lane
	3	Bebside
	4	Humford
	5	Stepping Stones
	6	Foggos
*NZ 18 SE/	2	Duddo Hill
	4	Catch Burn
	5	Glororum
*NZ 27 NW/	12	Church

* Sites registered on adjacent sheets

Scale

0 1 2 3

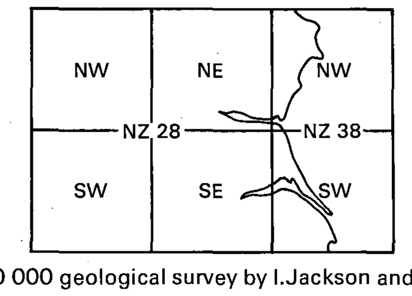
kilometres

LIMITATIONS

This map provides only general indications of ground conditions and must not be relied upon as a source of detailed information about specific areas, or as a substitute for site investigations or ground surveys. Users must satisfy themselves, by seeking appropriate professional advice and carrying out ground surveys and site investigations if necessary, that ground conditions are suitable for any particular land-use or development.

This map gives an interpretation of data available to May 1989.

This map should be read in conjunction with the report: *Geology and land-use planning: Morpeth-Bedlington-Ashington, Parts 1 and 2 by I.Jackson and D.J.D.Lawrence.*



Based on a 1:10 000 geological survey by I.Jackson and D.J.D.Lawrence, 1986-89.
D.H.Land, D.J.Fettes, (BGS) and H.Mallett, (DOE) Programme Managers.
F.G.Larminie, OBE, Director, British Geological Survey.

Drawn by K.A.Arbon, BGS, Keyworth