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Geological notes and local details for 1:10000 sheets NZ26NW, NE, SW and SE

Newcastle upon Tyne and Gateshead

Part of 1:50000 sheets 14 (Morpeth), 15 (Tynemouth), 20 (Newcastle upon Tyne) and 21 (Sunderland)

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PREFACE

This account describes the geology of 1:25 000 sheet NZ 26 which spans the adjoining corners of 1:50 000 geological sheets 14 (Morpeth), 15 (Tynemouth), 20 (Newcastle upon Tyne) and sheet 21 (Sunderland). The area was first surveyed at a scale of six inches to one mile by H H Howell and W Topley. The maps were published in the old 'county' series during the years 1867 to 1871. During the first quarter of this century parts of the area were revised but no maps were published. In the early nineteen twenties part of the southern area was revised by W Anderson and published in 1927 on the six-inch 'County' edition of Durham 6 NE. In the mid nineteen thirties G Burnett revised a small part of the north of the area and this revision was published in 1953 on Northumberland New 'County' six-inch maps 85 SW and 85 SE.

The resurvey on which this account is based started with NZ 26 SE in 1967; it recommenced with NZ 26 SW in 1975 and again in 1980. This account results from this resurvey by D A C Mills, G Richardson and D B Smith with a contribution by J G O Smart. It was edited by D B Smith.

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INTRODUCTION

The area described in this report lies within the administrative region of Tyne and Wear. The River Tyne flows eastwards across the middle of the area, separating Newcastle upon Tyne from the traditional county of Durham. Built on a coalfield with a navigable river, Newcastle upon Tyne has for many centuries been the industrial and commercial capital of North Eastern England. Although there is still a little agricultural activity at its northern and south-western fringes, this urban area is the most densely populated in the region.

The main streams and place names of the area are shown on Figure 1.

The landscape of NZ 26 was shaped before and during the last glaciation and has been modified only slightly since that time. About nine-tenths of the area is still mainly covered by glacial and later deposits (Figure 2) though many of these have been weathered and redistributed after deposition. Several of the areas where drift deposits are thin or absent are topographic highs and surrounding them are broad areas where the thickness of glacial deposits is less than 8 metres; these occupy about 40% of the area. The areas of thin drift deposits are separated by a system of valleys cut into the rockhead surface (Figure 3); the valley sides are relatively steep, and less than 10% of the area has glacial deposits between 8 and 15 metres thick. Almost half the area has drift deposits thicker than 15 metres. The River Tyne between Blaydon and Elswick flows at the northern margin of a major rockhead valley that is cut to below 45 metres BOD; the valley turns south at Elswick along the course now taken by the River Team, and its steep shoulders rise from beneath the alluvium of the Tyne and Team. The ridge of solid rock extending from Benwell to Elswick to Redheugh to Mount Pleasant to High Fell forms the northern and north-eastern side of this valley. North of the river, from the area of the Tyne bridges to Gosforth and east to Wallsend, the area has little surface relief. The Ouse Burn south of Gosforth is deeply incised in rock and follows the eastern margin of another buried valley running south to the River Tyne near Battle Field. The ridge of high ground that forms an arc from Benton to High Heaton to Byker and to the river at St Anthony's, along which solid rocks are exposed, lies on the eastern side of this buried valley. Sandstones cap much of the high ground where solid rock is exposed, but elsewhere the lithology of the rocks can be seen to have little bearing on the topography. The geological structure (see Figure 4) also appears to have little bearing on the general topography of the area.

SOLID ROCKS

Within the area there are about 800 metres of Coal Measures which rest conformably on the underlying Millstone Grit. The Coal Measures sequence in the area is shown graphically in Figure 5 in relation to the traditional British classification of Lower, Middle and Upper Coal Measures and the continental Westphalian stages (now almost universally adopted). A sketch map of the solid geology of the area is given in Figure 6. The rocks were originally laid down in a deltaic environment into which the sea occasionally penetrated. These marine incursions are marked by marine faunas, and the marine bands thus deposited form the basis of the Westphalian classification. The lithological sequence is rhythmic, with mudstone succeeded in turn by sandstone, seatearth and coal. This sequence of rock types is a typical Coal Measures cyclothem; such cyclothems average about 12 metres in thickness, but many are thinner where one lithological member is missing, or thicker where the sandstone is unusually thick.

Namurian strata

A borehole at Throckley proved 520 metres of Namurian strata which included 39 metres of the intruded quartz dolerite Whin Sill. Sandstones dominate the upper 75 metres of the sequence, below which mudstones, sandstones, thin limestones, coal and seatearths form the sequence down to the Great Limestone at the base. There are no coals thick enough to work in the Namurian sequence in this area, though there would be some scope for underground gassification of coal were it to become profitable. The thick, coarser-grained sandstones in the upper part of the Namurian sequence would, perhaps, have potential for gas storage.

Westphalian A strata

The Quarterburn Marine Band, a marine mudstone containing the fossil Lingula, is the marker at which the base of the Westphalian is taken. The strata between the Quarterburn Marine Band and the Harvey Marine Band contain the following named coals:

DURHAM NAME	NORTHUMBERLAND NAME	LOCAL NAMES	NCB INDEX LETTER
HARVEY	BEAUMONT	Townley Main	N
HODGE	HODGE	Elswick	O
TILLEY	TILLEY	Hand	P
TOP BUSTY	TOP BUSTY	Stone	Q1
BOTTOM BUSTY	BOTTOM BUSTY	Five-Quarter	Q2
THREE-QUARTER	THREE-QUARTER		R
BROCKWELL	BROCKWELL		S
VICTORIA	VICTORIA		T
MARSHALL GREEN	MARSHALL GREEN		U
GANISTER CLAY	GANISTER CLAY		

Equivalent names and symbols of the main coal seams in Westphalian A strata of Sheet NZ 26

There is no difference between the names used by the Institute and those used by the National Coal Board in this sequence, but, in addition to the names, the NCB assign an index letter for each of the main coals. A few coals traditionally have different names on opposite sides of the Tyne and several coals also have local names (see table).

Strata below the Brockwell do not crop out within the area and there are no surface exposures of Westphalian A rocks. All information on these strata comes, therefore, from borehole and shaft records, most of which are over one hundred years old, and from the records of old workings.

Below the Brockwell Coal, thick sandstones dominate the succession; all coals are thin and impersistant and none have been worked. The Brockwell is a good quality coal, widely about one metre thick. It has been worked extensively in the western half of the area but elsewhere only east of Benton and Mount Pleasant (Figure 7A). The seam is less than 0.30 metres thick over much of NZ 26 SE and NZ 26 NE, and splits into several thin coals separated by mudstone beds. A sandstone is common in the roof of the Brockwell and in many areas is more than 10 metres thick.

The Three-Quarter Coal is thin and generally of poor quality. It is worked in the North Elswick area, where it is 0.7 metres thick, and east of Benton (Figure 7A).

The Busty Coals are worked in the west of the area and the Bottom Busty in the Walker district (Figure 7B). In the northern and eastern part of the area both coals are very thin and the Bottom Busty is of poor quality. The Tilley is split into three or four leaves throughout the area; the coals are not of good quality and the group is commonly spread over up to 10 metres of strata. Only very small areas of Tilley have been worked (Figure 7C).

The Harvey or Beaumont Coal is marginally the most widely worked coal in the Westphalian A strata. Averaging about 1 metre in thickness in the worked area, it is of good quality. It has not been reworked in the north nor in a belt two to three kilometres wide down the middle of the area (Figure 7C). It appears to be too thin to work profitably beneath South Gosforth and Jesmond but there are probably areas of workable coal beneath Kenton, Fawdon and Brunton and also on NZ 26 NE to the north of the Ninety Fathom Fault. Beneath the Team Valley and Gateshead the Harvey Coal is only about 0.50 metres thick and is unworked. Little is known about the Harvey Coal beneath the north part of Gateshead, Newcastle city and the area immediately to the east of the city, but it may be workable.

Strata with abundant 'mussels' can be used locally for corellation but are rare in Westphalian A strata; one such bed is very persistant in the mudstones overlying the Harvey Coal.

Westphalian B strata

This division contains the strata between the Harvey Marine Band and the Ryhope Marine Band (the base of Westphalian 'C'). The main named coals are:

DURHAM NAME	NORTHUMBERLAND NAME	NCB NOMENCLATURE WHERE DIFFERENT	NCB INDEX LETTER AND LOCAL NAMES
RYHOPE FIVE-QUARTER	RYHOPE FIVE-QUARTER		C
RYHOPE LITTLE	RYHOPE LITTLE		THREE-QUARTER GOSFORTH 70-FATHOM D
MOORLAND	MOORLAND		
HIGH MAIN	HIGH MAIN		E
METAL	METAL	MAIN	F1
FIVE-QUARTER	FIVE-QUARTER	MAIN	F2
TOP MAIN	BENTINCK		
BOTTOM MAIN	YARD	YARD	G
MAUDLIN	BENSHAM		H
DURHAM LOW MAIN	DURHAM LOW MAIN		J
BRASS THILL	NORTHUMBERLAND LOW MAIN		K
HUTTON	HUTTON		L
RULER	PLESSEY		M

Equivalent names and symbols of the main coal seams in Westphalian B strata of Sheet NZ 26

A massive sandstone occupies most of the interval between the Harvey Marine Band and the Plessey or Ruler Coal in the south-west of the area but is thinner in the north and east. There are no mine plans for the Plessey or Ruler Coal in this area; it has, however, been worked beneath the western flank of the Team Valley in the Lobley Hill area, where it is almost a metre thick, and may have been worked together with its seatearth beneath Scotswood, where the coal is much thinner. Elsewhere in the area it is split into two thin coals and has not been worked.

The succeeding Hutton, Brass Thill and Low Main Coals are each difficult to correlate throughout the area, partly because there are few modern borehole records, few mine plans and a wide gap in continuity across the Tyne Valley. Bivalves are locally abundant in the roof measures of the Hutton and Brass Thill coals farther south but are not present in the area of NZ 26.

In the south-west the Hutton Coal is widely more than 2 metres thick and is worked with a very high rate of extraction as indicated in Figure 7D. It deteriorates sharply northwards and has not been worked north of the Tyne in the west (Figure 7D). In the east the Hutton south of the Tyne is a good coal commonly 2 metres thick but north of the river it thins and splits; it has been worked only in the south-east corner of NZ 26 NE (Figure 7D). The strata between the Hutton and the overlying Brass Thill are predominantly siltstones and mudstones, though locally in the south of the area a sandstone up to 10 metres thick underlies the Brass Thill Coal.

The Brass Thill Coal is divided into two seams throughout the area; west of the Team Valley, in the Whickham area, the Bottom Brass Thill Coal is thin and not worked, but beneath the Lobley Hill area and farther to the east on NZ 26 SE, the Bottom Brass Thill is commonly up to 1.5 metres thick and has been worked in several places (Figure 7D). North of the Tyne the Bottom Brass Thill is over 1 metre thick in the Scotswood area where it has been worked although plans of the workings have not survived. It has also been worked in the Elswick area where it is a metre or more in thickness. In the northern part of the area, although this seam can often be identified in the sequence, it is generally too thin to work. An exception is in the Wallsend area where it has the local name of the Wallsend Five-Quarter. The Top Brass Thill Coal lies between the Bottom Brass Thill and the Low Main in the extreme south of the area but elsewhere it is combined with the overlying Low Main Coal to form a good quality composite seam which is almost 2 metres thick in places.

Throughout most of the area the Low Main Coal is overlain by a massive, cross-bedded, medium-grained sandstone, the Low Main Post, which generally rests directly on the coal and provides an excellent roof for workings. It is widely between 20 and 40 metres thick and in places fills the interval between the Low Main and Maudlin Coal; locally, as under parts of Gateshead, the sandstone overlies an erosion surface that has removed the Low Main Coal and rests directly on the Brass Thill. Exceptionally the whole of the sequence between the Five-Quarter and Low Main Coal is composed of sandstone. This sandstone-dominated sequence is found in the Whickham area and also north of the Ninety Fathom Dyke in the Newbiggin area. As with the underlying Bottom Brass Thill and Hutton Coals, the Low Main/Top Brass Thill Coal deteriorates in the northern part of the area and has not been worked there (Figure 7E).

The Maudlin Coal, called the Bensham in the northern part of the area, is thin and commonly contains mudstone beds. It has been worked in the Whickham area and fairly extensively on NZ 26 SE (Figure 7E) where exceptionally it is nearly 2 metres thick. It has also been worked extensively in the Wallsend area where, although still banded, it is commonly more than a metre thick. Between the Maudlin/Bensham Coal and the High Main are about 60 metres of mainly argillaceous strata, although thick impersistent sandstones occur above the Maudlin/Bensham in the Scotswood and Gateshead area and in parts of NZ 26 NW.

The first worked coal in the sequence above the Maudlin/Bensham is the Main, which is split into a Top Main and a Bottom Main in much of the area; neither seam is generally thick enough to work. In the Heworth area the Top and Bottom Main combine to give a workable seam one metre thick (Figure 7F). Similarly in the Longbenton to Walker area the seam has been worked, although here the combined seam rarely reaches one metre in thickness; mine plans exist for these two areas but none are in existence for the Gateshead area where borehole data indicate that the combined seam has almost certainly been worked. A thick sandstone overlies the Main Coal in parts of the area.

The overlying Five-Quarter Coal is also a split seam in most of the area and is everywhere of poor quality. Although borehole records indicate that it has been worked beneath Gateshead, in the Spital Tongues to Hunters Moor area to the west of the city and to the north of Scotswood, these workings are old and no mine plans are available. The Five-Quarter has also been worked north-west of Kenton Bank Foot where its lower leaf is a banded coal up to 1.3 metres thick. Shallow workings have also been proved in boreholes immediately north of the Ninety Fathom Dyke near Montagu Colliery. The Metal Coal is also generally thin and is found about midway between the Five-Quarter and High Main Coals. Old workings have been found at the Metal seam horizon in boreholes in Gateshead and in the Gallowgate area of Newcastle. Elsewhere, although present in the sequence, it is too thin to work, generally being less than 0.6 metres thick.

The High Main Coal is the thickest and most consistent coal in the area and is of excellent quality. The early coal mining industry of the area was based on the exploitation of this coal which is only locally less than 1.5 metres and generally more than 2 metres thick. Although very small areas of this coal may remain unworked beneath parts of Gosforth and Gateshead, it can be taken that the High Main has been worked everywhere in the area, usually to the point of almost total extraction. The High Main Coal is succeeded by a thick sandstone, the High Main Post, which is almost as consistent as the underlying coal. Only locally less than 20 metres thick, and generally nearer 30 metres, this medium- to coarse-grained massive cross-bedded sandstone normally lies immediately above the coal. Capping northern Gateshead, and forming the northern flanks of the Tyne from the Old Benwell to the western fringes of the city (Figure 6), the high ground of its outcrop dominates the landscape. It is an excellent building stone and has been extensively quarried in Gateshead, Benwell and indeed wherever it crops out either at the surface or under thin glacial deposits. Only in the Kenton and Fawdon areas to the north of the Ninety Fathom Dyke does the High Main Post thin and in places disappear completely from the sequence.

The High Marine Band, which is generally found only where the High Main Post is thin or absent, has been found in this area only in boreholes in Fawdon and Kenton where it lies 4-10 metres above the High Main Coal.

The poorly-documented and laterally variable strata between the High Main Marine Band and Kirkby's Marine Band contain three named coals, the Moorland, Ryhope Little and Ryhope Five-Quarter, but there are no plans of former workings. The Moorland Coal lies 40-50 metres above the High Main Coal and is thickest in the north-west of the area but even there it is generally less than 0.30 metres thick; it may have been worked in the extreme north-west of the area but is generally very thin or absent in the south-east. Fish scales and a few mussels are widespread in the black shales that generally overlie the Moorland Coal.

The Ryhope Little Coal lies about 30 metres above the Moorland Coal and is widely underlain by a sandstone up to 10 metres thick. It contains many thin mudstone beds and is not generally of good quality in this area; it is widely split into Top and Bottom Ryhope Little coals by several metres of mudstone. Exceptionally, in the South Gosforth and Jesmond areas it is a single seam of fair quality 1 and locally 2 metres thick, and has been worked from South Gosforth Colliery and from several shafts and drifts in Jesmond Dene; the coal here is known locally as the Seventy Fathom Coal and is widely overlain by a sandstone known as the Seventy Fathom Post which is up to 10 metres thick.

The Ryhope Five-Quarter Coal is also a banded seam of mediocre quality; it contains many thin mudstone beds and is commonly in two separate seams separated by several metres of mudstone. The coal is thickest, almost 1 metre, and of highest quality in the north of the area and has been worked around Gosforth where it was known as the Gosforth coal. The Ryhope Five-Quarter is widely overlain by a thick sandstone in the north of the area but elsewhere the sandstone is generally thinner and lies a few metres above the coal.

Kirkby's Marine Band lies about 30 metres above the Ryhope Five-Quarter Coal, and generally overlies a thin coal that has not been worked in the area. The Marine Band has a distinctive bipartite structure and has been found in several boreholes south-west of Byker and in surface exposures beside the Tyne at St Anthony's.

In the area south of the Ninety Fathom Dyke, strata overlying Kirkby's Marine Band are mainly sandstones; about 50 metres of strata occupy the interval between Kirkby's and the Ryhope Marine Band but the Hylton Marine Band may locally be present near the middle of this sequence. The Ryhope Marine Band has been recorded in the railway cutting near Benton and it is presumed to be present widely in the eastern part of the area. A thick sandstone overlies the Ryhope Marine Band, and this, together with the sandstone immediately underlying the marine band, comprise much of the high ground of Gateshead and east Newcastle; both have been quarried for centuries for building stone, grindstones and road material. The unworked Usworth Coal lies towards the top of the sandstone overlying the Ryhope Marine Band and is generally less than 0.5 metres thick. The thin Hebburn Fell Coal lies at the top of this sequence and is generally split.

Strata above the Hebburn Fell Coal are generally argillaceous but there are several thin coals between the Hebburn Fell and the coal beneath the Down Hill Marine Band. The West Moor Coal is about 15 metres above the Hebburn Fell and is almost 1 metre thick north of the Ninety Fathom Dyke where it may have been worked (although no records of such workings exist). Immediately north of the Ninety Fathom Dyke the Killingworth Coal lies about 25 metres above the West Moor Coal but is generally less than 0.5 metres thick in the few boreholes where it has been proved; almost certainly it has not been worked. Other coals between here and the Down Hill Marine Band are all thin and have not been named or worked. The Down Hill Marine Band itself has not been proved within the area, but strata above this level lie immediately north of the Ninety Fathom Dyke on NZ 26 NE. They are amongst the highest Westphalian strata in Northumberland and it is possible that some Permian rocks may lie immediately north of the Dyke in the Forest Hall area.

Igneous Rocks

The Hebburn Dyke is a near-vertical sheet of Tertiary tholeiitic dolerite between 10 and 25 metres wide. It has been found in underground coal workings from Spital Tongues in the west to Walker but has not been seen at the surface where its outcrop is drift-covered. North of the Ninety Fathom Dyke it appears to run en echelon with the fault, penetrating at least up to the level of the Harvey Coal. No vertical displacement of strata across the dyke has been noted and its course takes no account of earlier dislocations. In some seams the coal has been cindered for up to 40 metres from the dyke.

Geological structure

The Carboniferous rocks of this area were faulted and gently folded in late Carboniferous Hercynian movements and probably further faulted and tilted eastwards in late Jurassic and Tertiary times. A structure contour map of the Harvey Coal is presented as Figure 4 and geological cross sections are presented as Figure 8. Although the Harvey is one of the coals which has been worked under much of the area, surveyed levels are found in only a small percentage of the workings; the contour map therefore is a compilation of these surveyed levels, together with levels estimated from seams above and below and from borehole records.

The structure of the area is generally simple, and is divided into two provinces by the WSW-ENE fault known as the Ninety Fathom Dyke. North of this fault there is a gentle WSW-ENE anticline which fades out eastwards; beds on the southern limb of the anticline dip into the fault at up to 45°. South of the Ninety Fathom Dyke the structure is one of gentle generally eastwards dips with the strike (widely less than 2° and nowhere exceeding 6°) gradually swinging from SSE in the south-east to NE in the north-east, around the north-west end of the Jarrow Syncline.

The Ninety Fathom Dyke is a simple normal fault with a downthrow north of about 210 metres in the west of the area and about 290 metres in the east. Like most major faults in the coalfield it hades north at about 45° and strata on the down-dip side thus meet it at right angles. Despite its name, no igneous intrusion is associated with the Dyke. The only other major faults in the area are the W-E Heworth Fault and its branch, the WSW-ENE Felling Fault, in the south of the area; the throw of the Heworth Fault is to the north and increases eastwards to about 60 metres and that of the Felling Fault exceeds 30 metres to the south. Smaller faults, many too short or of too small a displacement to show on Figure 4, form an irregular grid with predominant SW-NE and NW-SE trends; minor anticlines and synclines within this grid are superimposed on the general easterly dip.

Distribution and patterns of mining

Coal mining on Tyneside has a long and complex history and much has been unrecorded; it therefore presents planners and engineers with a varied range of problems and to understand these some historical information is pertinent.

Mining by monks probably started in the thirteenth century, and was concentrated in areas of exposed rock within a few hundred metres of the Tyne; workings were either adits driven into hillsides or bell pits, reached by shafts 1 to 1.5 metres in diameter and generally less than 12 metres deep. The name 'bell pit' alludes to the shape of the cavity after the roof of workings had collapsed, and workings generally extended no more than 10 metres from the shaft bottom; such pits are numerous in areas of outcropping coal. Improvement of winding, pumping, and ventilating techniques during the sixteenth and seventeenth centuries allowed shafts to be dug to deeper levels and workings to be more extensive, and the development of wagonways facilitated transport from areas farther from the river; new collieries were established at places such as Jesmond and Heaton and the coal was worked by pillar and stall methods with pillars about 3 square metres and stalls about 2.5 metres across. Later, in the middle of the eighteenth century, further improvements made the exploitation of even deeper seams possible and several major collieries (Gosforth, Kenton, South Gosforth, Walker, Wallsend, Byker, Heworth and Felling) were established; stall and pillar workings remained standard practice, with extraction rates of 40 - 50%, but pillars were commonly about 5.5 metres x 3 metres and stalls about 3 metres. Before the beginning of the nineteenth century many of the thicker coals were almost worked out and panel working, with an extraction rate of up to 80% was introduced both for new areas and for some areas that had previously been worked by stall and pillar methods. Later in the nineteenth century, longwall working with total extraction was introduced but was mainly applied to the lower seams and is therefore seldom seen in excavations. Deep mining in the area ceased in 1975. Coal beneath the Town Moor and Nun's Moor, Newcastle, was also worked by opencast methods during the 1940's and there were other opencast coal workings at Whickham.

In addition to coal, fireclay has been worked at Scotswood (probably with the Main and Five-Quarter coals) and beneath Gallowgate where removal of the thin Metal Coal and its seatearth has left galleries more than 2 metres high only a few metres below the surface.

Mining and urban redevelopment

The importance of coal mining in this area does not lie in its potential for further development but in the hazards past mining now presents to the planner and civil engineer. Analysis of the historical development of methods of working together with the growth and distribution of collieries permits some useful generalizations:

1. There are no records and few indications of the position and extent of almost all workings more than 200 years old. Any plans of such workings are inaccurate, and show only limited geological information. Younger workings, until about 1850, are patchily and generally poorly recorded. Even later, although the keeping of accurate plans was mandatory and, after 1872, plans

had to be lodged with the Mining Records Office, many plans showed only the extent of workings and not their levels or any geological information: only the latest plans, especially of the lower seams exploited since 1947, are fully reliable and comprehensive and these are the ones with which the planner and engineer and likely to be least concerned. It follows that, without accurate sources of information on many past mining activities, extra care and research to determine the position of old workings is necessary throughout the area of NZ 26.

2. Mine shafts are very numerous in drift-free areas where coals crop out; bell pits are common. The existence and position of many is not known. An impression of the density of shafts in parts of this area can be gained from the Denton Hall manuscript which relates that there were one hundred and forty pits in Denton in the mid-eighteenth century. Although, in drift-free areas, shafts and bell pits are normally very old, they still present a hazard today. Many such shafts were only capped at surface level, and remain open below; bell pits have a surprising capacity to resist complete collapse.

3. Early workings in thick coal seams were by bell pits and pillar and stall working. Subsequently these seams were re-exploited by panel working, giving a high level of extraction. Two of these coal seams present persistent subsidence hazards:

   a. the High Main Coal, throughout the area, has been worked to give an extraction exceeding 75% and commonly nearer 90%. Having a thick sandstone roof which has a high bridging strength, few of the workings have collapsed and cavities are common. Gateshead, Benwell and the northern and western fringes of the city where the High Main is worked at shallow depths present this problem;

   b. the thick and almost completely extracted Low Main and Brass Thill coals in the Whickham and Scotswood areas have a similarly strong sandstone roof that has widely resisted collapse.

A secondary problem with the High Main is that subsidence movement in the sandstone is concentrated at the outcrop of master joints; severe local differential movement and, in places, deep yawing cracks are thereby initiated.

4. Many coals a metre or less in thickness have been worked only once and 40% to 60% of the coal remains in the ground as supporting pillars. Cavities are common and only about half of boreholes through the workings are likely to indicate that the seam has been worked.
5. It is safe to assume that even quite thin coals have been worked wherever they crop out in areas where drift is thin or absent.
6. Only the thinner and deeper coals are likely to have been worked by the longwall system.
7. Where collapse has occurred in pillar and stall workings, there are commonly cavities in the overlying strata caused by bed separation.
8. At the level of old workings, in borehole cores there is often little sign of collapse. Packing of old workings with country rock was not necessary in pillar and stall workings and the roof measures may now rest on the seat-earth with little disturbance. In borehole cores often the only indication of working is a little powdered coal overlying a stained and slightly weathered seatearth; traces of rust are common.

Future workings in Coal Measures strata

Coal and fireclay mining in the area has now ceased and all the collieries have been closed. Many of the coal seams have not been fully exploited, and many patches of coal of workable thickness and quality still remain. This is particularly true of the highest seams, especially the Ryhope Little and Ryhope Five-Quarter, and some of the lowest seams, particularly the Harvey in the Kenton to Brunton area. Nevertheless, the amounts of coal remaining and the constraints imposed by the cost of exploiting it in an urban area effectively rule out economic working for the foreseeable future.

Some potential for opencast mining still exists where only partly worked seams crop out in open areas; planning constraints probably rule out such exploitation whilst coal is available from other sources.

All workings in sandstone have now been closed and the opening of new workings or the re-opening of old workings is unlikely under present economic conditions.

Engineering characteristics of Coal Measures rocks

Mudstones and siltstones. Together these fine-grained rocks are the most abundant in the Coal Measures; their content of clay minerals is stable, but the mudstones weather readily on exposure and in this area are generally intensely jointed to a depth of 3 to 5 metres. Trenching through such rocks is relatively easy but tunnelling at depths of 12 metres or less presents substantial support problems; explosives are not generally required in surface excavations.

Sandstones. These are the next most abundant rock type in the local Coal Measures and in the higher parts of the sequence they predominate under much of the eastern part of NZ 26. They occur in two main modes; sheet sandstones that are generally fine-grained and up to 5 metres thick and massive medium- to coarse-grained sandstones in units individually several metres thick. Sheet sandstones are common at all levels in the local Coal Measures sequence whereas massive sandstones are most widespread above certain coal seams (notably the Low Main and High Main) and marine bands [(notably the Low Main and High Main) and marine bands] (notably Kirkby's and Ryhope); the massive sandstones have been extensively quarried for building stone and grindstones.

Excavation and tunnelling in Coal Measures sandstones presents few support problems but generally requires explosives for depths below 2 to 3 metres from the surface. Some of the coarser-grained sandstones are gritty and highly abrasive and some sandstones are quartz-cemented and are extremely tough. Ganister, a variety of sandstone found beneath some coals, is a particularly tough rock. Joint blocks that have been weakened by subsidence over old coal workings may require support in deep open excavations and the presence of deep open joints may itself necessitate specially strengthened foundations; this is particularly the case where the Low Main and High Main Posts (sandstones) have been underworked. Seatearths. These varied rocks lie immediately beneath coal seams and are generally less than 1 metre thick; clays predominate but silt- and sand-grade rocks (including ganister, see above) also occur. Clay-seatearths contain readily-weathered clay minerals and these and their generally abundant random internal polished ('listric') surfaces make them unstable both in excavations and under load. Seatearths may provide a plane for slip failure in excavations on steep valley sides such as those in north Gateshead and in Whickham.

DRIFT DEPOSITS

The Glacial Deposits

All the glacial deposits of this area belong to the Late Devensian Stage of the Pleistocene Period and are between 18 000 and 10 000 years old. They comprise lodgment till (boulder clay), flow till, laminated clay and silt, sand and gravel and several types of superficial clay. Modern alluvium and some peat overlie the glacial deposits in the main river valleys. The distribution of the various drift deposits is shown in Figure 9, and their mutual relationships are shown diagrammatically in Figure 10; the drift is generally of stony clay (lodgment till and flow till) except in the buried valleys where thick complexes of sands, silts, laminated clays, stony clays and some gravel are found; in general, sand and laminated clays are uncommon where the drift is less than 15 metres thick.

Laminated clays are found at surface filling the Tyne and Team buried valleys at levels generally below 35 metres AOD. Thick deposits of fine sands also occur in the Tyne buried valley west of Redheugh, although their outcrop is covered by alluvium. West of the Salt Meadows, glacial sands are exposed along the southern margin of the buried valley.

The Team Valley buried valley deposit is almost entirely of laminated clay and silt though there are indications in some boreholes of a thin coarse gravel immediately overlying rockhead. The buried valley from South Gosforth to Battle Field, now bounded to the east by the Ouse Burn, seems to contain only lodgment till and flow tills, although farther to the north-west it contains thick glacial sands. The deposits in the buried valleys east of Heaton and south-east of Longbenton are predominantly of till, though a few boreholes and surface exposures indicate that laminated clay and sand are present locally. East of the South Gosforth - Battle Field buried valley and east of the Gateshead ridge, thin stony clays overlie the tills in most areas except on the highest ground near the solid rock outcrops. In the west of the area these upper stony clays are less widespread and have not been mapped.

Characteristics of the drift deposits

Lodgment till ('boulder clay'). This is a mixture of sandy clay and stones. The sandy clay matrix is dark brown to grey, tough and gritty; the stones range from a few millimetres to several metres across and are generally subrounded to rounded. Rocks of Carboniferous age are dominant and include (in order of abundance) sandstones, ironstones, limestones and coal. Igneous and metamorphic rocks from north-west England and south-west Scotland are present, together with boulders of dolerite from the Whin Sill. The clasts are generally aligned in the direction of ice movement. In civil engineering terms the lodgment till of Tyneside is a tough overconsolidated deposit. Shear strength determined by simple undrained triaxial compression tests range from 2000 to 4500 cu lb/ft^2, which is within the general range of 50 to 350 KN/m^2. It is a good foundation material, and presents few problems in trenching, tunnelling and in excavations apart from its toughness and the local presence (particularly near its base) of very large boulders. Scattered lenses of sand and silt in the till create local stability problems, partly because they contain water which increases the plasticity of the surrounding clay.

Flow till ('boulder clay'). Flow till on Tyneside is a mixture of brown or grey clay and stones: it has been derived from boulder clay by mass downslope movement whilst waterlogged. The resulting deposit generally contains fewer and smaller stones than the original boulder clay and has a less well-ordered fabric.

In civil engineering terms, Tyneside flow till is generally weaker than lodgment till and is less overconsolidated; simple undrained triaxial tests indicate shear strengths of 1000 to 4000 cu lb/ft^2, with most samples lying low in this range. Although itself generally adequate as a foundation material, it is commonly interbedded with much weaker water-bearing sand, silt and laminated clay; where this is the case, the walls of excavations and tunnels must be supported.

Laminated clay and silt. These deposits are generally dark brown to purple-brown, the lamination resulting from variations in the content of silt-grade quartz grains: films of pale brown micaceous fine-grained sand are common and many laminated clays on Tyneside contain thin beds of sand. Scattered small stones are generally present. The deposits are generally evenly bedded and their relatively high water content makes them plastic.

Simple undrained triaxial tests indicate shear strengths of 500 to 1500 cu lb/ft^2. The clays are highly compressible and foundations for even moderate-sized buildings need to be specially designed; piling to rock or underlying lodgment till is necessary for heavy buildings and other structures. All excavations in such clays need support and the presence of water-bearing laminae and thin beds of sand leads to slip failure even on gentle slopes. Any alteration of drainage or loading on the sides of valleys containing laminated clays can lead to slope failure. Heave, the decompression of laminated clays in the footings of excavations, is a common problem. The excavation of shafts and tunnels in these deposits is fraught with difficulties and can demand the use of expensive techniques like ground freezing or grouting.

Sand and gravel. On Sheet NZ 26 sand greatly predominates over gravel. The sand is generally pale brown and fine-grained. Although the grading varies from place to place, generally 70% of the sand is between 0.07 and 0.25 mm in diameter. Thin beds with a high clay content are common and there are some beds of laminated silt. Beds and lenses of gravel within the sand sequence are more common at higher levels, although thick gravel also occurs in places near or on rockhead in the bottom of the buried valleys; sandstone is the main rock-type in pebbles in the gravels, but coal grains and fragments are widespread.

Although sands and gravels are cohesionless, where dry or confined they can support considerable loads. Some sand is subject to slight compression under certain conditions and some, particularly fine-grained silty sands, are liable to become 'quick' where water-saturated; such quickness has been a considerable problem in shaft and tunnel excavation in the area.

Superficial stony clays (Pelaw and prismatic clays). Brown and purple-brown silty clays with scattered small stones are the surface deposit over much of the area. They are blocky, typically 1 to 2 metres thick (though locally up to 6 metres) and commonly contain thin beds of fine sand. Most of the stones are small and have no preferred orientation. Closely-spaced sub-vertical polygonal joints are ubiquitous at the top of these clays.

The superficial stony clays are the weakest of the stony clays, they are not overconsolidated and simple undrained triaxial tests reveal a strength range of 1000 to 2000 cu lb/ft^2. This is locally exceeded where the clays are dry or where secondary effects have led to unusual compaction, but lower parts of the deposits are commonly soft and plastic where in contact with underlying water-bearing strata. The reversed strength gradient thus induced must be taken fully into account in foundation design, but 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; the sub-vertical joints are a major source of weakness in such situations and also lead to instability on natural slopes where superficial stony clays overlie plastic laminated clay.

Alluvium. The alluvial gravels, sands, silts and sandy clays deposited by the rivers Tyne and Team have accumulated to a thickness of about 14 metres in the oldest parts of their present valleys. Lateral and vertical alternation of sediment types in rather thin beds is the rule. Peat and organic clays are found at all levels in the alluvium but are most common within a few metres of sea level. They are most abundant on the broad alluvial flats in the Tyne Valley, west of its confluence with the Team, and in the Team Valley.

The alluvium creates foundation design problems because of its variability and generally high water content, but these problems are predictable; peats and organic clays within the alluvium are less predictable and have led in recent years to spectacular structural failures. In one such case, the presence of peat was noted on a readily-available geological map but had been disregarded. Adequate preliminary site investigation is an essential precursor to engineering works on Tyneside alluvium.

Made Ground. Made ground has been shown on the 1:10 560 and 1:10 000 maps of NZ 26 only where it is generally more than 2.5 metres thick, although thinner made ground has been shown in places where it can be clearly defined; spreads of urban rubble are not shown but are widely 1 - 2 metres thick under the older built-up areas. The made ground is a major component of the superficial deposits of the area, of which it covers about 15% (Figure 11); it includes domestic and industrial waste, colliery and quarry spoil, chemical waste, ships' ballast (mainly flint gravel) and areas of landscaped fill and piled-up overburden. Much of the industrial waste forms man-made mounds on the surface and its position is generally well-documented; waste of a wide range of materials has also been tipped in the course of riverside reclamation and engineering works, commonly over alluvium, and this is similarly readily delimited. In contrast, much domestic and other waste fills former valleys and quarries and its extent and thickness here are commonly poorly documented; careful study of old maps and records, thorough exploration by boreholes and other methods and careful contingency planning are essential to safe and economical design and development wherever there is reason to believe that such areas of fill may exist.

Most of the old colliery spoil heaps have now been landscaped and their contents used to fill holes or valleys and to raise land or build embankments.

Some, however, still remain either wholly or as redistributed spreads; these include heaps at Heworth, Montague Main (south-west of Blakelaw), south-west Gosforth (Jubilee and Regent Pits) and in the eastern half of NZ 26 NE.

Wedges of made ground commonly up to 5 m thick line both banks of the Tyne for much of its length and are also found beside parts of the River Team; much of this fill is several centuries old and its heterogeneous composition reflects the diverse industrial history of the Tyne. Chemical waste is widespread on the south bank of the Tyne between Salt Meadows and Pelaw, and ground water here, and perhaps some of the fill, may be toxic or have deleterious effects on the strength of concrete.

Waste-filled valleys are most common north of the Tyne where former deeply-incised denes such as the Ouse Burn, the Swirle (near Sandgate), Pandon Dene and Skinner Burn have been the recipients of domestic waste for centuries. Much of the tipping took place before there were any accurate maps of the area, and the boundaries of the waste are not recorded. Planned tipping in the early part of the nineteenth century followed culverting of the streams in these valleys and the newly-filled areas were quickly covered by new streets and buildings. A study of Pandon Dene by members of the Engineering Geology Department of the University of Newcastle upon Tyne revealed heterogeneous fill up to 24 metres thick; structural damage has occurred in the older buildings, especially where only part of the foundations are on the fill. In tunnels, the valley-filling waste has presented a range of engineering problems but has proved to contain little running water.

Waste fill in abandoned quarries and clay pits presents similar problems to that in former valleys. Most of the abandoned quarries were in sandstone and many were 10 or more metres deep; compaction of the waste is a particular hazard to the stability of structures spanning the edge of old excavations. Some old sandstone quarries are not shown on any maps and their possible former existence should always be considered in planning civil engineering works in the areas of sandstone outcrops (see the geological maps) or where sandstone is covered by thin drift. Abandoned clay pits were generally less than 10 metres deep and are most abundant in areas of outcropping or thinly buried laminated clay; as with the quarries, some such pits are not shown on any maps. Reinstated opencast coal workings, like those in the High Main Coal on the Town Moor, are a special case of infilled old workings; they differ from quarries and clay pits in that they are filled with rock waste and their position and former depth are well documented.

Hydrology

The hydrology of the area is complex, poorly documented and not well understood. The natural drainage pattern and water table has been severely modified by coal mining. During the late eighteenth and nineteenth century pumping became a major factor in the working of deeper coals. Connections were made between collieries and used to drain water from one colliery to another; certain collieries acted as drainage sumps, taking the water from several pits and pumping it to the Tyne. The general water table was thus artifically lowered but is recovering now that mining has ceased and pumping has stopped. The large number of old shafts and abandoned underground workings still, however, has a profound effect on the local hydrogeology.

Within the glacial deposits the movement of water within boulder clay rarely presents problems to the civil engineer, but seepages and springs from water in lenses of sand and gravel cause instability in places. Perched water is locally present in sands of the buried valley-fill complex and is a potential hazard because of its weakening effect on adjoining clays.

Geological Hazards to Development

General distribution. In planning civil engineering works in this area, three main questions have to be asked:

1. What is the nature and thickness of superficial deposits, including made ground?
2. Are there records of coal workings and, if so, at what depth?
3. Is there any information on the local hydrology?

There is little information on the last but considerable information on the first two. A general appraisal of the hazards presented by some glacial deposits, made ground, and old mine workings has been given in preceeding sections of this report. There is, however, a relationship between the different types of hazard; thus, for example, the absence of glacial deposits implies that coal seams may crop out at the surface and this usually indicates, in this fully exploited area, the likelihood of shallow old workings and many shafts. Where the glacial deposits are more than 13 metres thick, however, mine workings are usually deep enough to constitute only a minor hazard, although their possible effect cannot be ignored. The glacial sequence in such areas is likely to be complex, with the possible presence of soft laminated clays presenting a major potential hazard. [redacted]

Landslips. Landslips have not been a major hazard on Tyneside but have occurred on the steep slopes of Jesmond Dene and almost certainly on the steep southern slopes (now obscured by made ground) of the Tyne Valley in the area of the High Level and Tyne bridges; their possible presence must be borne in mind there and elsewhere. Minor landslips have also occurred in laminated clays in the flanks of the main valleys and must be regarded as a constant potential hazard wherever the geological maps show laminated clay to crop out on slopes; the risk is greatest where beds of water-bearing fine-grained sand are also present.

Future workings in drift deposits

All workings in clays for brick and tile-making have now been abandoned and are unlikely to be re-opened; substantial areas of thick laminated clays still remain but can also be found outside the urban area and so sterilization would not be crucial. Glacial sands in the area have been worked on only a limited scale in the past and are of little value today; new workings are unlikely and no outcropping sands need to be protected for future extraction. No workable gravels are known in the area of Sheet NZ 26.

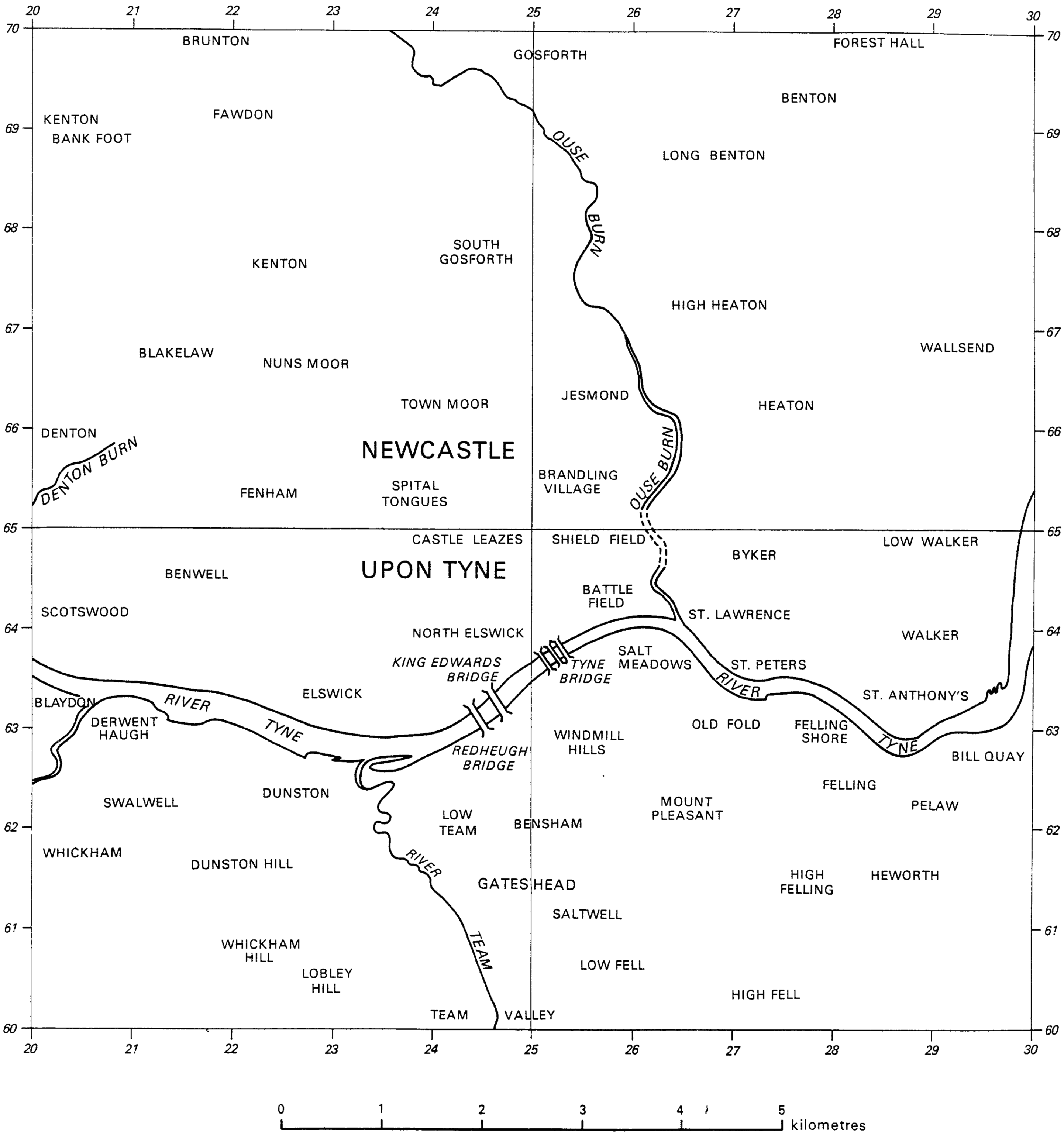


Fig. 1 Outline map of the area showing the main localities referred to in the text.

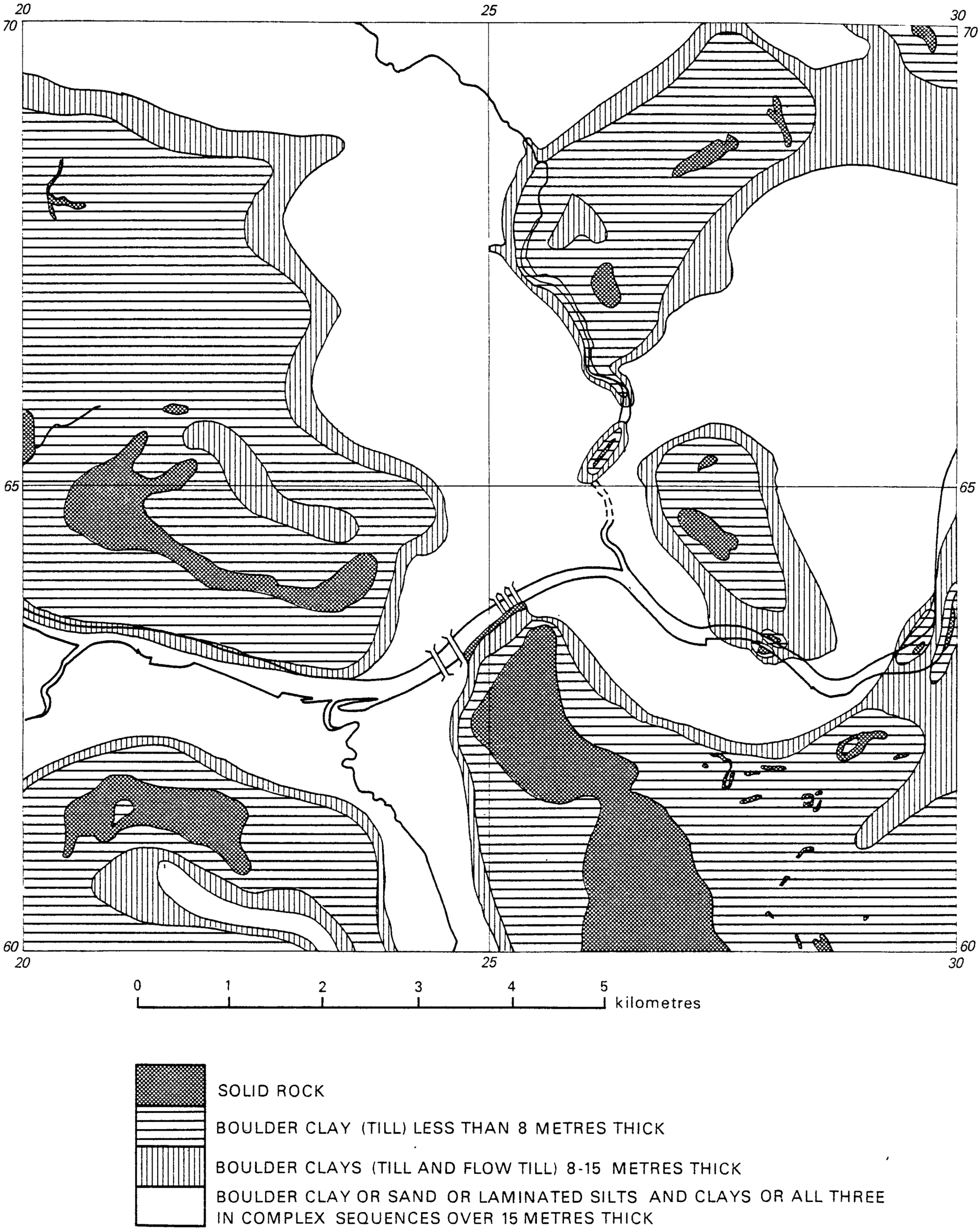
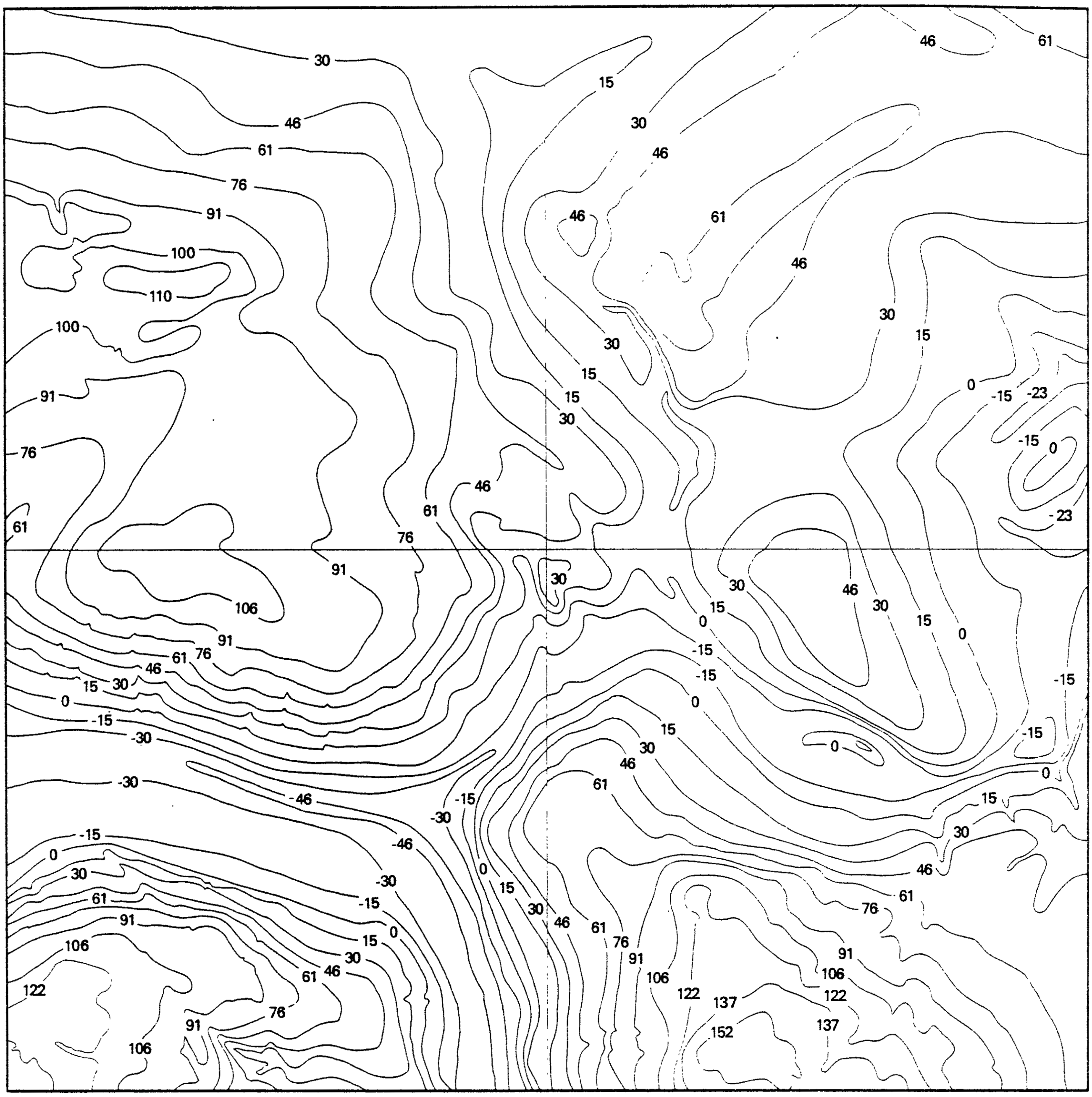
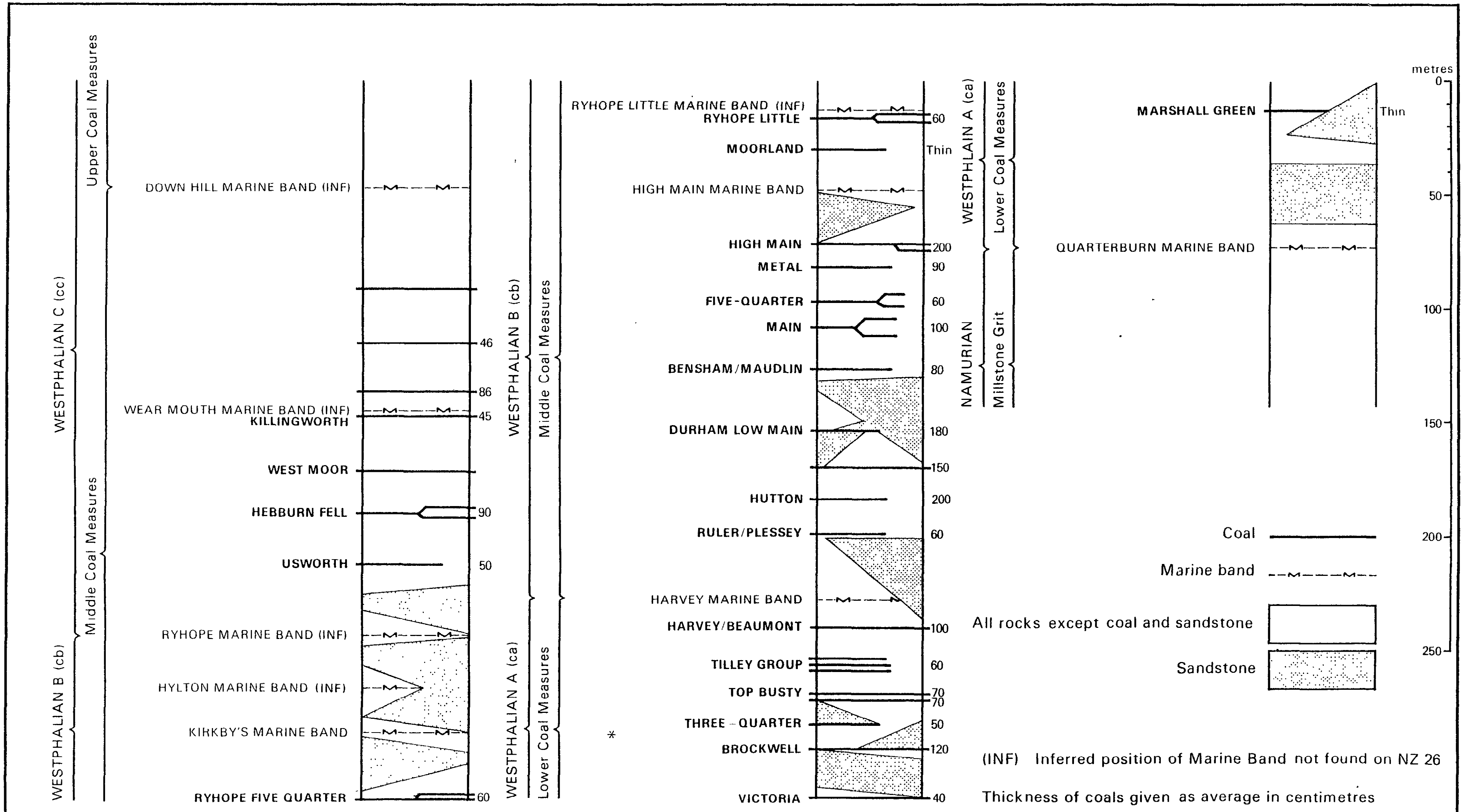


Fig. 2 GENERALIZED GEOLOGICAL MAP OF NZ 26



0 1 2 3 kilometres

Fig. 3 Rockhead contours of the area. Heights in metres. Figures without a prefix are heights above Ordnance datum those preceded by - are below.



For details of vertical sections see margins of each quarter sheet of NZ 26.

* Strata below this level do not crop out within the area and are proved only in boreholes, shafts and underground workings.

Fig. 5 GENERALIZED GEOLOGICAL SECTION OF THE SOLID ROCKS OF NZ 26

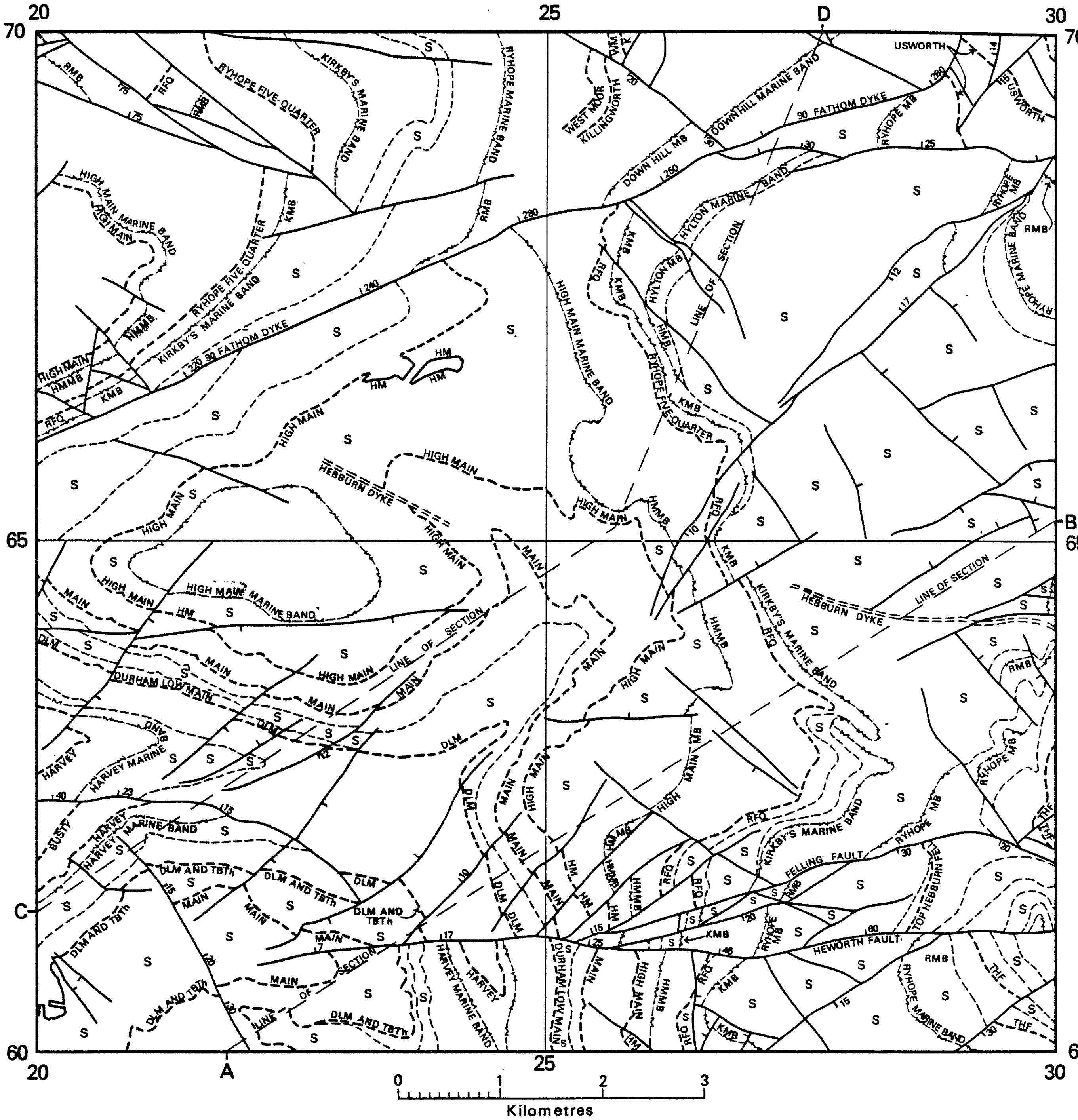


Fig.6 Sketch map of the solid geology of the area showing the outcrop of a selection of coals and marine bands. Thick sandstones are also shown, and major faults. For key see six-inch map margin.

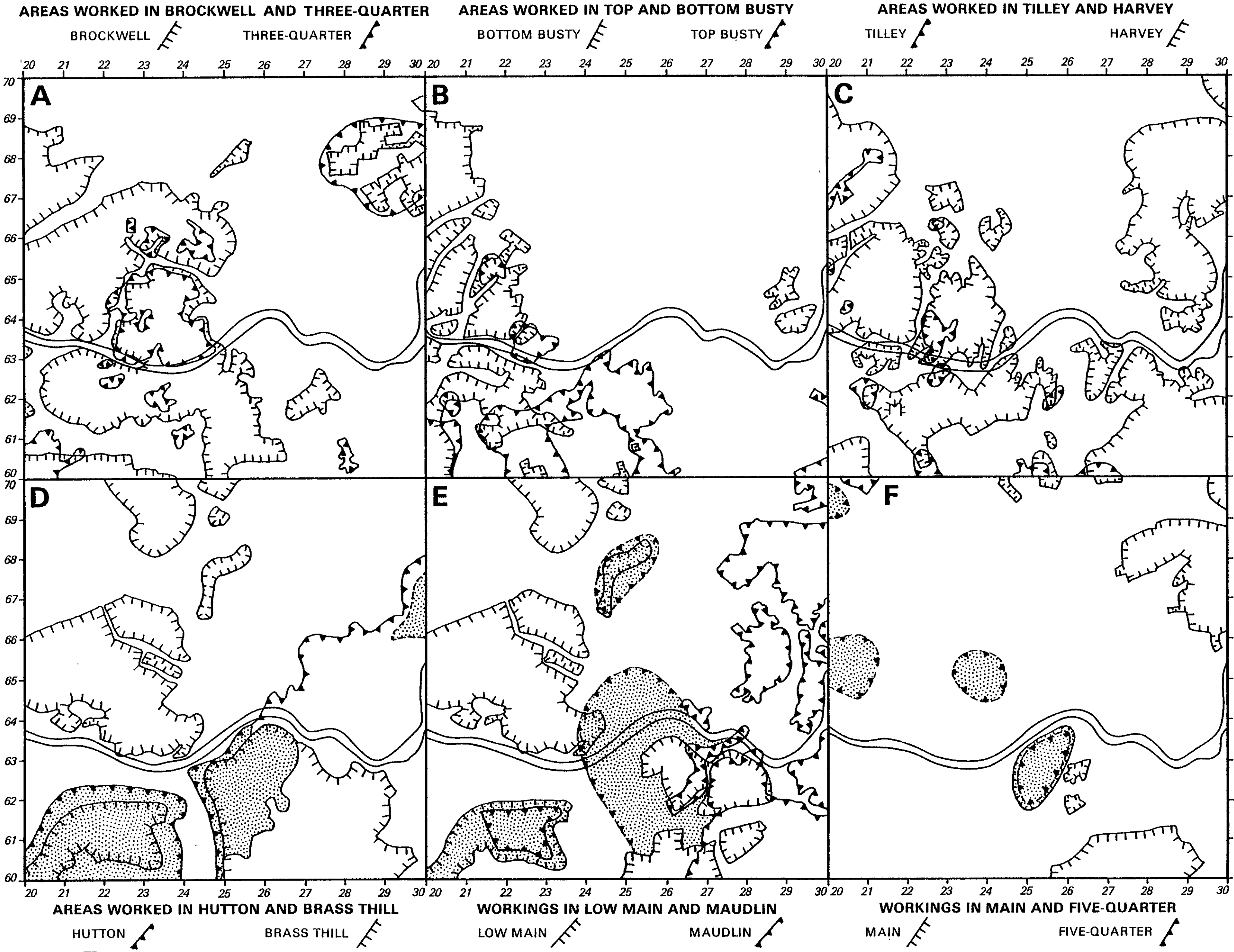


Fig. 7

WORKINGS ON ORNAMENTED SIDE. NO MINE PLANS AVAILABLE IN STIPPLED AREAS. BROKEN LINES INDICATE UNCERTAIN BOUNDARIES.

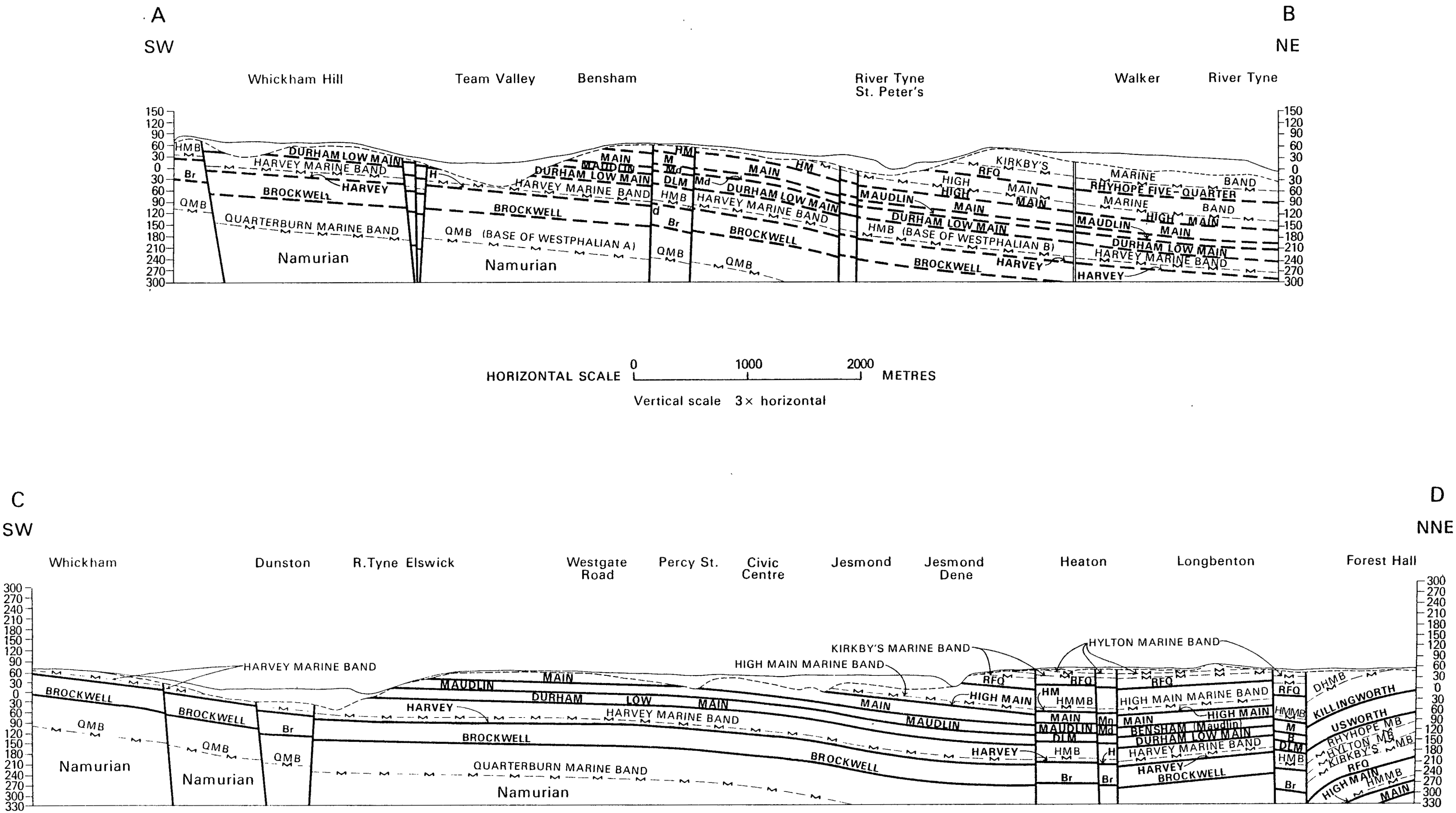


Fig. 8 Generalized longitudinal sections illustrating the broad structure of the area. (see Fig. 6 for position of sections)

Only a selection of coals is shown.

Minor faulting is not shown.

For key see relevant six-inch maps.

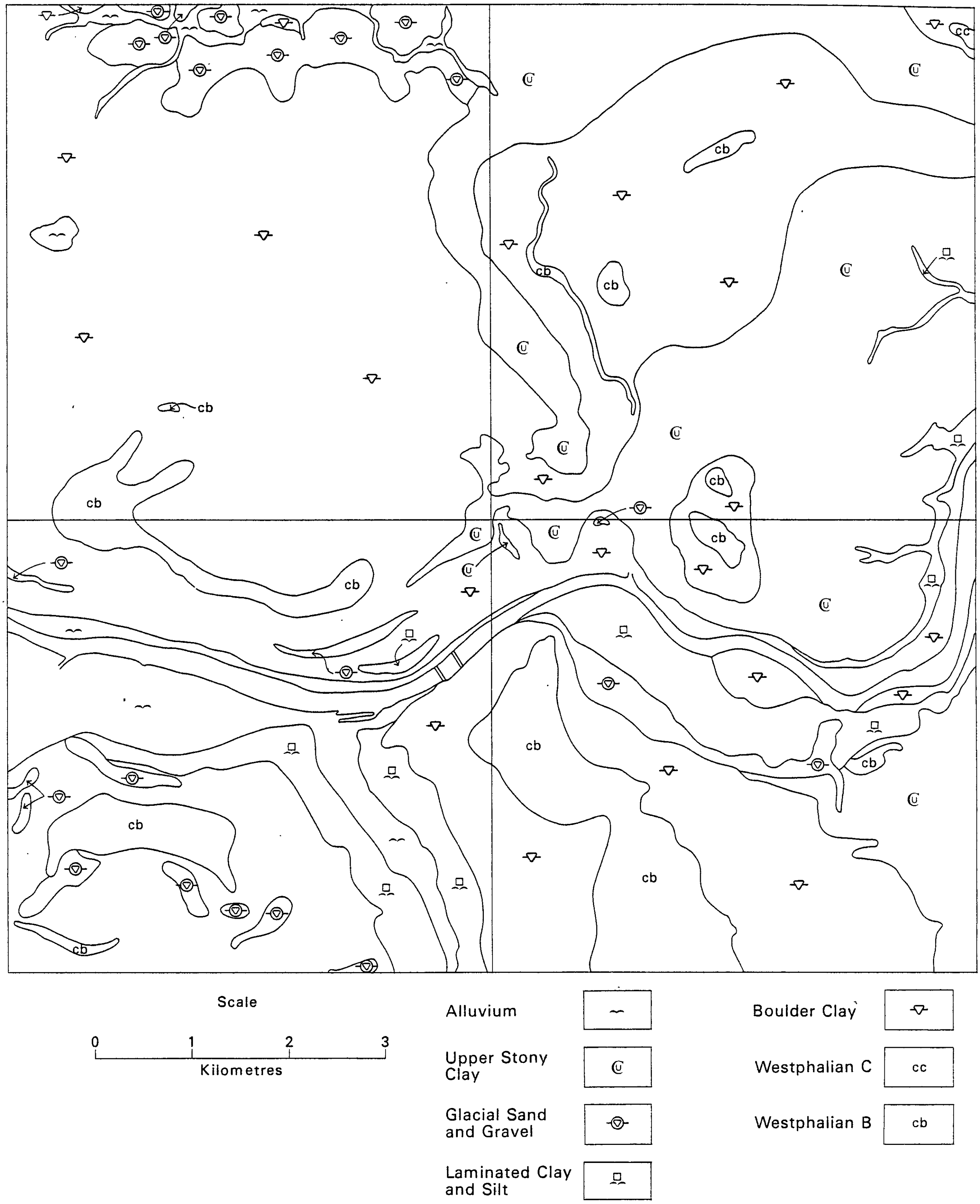


Fig. 9 Distribution of superficial deposits, made ground excluded.

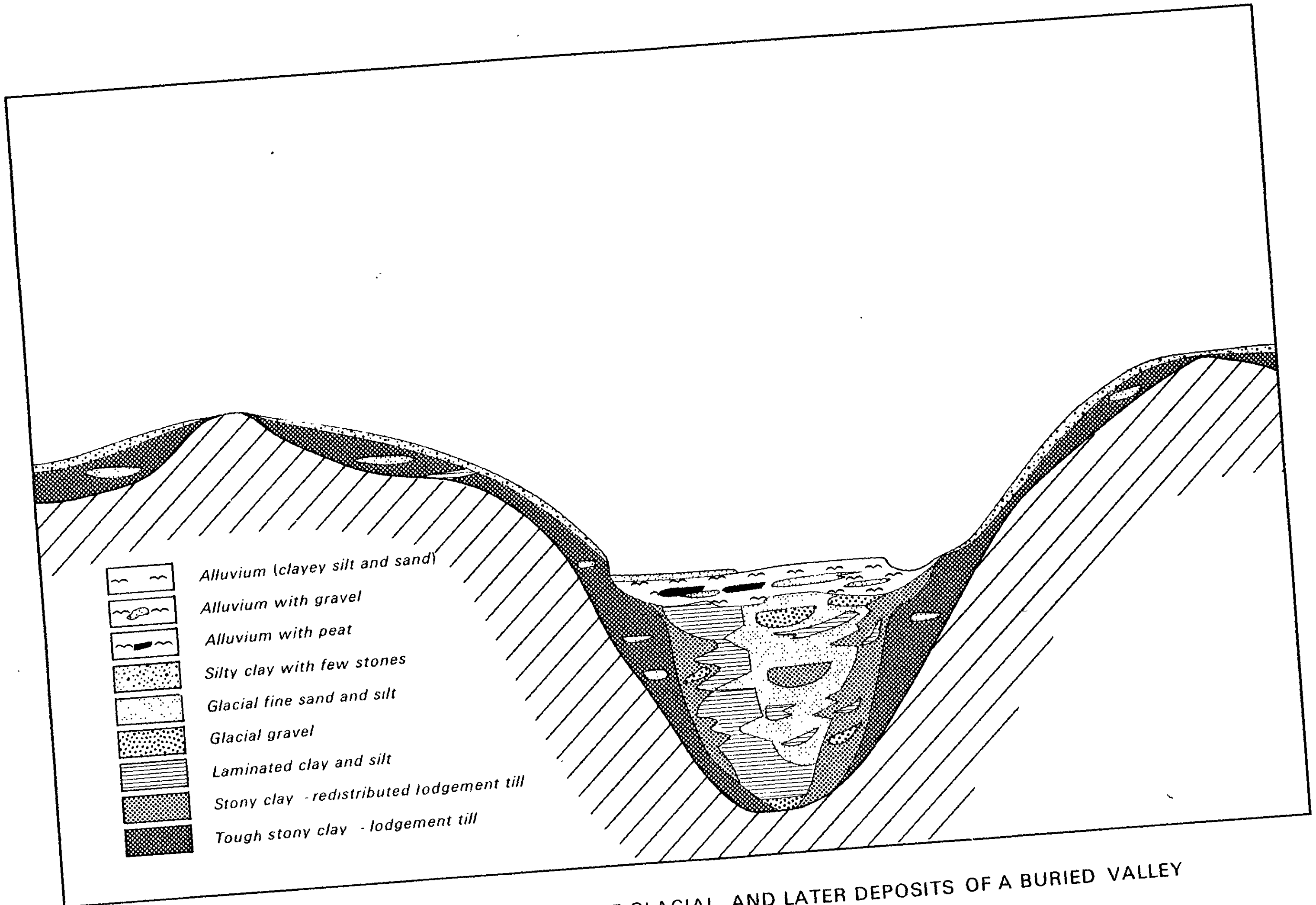


Fig. 10 DIAGRAMMATIC SECTION THROUGH THE GLACIAL AND LATER DEPOSITS OF A BURIED VALLEY

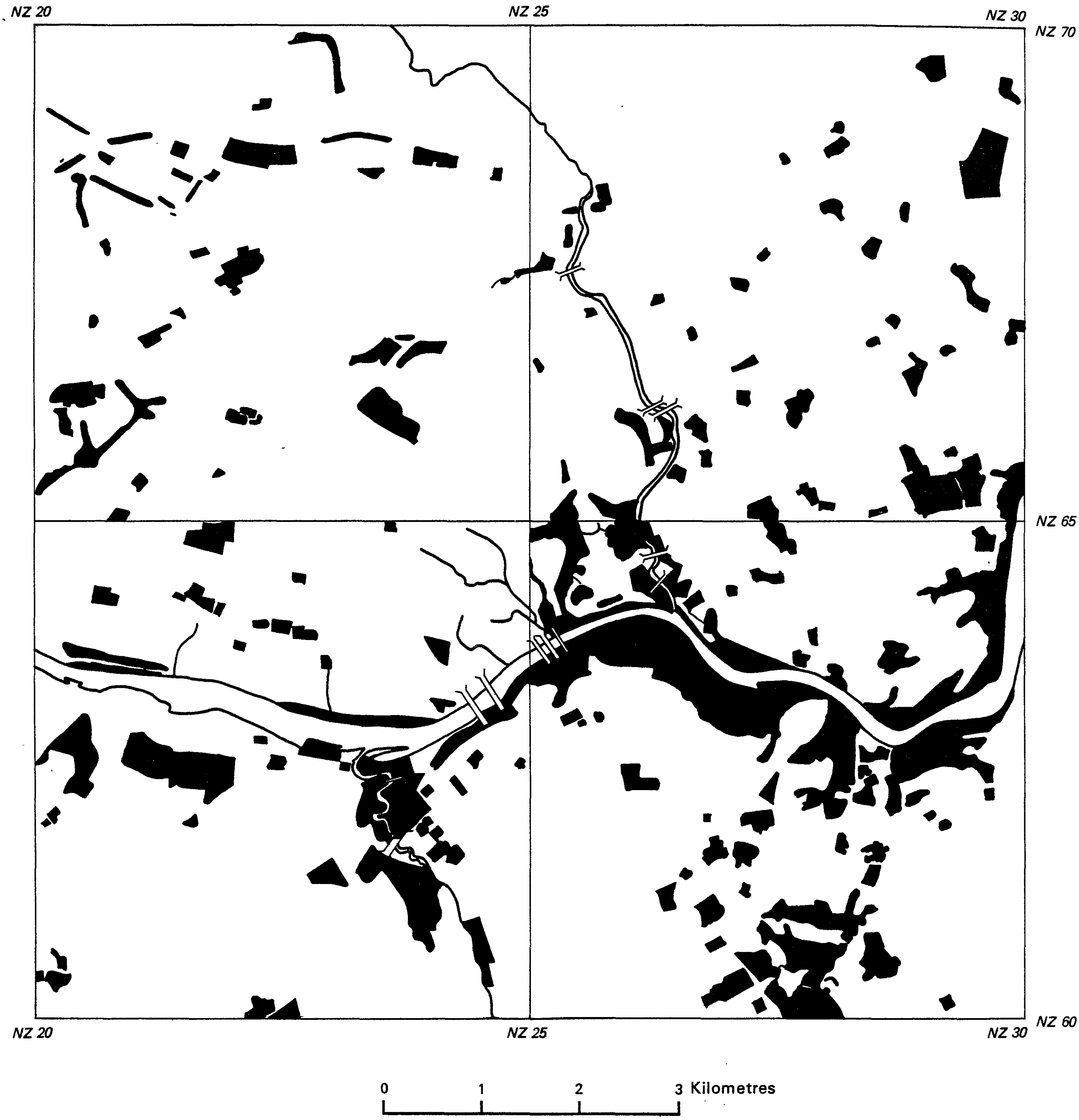


Fig. 11 Distribution of made ground