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# Geological notes and local details for 1:10000 sheets NZ25NW, NE, SW and SE

# Kibblesworth, Birtley, Craghead and Chester-le-Street

Part of 1:50000 Sheet 20 (Newcastle upon Tyne) and
Sheet 21 (Sunderland)

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# PREFACE

This account describes the geology of 1:25 000 sheet NZ 25 which lies within 1:50 000 Sheets 20 (Newcastle upon Tyne) and 21 (Sunderland). It was first surveyed by H.H. Howell, the maps being published on the old county meridian six-inch scale between 1868 and 1871. The area was resurveyed between 1923 and 1948 by A. Fowler and W. Anderson on the new county meridian, some of the maps being published in 1954.

The eastern margin of the sheet was revised by R.H. Price (1953-1955) and D.B. Smith (1966-1974) as part of the revision of 1:50 000 Sheet 21 (Sunderland). 1:10 000 sheets NZ 25 NW and SW were the subject of a desk revision in 1966 by A.J. Reedman and G. Richardson. The present maps are the result of a revision begun in 1980 by F.C. Cox and incorporate much of the earlier work.

The aim of this report is to provide, in conjunction with the accompanying 1:10 000 and 1:10 560 maps, a framework and guide to the main aspects of the geology as they affect the long-term planning and development of the area. The more fundamental scientific aspects of the geology will be included in a study of a wider area. The information on which it is based is lodged at the North of England Office of the Institute of Geological Sciences, Windsor Court, Windsor Terrace, Newcastle upon Tyne NE2 4HE. Any enquiries should be directed to the District Geologist at the above address.

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## GEOGRAPHY LAND USE AND POPULATION

Most of the area of Sheet NZ 25 is rural, with rounded fells rising to more than 200 m in the west and to more than 150 m in the east. Mixed farming dominated by beef cattle, hay and barley production, is the main agricultural use, but scattered settlements and small towns have grown up around individual coal mines and sandstone workings, most of which have now closed. The drainage of the area is deeply-incised, and mainly flows eastwards and north-eastwards; in the north the main stream is the River Team and its tributaries, which flows generally eastwards from Stanley to Urpeth Bridge [NZ 235 542] where it joins the broad NNW-SSE Team Valley. The main drainage in the south of the area is accomplished by the Cong Burn and the Twizell Burn which join the meandering River Wear at Chester-le-Street. A major dry valley extends northwards from Chester-le-Street to join the Team Valley west of Birtley.

Apart from the scattered mining and quarrying settlements, industry and population are concentrated mainly along the Team Valley (including its extension southwards to the Wear valley at Chester-le-Street) and along its eastern shoulder. The main railway from London to Newcastle and Scotland also follows this valley, linking the main communities, and the main arterial north-south road lies a short distance to the east. Manufacturing industry is concentrated in the Team Valley Trading Estate north of Lamesley in the north of the area and at and immediately to the south of Birtley in the east-centre of the area. Few of these industries depend on locally-produced raw materials. Other manufacturing industry is now being established on the western fringes of Washington New Town on the high ground east of Birtley. The main physical features and settlements of the area are shown on Fig. 1.

## GENERAL GEOLOGY

The area is underlain by gently-dipping Westphalian Coal Measures strata near the western edge of the Northumberland and Durham Coalfield. Solid rocks are exposed only patchily because drift covers most of the area and locally exceeds 60 m in thickness. A sketch map of the solid geology of the area and the outcrop of the main coal seams is shown in Fig. 2.

Details of the distribution, nature, conditions of deposition and sedimentology of Carboniferous strata in north-east England are outlined in publications such as Taylor et al. 1971, and full descriptions of the Coal Measures of the Tynemouth District and of the Durham and West Hartlepool District were given by Land (1974) and Smith and Francis (1967).

(a) Exposure of Coal Measures rocks and drift deposits

Areas shown as drift-free on the 1:10 000 maps commonly have a cover of up to 1.8 m of drift deposits and exposures of rock are relatively uncommon in these areas. Coal Measures strata are exposed in places in the lower part of the incised valleys of several of the minor streams, both in the west of the area and in the south-east, but many areas shown as being cut into solid rock have a veneer of slipped clay from the overlying drift and so the rocks themselves are exposed only locally. The quarrying of sandstone, particularly on Gateshead Fell, formerly afforded many excellent sections that also included coals and other strata, but with the decline of the quarrying industry many of the old workings have now been filled and sections are no longer available; the best exposures of Coal Measures rocks now are in periodic opencast coal workings. Temporary exposures were created during the construction of several of the main roads and railways in the area but most of the these exposures were subsequently graded and grassed-over or are otherwise obscured.

The drift deposits are rather more widely exposed than the Coal Measures, having been widely worked for brick clays, sand and gravel. Although many such workings have been abandoned and are either flooded or filled with refuse, brick clays are still worked in the southern extension of the Team Valley and sand and gravel are locally still visible in the sides of old workings; unfortunately, the method of exploiting brick clays by scraper rarely affords good sections, and the best sections in the clay pits are created by landslips or by the digging of excavations for other purposes. Excellent sections in the drift are also to be seen in the sides of opencast coal workings, although these are mainly in areas where drift is relatively thin and comprises mainly boulder clay; much information on the drift deposits has also been derived from the examination of temporary exposures created during the construction of, for example, the Durham Motorway, some of the factories at Washington, the courts at Chester-le-Street and the swimming baths at Birtley.

(b) Geological Sequence and Classification

The drift (superficial) deposits and solid formation shown on the maps and generalized vertical sections of Sheet NZ 26 are:

Drift (superficial) Deposits

| | |
|---|---|
| | Made Ground |
| Holocene | Landslip |
| | Alluvium - sand and silt with peat beds |
| Pleistocene | River Terrace Deposits - sand and medium to coarse gravel; some silt |
| | Upper stony clays - silty clay with mainly small stones; found chiefly in the east of the area |
| | Glacial sand and gravel - sand and gravels; locally contains discrete beds of clay or silt and lenses of stony clay |
| | Laminated glacial clay and silts - locally contains interbedded fine sands and stony clays; large boulders recorded at some levels |
| | Till - tough stony clay |

Solid Rocks

| | | |
|---|---|---|
| Upper Carboniferous | Westphalian C | bedded mudstones, siltstones and sandstones with thin seatearths and shales and up to 70 coal seams |
| | Westphalian B | |
| | Westphalian A | |

Strata here referred to Westphalian A comprise the former Lower Coal Measures and Westphalian B and C strata comprise the former Middle Coal Measures; most of the older geological literature on this area uses the earlier classification. Strata in the lower part of Westphalian A do not crop out and are known only from a few shafts and boreholes.

The generalized geological sequence is shown in Fig. 3 and is known mainly from shafts and boreholes; most of this information is old and the amount of detail varies widely. Much information also comes from mine plans, which are also of varied quality; the IGS mining records are indexed under the Six-Inch County Map Series and NOT on National Grid Sheets; for ease of reference, the key to the Six-Inch County maps contained within the area of NZ 25 is shown on the bottom right hand corner of each map.

For an overall view of the workings in each seam the Six-Inch National Grid Plans of the N.C.B. may be consulted by arrangement with offices of the Board, but for detail the original plans must be consulted; a small charge is made for such consultation in the case of plans of working collieries.

(c) Nomenclature

The main coal seams have been assigned an index letter by the N.C.B., mainly for the purposes of uniformity throughout the coalfield, and the names of the coals are now largely standardized. Many of the coals had local names and these have been shown in brackets on the sections on some of the maps; some of these traditional names were also used on the older geological maps of the area.

## SOLID ROCKS

(a) General

Pre-Westphalian strata have not been recorded in this area. The deepest borehole penetrates only about 30 m below the Ganister Clay seam within the Lower Coal Measures of Westphalian A.

The Westphalian rocks comprise rhythmic sequences of shales, mudstones, siltstones, sandstones, seatearths and coal. The shales and mudstones are commonly ribbed by ironstone nodules. Coal forms only a small part of the sequence but the 14 seams that individually locally exceed 2 m in thickness dominated the local economy. Almost the entire area has been undermined by coal workings at various levels (Figs. 4A-D). Sandstone has been worked locally for building, as at Causey Arch and in many quarries around Wrekenton and Springwell, and there was once a thriving grindstone industry; almost all the sandstone quarries are now disused.

(b) Details

(i) Westphalian A strata (Victoria seam to Harvey Marine Band): The Westphalian A rocks encountered in boreholes on this sheet include the following named units:

| | N.C.B. Index Letter |
|---|---|
| Harvey Coal | N |
| Tilley Group of coals (commonly four) | P |
| Busty Coal (usually split into Top and Bottom) | Q |
| Three-Quarter Coal | R |
| Brockwell Coal (usually split into Top and Bottom) | S |
| Victoria Coal(s) | T |
| Marshall Green | U |
| Ganister Clay | |

Strata below the Victoria Coal are known from only a small number of boreholes which suggest that the sequence is sharply varied and that several thick sandstones are locally present; none of the coals exceeds 0.5 m in thickness and, in the absence of diagnostic fossils, their correlation is uncertain. The lowest beds proved are thought to lie about 20 m above the Quarterburn Marine Band which marks the local base of Westphalian A.

The Victoria Coal has been proved in shafts and boreholes throughout NZ 25. It is thickest, up to 0.6 m, in the area around Craghead, but elsewhere is generally less than 0.3 m; in the Ravensworth Park area and some other parts of the sheet it is split into two or more thin seams.

The Brockwell Coal is widely divided into two or more seams with an aggregate thickness ranging from 0.5 m to more than 2.5 m; individual leaves commonly exceed 1 m in thickness. The united seam has been worked from Ouston Colliery, west of Birtley, and from Marley Hill Colliery, and most workings are in the west of the sheet; both main leaves have been worked in places, but most of the workings are in the Bottom Brockwell.

The Three-Quarter Coal, though generally banded and comprising less than 1 m of coal, has been worked from Ravensworth Colliery in the district north-east of Birtley for an area of about 1 square mile extending northwards to Eighton Banks and has also been worked westwards from Washington Colliery under the area of Washington Moor.

The Busty Coal is the lowest of the widely worked seams of the local Coal Measures; in places, as at Beamish, it is a united seam with only thin shale bands, but in much of the area it comprises two main leaves (the Top and Bottom Busty coals) separated by up to 10 m of mixed strata in which sandstone is locally predominant. Around Beamish and Pelton the united seam ranges to 1.8 m thick but neither the Bottom Busty nor the Top Busty generally exceeds 1 m in thickness. The Bottom Busty has been worked mainly in the west of the area but workings in the Top Busty are much more extensive and include considerable areas in the east of the area where the seam has been completely exploited; there are no workings in either of the Busty seams in a broad belt stretching south from Gateshead Fell to Portobello and Harraton, and this unworked belt thence extends southwards beneath the eastern parts of Lambton Park and Lumley.

The Tilley group of coals occur as two to four thin coals although in some places, as at Allerdene Pit, the Tilley is a single composite seam. One seam generally is thicker than the others and ranges to 0.45 m. The Tilley coals have been worked in a central belt from the outskirts of Gateshead southwards to

Waldridge and Edmondsley, and in a salient extending southwards to Birtley; it has not, however, been worked under the southern extension of the Team Valley between Ravensworth and Chester-le-Street and beyond, nor has it been worked anywhere in a belt 2 - 3 km wide along the eastern side of NZ 25.

The Harvey Coal is a good quality clean coal that is generally not split but only locally exceeds 1.2 m in thickness. Despite its general thinness, however, it has been widely worked in the south-west of NZ 25, particularly in the area of Pelton and to the west of Chester-le-Street. Workings are also extensive in the north-east of the area but the seam has not been worked in the south of the area east of the main north-south railway. Because of the high quality of the coal it was widely worked where as little as 0.45 m thick and a good average thickness for many workings was 0.6 m.

(ii) Westphalian B and C strata: Westphalian B and C strata include the following named units:

| | N.C.B. Index Letter |
|---|---|
| Hebburn Fell Coal | A |
| Usworth Coal | B |
| Ryhope Marine Band | |
| Hylton Marine Band | |
| Kirkby's Marine Band | |
| Crow Coal | |
| Ryhope Five-Quarter Coal | C |
| Ryhope Little Coal | D |
| High Main Marine Band | |
| High Main Coal | E |
| Metal Coal | F1 |
| Five-Quarter Coal | F2 |
| Main Coal | G |
| Maudlin Coal | H |

| | N.C.B. Index Letter |
|---|---|
| Durham Low Main Coal | J |
| Brass Thill Coal | K |
| Hutton Coal | L |
| Ruler Coal | M |
| Harvey Marine Band | |

The Harvey Marine Band, a marine shale or mudstone containing Lingula, is the lowest member of Westphalian B and of the former Middle Coal Measures: strata above and including the Ryhope Marine Band form part of Westphalian C. Strata between the Harvey Marine Band and the Hutton Coal commonly include several thin coals but in places these have been washed out by extensive thick sandstone. Only the Ruler Coal is named and this is generally thin and locally absent; none of the coals has been worked.

The Hutton Coal is one of the major worked seams of the coalfield and has been worked out almost completely (Fig. 4A); it is an extremely uniform coal and locally is more than 2.5 m thick; it is generally 1.3 to 1.6 m. Because of its thickness and uniformity, the Hutton was one of the earliest seams to be worked and there are no detailed records of many of the earlier workings. It crops out low on the slopes of the deeply incised valleys in the west of the area and also crops beneath thick drift in parts of the deep buried valley between Chester-le-Street and Birtley: in places here it appears that some very old deep workings actually reached the sub-drift outcrop.

Although the Brass Thill Coal commonly comprises three separate thin coals in much of the Northumberland and Durham Coalfield, on NZ 25 the Brass Thill widely comprises a thick workable upper leaf (the Top Brass Thill) and a widespread much thinner lower leaf, the Bottom Brass Thill. The Top Brass Thill is widely 0.7 - 1.2 m thick although a thin shale bed is widespread towards the base of the coal; as with the Hutton Coal, the Brass Thill has been extracted from almost all the area of NZ 25 (Fig. 4B) although the area where the seam has been eroded by the cutting of the deep sub-drift valley between Team and Chester-le-Street is considerably more extensive. In the north-west part of the sheet, around Marley Hill and to the north, the Top Brass Thill rises to join the Durham Low Main; the compound seam locally exceeds a thickness of 2.5 m and is extensively worked. In the north-east of the area, around Springwell, the Top Brass Thill is strongly banded and the lowest leaf ("the Middle Brass Thill") is worked alone in some places. Where separate from the Brass Thill Coal, the Durham Low Main Coal is a single seam commonly 0.9 m - 1.4 m thick. It has been worked fairly extensively in the south of the sheet and more patchily in the north (Fig. 4C) but only small areas of this coal have been worked in a belt stretching across central parts of the sheet and in the north-east: coal eroded along the course of the Team to Chester-le-Street buried valley is more extensive than in the Brass Thill seam. The Durham Low Main Coal is widely overlain by a thick sandstone which lies on an erosion surface that locally cuts down through the Durham Low Main Coal and even the Brass Thill Coal to produce extensive washouts. This sandstone, the Low Main Post, has been extensively quarried in the past for building stone. Both the Brass Thill and the Durham Low Main Coal have been worked in a number of opencast pits in the west of the area.

The Maudlin Coal, one of the most widely worked and consistent seams in the northern part of the Durham Coalfield, is rather variable in the area of Sheet NZ 25. It is relatively thick (1.2 m - 2 m) in the north and east of the area but is patchy and widely split into two or more leaves in the west of the area. Where the Maudlin Coal is absent, its place is taken by a thick sandstone which in some places extends down to unite with the Low Main Post. Workings in the Maudlin Coal are concentrated in the east of the area and the seam has been extracted almost completely to the east of the Team to Chester-le-Street buried valley; many of the workings are old and the information here is sparse and in places perhaps unreliable.

The Main Coal is the lowest of the major workable seams to reach surface widely in the west of NZ 25 (Fig. 2); where present it has generally been almost completely worked out but the seam is generally of poor quality in much of the area between Pelton and Chester-le-Street and here only limited patchy working has taken place. By contrast, the seam is present everywhere on the east side of the Team to Chester-le-Street buried valley and, apart from a few small pockets, has been worked out almost entirely here; the coal is consistently 1.6 - 1.8 m thick in this area and also in parts of the west of the sheet and locally exceeds a thickness of 2.2 m. The Main Coal has been worked opencast at a number of places around its outcrop in the western part of the sheet.

The Five-Quarter coal is of limited extent in the west of the sheet but is present everywhere to the east of the Team to Chester-le-Street buried valley. Underground workings are accordingly limited in the west although several opencast sites have exploited the seam at outcrop where it is of the order of 0.6 m - 1.0 m thick. A similar thickness is widespread to the east of the buried valley, where the Five-Quarter coal has been largely worked out in a belt about 2 km wide stretching from the southern outskirts of Gateshead south-south-eastwards to Portobello and then southwards down the eastern margin of the sheet. The seam has not, however, been worked under a wide tract of country in the north-east, mainly around and to the north of Springwell and, farther south, under Washington Moor. A small opencast site worked the Five-Quarter north of Portobello.

The Metal Coal is generally thin in the area of NZ 25, and crops out in the west in only a few limited areas where it has been worked opencast. The seam is generally less than 0.5 m thick but locally reaches 0.9 m. Farther east the seam is widely present but is commonly divided into a thin upper leaf and a lower leaf that ranges from 0.5 - 0.7 m in thickness. East of the Team to Chester-le-Street buried valley the Metal Coal was mined from Ravensworth Colliery in an irregular belt extending SSE from west of Wrekenton to the north-eastern outskirts of Birtley, and may have been worked from several old shafts on the rising ground east of Birtley. It was worked opencast at a site north of Portobello.

The High Main Coal, which on Tyneside was the mainstay of the early coal industry of the region, is widely split into two leaves (Bottom and Top High Main), neither of which are widely of workable thickness. The seam has, however, been worked in roughly W-E belts beneath Beamish and Craghead (Fig. 4D) and from a number of opencast sites where it locally reaches a thickness of 1.1 m. East of the main buried valley the two leaves of the High Main Coal are sufficiently close for the seam to be worked as a single unit in a limited area west of Wrekenton and Eighton Banks, and the seam has also been worked over an area of about 4 square kilometres from Springwell Colliery, mainly in the area to the north of Springwell village. The Bottom High Main and part of the Top High Main were also worked opencast in a small down-faulted trough north of Portobello. A thick and massive sandstone, the High Main Post, widely overlies the High Main Coal, as in the area to the north.

The coals and marine bands above the High Main Coal are only poorly known in the west of the area but are more extensive and better known to the east of the buried valley. The Bottom Ryhope Little has not been worked from deep mines anywhere on the sheet but has been opencasted at sites near Craghead, Edmondsley and east of Portobello. It is a thin coal, generally less than 0.6 m thick. The Top Ryhope Little is generally even thinner than the Bottom Ryhope Little Coal and has not been worked.

The Ryhope Five-Quarter Coal is, like the underlying Ryhope Little coals, generally thin and unworked; it has, however, been worked at a small number of opencast sites south-west of Craghead in the south-west corner of the area. The Ryhope Little coals and the Ryhope Five-Quarter coals may have been worked on the high ground east of Birtley from shallow shafts and bell pits but such workings are inadequately documented. The highest seam of the area, the Crow, crops out in the south-west of the sheet and was opencasted near Craghead Colliery where it was up to 0.68 m thick. This coal has not been recorded with certainty east of the buried valley.

Strata above the Crow Coal include Kirkby's Marine Band, the Hylton Marine Band and the Ryhope Marine Band, each of which generally overlies a thin coal but none of which have been proved within the area of NZ 25; the highest strata in the area comprise the Usworth and Bottom Hebburn Fell coals, which are thought to crop out in the extreme north-east corner; the Usworth seam is probably thin but the Bottom Hebburn Fell may be up to 1 m thick.

(c) Structure

The geological structure of the Coal Measures of NZ 25 is relatively simple. The area lies on the west limb of the Boldon Syncline and strata dip generally eastwards and east-north-eastwards throughout most of the sheet, but the strike swings to WNW - ENE in the extreme south; dips lie generally in the range of $3^{\circ}$-$5^{\circ}$ (1 in 19 to 1 in 11) but the dip diminishes to $2^{\circ}$ or less in some places and increases to $6^{\circ}$ elsewhere. The overall dip is steepest, generally about $6^{\circ}$, in the north-east of the area.

The area is crossed by two main sets of faults, almost all of which are of small displacement; the two sets of faults trend roughly NNW - SSE and WSW - ENE. Neither fault trend appears to be dominant. Displacements of 2 - 10 m are common but there are some exceptions and the Portobello Fault locally throws down to the south by as much as 60 m. A group of faults in the south-east corner of the area, in the area of Lumley, trend generally west-east and do not fit the general pattern. Other variations from the general pattern lie in the vicinity of several of the faults, where strikes locally change sharply to accommodate equally sharp changes in the displacement along fault lines.

The structure of NZ 25 NE is representative of that of NZ 25 as a whole and is summarised in Fig. 5.

(d) Commercial uses of Coal Measures rocks

(i) Coal: Exploitation of coal, at first by bell pits high on Birtley Fell and elsewhere, and later from many shafts and a few drifts, dominated the commercial economy of the area from the latter part of the eighteenth century to the middle of the twentieth century. During this period almost all the coal seams of workable thickness were exploited somewhere or other within the area of the sheet, and several of the thicker seams were worked out almost completely. The mines of the area witnessed the era of great expansion connected with the Industrial Revolution and, in later years, the traumas of pit closures as workings became uneconomic or seams were exhausted; with the closure of Marley Hill Colliery early in 1983, deep mining in the area of NZ 25 came to an end although workings are still active from collieries at Bearpark and Sacriston a short distance to the south. Although much coal undoubtedly still remains, particularly in areas of former pillars and in places where isolated patches of coal were cut off by faults and other geological structures, it is unlikely that deep mining will ever again be a commercial proposition. It remains possible, however, that small-scale mining from relatively shallow shafts and driveages may profitably exploit remaining areas of coal where these are fairly close to the surface; constraints imposed by the restrictions of urban development in the area probably confine such enterprises to the western part of the area.

The evolution of the coal mining industry in the area immediately to the north of NZ 25 has been discussed in detail by Richardson (1983) and he also discussed the interaction and the needs of urban redevelopment; many of his comments are equally relevant to the problems of NZ 25.

In addition to deep and drift mining of coal in this area, most of the seams that crop out have been worked opencast, mainly in the western and central parts of the area. Opencast mining began during the early 1940's and restored opencast sites are widely scattered (Fig. 7). Some of these sites exploited the thicker coals of the main productive Coal Measures, especially those parts that were too near the surface to have been worked by deep mining, but some of the sites also worked thin seams higher in the sequence where these were close enough to the surface and of sufficient aggregate thickness for them to be worked profitably. Only one site is currently active but a programme of future workings (subject to detailed planning decisions) will be the subject of agreement between the National Coal Board and the several local authorities. There is also some potential for the opencast working of small sites by independent operators.

(ii) Sandstone: Gateshead Fell was once one of the most important sources of grindstones in England and a thriving industry based on quarries in the north-east of the area and adjoining parts of sheet NZ 26 worked sandstones such as the "Grindstone Posts" between Kirkby's Marine Band and the Usworth Coal. Most of these quarries also worked stone for building purposes, especially before the widespread development of brick-making from glacial clays, and this use became predominant as the trade in grindstones waned. Almost all the quarries in sandstone are now closed, only the workings at Springwell being currently in large-scale operation.

There are no commercial workings of other Coal Measures strata such as shales, mudstones and fireclays.

(e) Engineering characteristics of Coal Measures rocks

The following extract is from the account by Richardson (1983) and refers specifically to the area immediately to the north of NZ 25. It is reproduced here because the strata on NZ 25 and NZ 26 are essentially the same and Richardson's comments are therefore almost equally applicable to the present sheet.

"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 (notable Kirkby's and Ryhope); the massive sandstones have been extensively quarried for building stone and grindstones.

Excavation and tunnelling in Coal Measures sandstones present 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."

## THE ROCKHEAD SURFACE

The rockhead surface of NZ 25 is summarized in Fig. 6. The relief of this surface is appreciably greater than that of the modern land surface, mainly as a result of the infilling of several preexisting river valleys which, in general, are sub-parallel with the existing drainage. Drift is relatively thin over much of the area, especially on the more elevated parts, but is particularly thick, locally more than 60 m, in the deep NNW-SSE buried valley between Team and Chester-le-Street. The most striking feature of this valley, the floor of which is in several places below Sea Level, is the presence of several apparently closed elongate hollows in the floor. The lower courses of the tributary buried valleys have been truncated at the point where they join the main NNW-SSE valley and have been left hanging; this applies not only to the buried valleys of the proto-Team and proto-Twizell Burn in the west but also to a major buried valley that trends roughly west-east through Lambton Park to join the main buried valley of the proto-River Wear at Fatfield on neighbouring Sheet NZ 35.

The history of the evolution of this diverse rockhead surface has been long and complex; the major drainage lines were probably developed before the Pleistocene Period, but were profoundly modified during several glacial and interglacial episodes. Ice sheets are thought to have covered the area at least twice and on each occasion large quantities of regolith and underlying rock were doubtless removed from large parts of the area. The origin of the major NNW-SSE buried valley from Team to Chester-le-Street is uncertain but it is thought that it may have originated, at least in part, by the erosive action of highly pressured meltwater flowing beneath thick ice.

## DRIFT DEPOSITS

The drift deposits of the area are divisible into the glacial sediments that are present over almost the entire area and younger alluvium that lies mainly along the valleys of the present drainage courses. The glacial sediments mainly comprise several varieties of till, laminated silts and clays, and sand and gravel; the alluvium of the main valleys is mainly of silt and sand but up to

2 m of peat have been recorded in places.

(a) Details of the drift deposits

The broad characteristics of the main drift deposits of NZ 25 are listed below; for further details of the engineering and other characteristics of some of the main types of drift see Richardson 1983 (p. 20-23).

(i) Tills (Boulder Clays): A sheet of boulder clay ranging up to about 10 m in thickness rests on rockhead almost throughout the area, being absent only on some of the higher fells such as parts of Gateshead Fell and in the bottom of several of the deeper buried valleys; this clay is the Durham Lower Boulder Clay (Smith 1980) and is a dark brown or grey-brown tough clay with many fragments of Coal Measures sandstone, siltstone and shale and with a small proportion of boulders of rock derived from the Tyne Valley and from areas farther to the west and north-west. It has a high bearing strength and poses few problems in excavations. Locally, however, it contains lenses of sand and gravel that may be water-bearing.

Stony clay with a strong superficial resemblance to the Durham Lower Boulder Clay is present in places along the margins of the main NNW-SSE buried valley and is thought to be a flow till; it forms lenticular bodies interbedded with laminated clays and sands. Despite its resemblance to the widespread boulder clay at the bottom of the drift sequence, this stony clay has a considerably lower bearing strength but nevertheless provides an adequate footing for most structures. A third type of stony clay is widespread on some of the higher sandstone fells of the area, where it is widely up to 2 m thick; it is a very sandy deposit with many fragments of degraded and weathered sandstone and it may be mainly a weathering product associated with local downhill mass movement. A fourth type of stony clay is widely present on the high land east of the main buried valley; this deposit is commonly 1-2 m thick and is a slightly reddish brown silty clay with scattered mainly small stones similar to those in the Lower Boulder Clay. This deposit is the westernmost edge of the widespread

Pelaw Clay of Tyne and Wear and is a relatively weak deposit that affords poor footings for heavy structures and is unstable in excavations.

(ii) Laminated silt and clay: Apart from patchy Lower Boulder Clay on the flanks and gravel along some of the deepest parts of the floors, almost all the fill of the deep buried valleys comprises laminated silts and clays. The deposit is generally exceptionally uniform but scattered stones are present at some levels and boulders up to 2 or more metres across have been recorded. Lenses of stony clay (see above, under till) are present in places near the margin of the buried valley and, as noted above, the deposit passes upwards by alternation into a sheet of sand up to several metres thick that is now preserved mainly at the sides of the valley. Laminated silt has also been recorded over small areas at various levels in the main till sheet.

The shear strength of the laminated clay and silt of the Team Valley and other parts of NZ 25 ranges from low to moderate according to whether it is moist or dry. On the valley floor where the water table is close to the ground surface, the clays are generally weak, with a shear strength commonly ranging from 500 to 1500 cu $lb/ft^2$. Under vertical load the clays are prone to strong compression and ductile flow, and foundations need to be specially designed to overcome this weakness; the insertion of slab foundations or the placement of piles to rock or to the boulder clay at the base of the till sequence is generally necessary for heavy structures. The laminated clay and silt has a low safe angle of rest and excavations in these deposits generally need close support; tunnelling and the excavation of shafts is moderately hazardous where these deposits are dry but calls for extreme care where they are water-bearing and therefore highly prone to fluidization and ductile flow. A number of heavy structures on similar deposits elsewhere in north-east England have failed during the last few years and great difficulty has been experienced during the digging of, for example, main sewer trenches.

(iii) Sand and gravel: There are patches of sand and gravel unevenly distributed throughout the area of NZ 25; they were deposited during the glaciation and deglaciation of the region, mainly from transient streams that carried out sand and gravel from the melting ice. The former presence of such streams is indicated by the presence of lenses and channels filled with sand and gravel in the main spreads of boulder clay, as, for example, at two places [NZ 217 512 and NZ 221 521]. Such lenses of gravel may be complex, ranging from coarse angular gravel formed mainly of fragments of Coal Measures sandstone to fine to medium-grained quartz sand; exceptionally the sand may pass into laminated silt. The isolated deposits of sand and gravel are commonly underlain by the Durham Lower Boulder Clay; thus, for example, a borehole [NZ 2178 5216] north of Craghead passed through 13.25 m of sand, gravel and laminated silt before reaching the boulder clay.

The thickest sequences of sand and gravel lie in a belt trending NW-SE from Grange Villa [NZ 232 521]. This was probably deposited by braided streams during a prolonged halt stage during the retreat of the main ice sheet from which the Durham Lower Boulder Clay was laid down. Within this belt there are two elements; the lower part is up to 30 m thick and mainly comprises well-sorted cross-bedded sands and silts with thin clays, whereas the upper part mainly comprises coarse and medium subangular to angular gravel which ranges up to c 3 m in thickness. The interbedded silts and sands pose a particular problem for major construction works in valley sides and should be avoided wherever possible.

Although coarse gravel overlies sands and silts in most of the larger areas of sand and gravel indicated on the map, in places the sequence is considerably more complex and comprises alternations of stony clay (till), gravel and sand. For example, a borehole [NZ 2082 5650] proved 88 m of sands, gravels and stony clays before reaching rockhead, and probably represents a channel-fill sequence within the main outwash sheet.

In addition to the patches of sand and gravel, fine-grained almost stoneless sand up to 3 m thick occurs widely along the margins of the broad valley between Team and Chester-le-Street, widening out to form a considerable spread between Chester-le-Street and Pictree [NZ 281 531]. Where exposed in the sides of several clay workings in the valley near Birtley and Ouston, this sand is seen to pass down by alternation into the laminated silts and clays of the floor of the buried valley. The presence of clay layers within this sand and of local perched water may combine to create difficulties in excavations in this deposit.

(iv) Alluvium and peat: Thin deposits of alluvial silt and sand form narrow tracts in several of the minor valleys in the west of the area and overlie the laminated clays of the Team Valley and much of its southwards extension towards Chester-le-Street. Alluvium also forms considerable spreads along both sides of the River Wear in the south of the area but forms only narrow tracts alongside the river where it passes through the gorge in Lambton Park. None of this alluvium appears to be more than a few metres thick and it is unlikely to present severe problems to constructional engineers. Peat, however, is locally present up to a thickness of 2 m in the alluvium and its possible presence must be anticipated in planning engineering works near to drainage courses. Peat is also present in many small patches scattered unevenly across NZ 25; it is most common in hollows on sand or on the sheets of till, where it was formed by the infilling of ponds formed during and after the retreat of the ice. A good example of such a peat-filled hollow lies [NZ 225 519] north of Twizell Wood.

(v) Made Ground: Made ground is extensive on NZ 25 (Fig. 7) and is shown in detail on the 1:10 000 maps; it has not generally been depicted where blanket spreads of urban rubble occur beneath many of the old settlements, nor has it generally been shown where it is less than 2.5 m thick. The made ground takes a variety of forms; it includes industrial and domestic waste, spoil from quarries and from coal workings, chemical waste and areas of landscaped fill.

Much of the industrial waste and quarry and colliery spoil is in artificial mounds, the position and extent of which are well known. In places, however, such spoil heaps have been landscaped and their extent and thickness has been considerably blurred. In addition to the tipping of waste on ground adjacent to collieries and other mineral workings, much waste has been tipped into abandoned clay pits, sandstone quarries and other excavations; the character, extent and thickness of these deposits are poorly known and the careful study of records such as old maps and the sinking of exploratory boreholes are an essential precaution in the planning of any engineering works in areas where such made ground may be encountered. Some of the abandoned sandstone quarries and clay pits were more than 10 m deep and would promote strong differential settlement of any structures built across their edges. It is possible that some old sandstone quarries and clay pits were opened and filled between the various editions of the Ordnance Survey maps and that no record of their existence exists; their possible presence should be anticipated in areas where sandstone crops out (as on Gateshead Fell and around Wrekenton) and where laminated clay is the surface deposit (chiefly in the valley between Team and Chester-le-Street).

Backfilled opencast coal workings are extensive and numerous on NZ 25 and differ from most other infilled workings in that they are filled almost entirely with the spoil that was originally taken from them; the position and former depth of these excavations are well known and because of this they should not be a major hazard in the planning and implementation of major engineering works.

(b) <u>Commercial uses of the drift deposits</u>

(i) Sand and gravel: The sand and gravel of NZ 25 has been worked on a generally small scale from pits concentrated in the western part of the area; none of these were being worked at the time of the survey.

The largest resource of natural sand and gravel for use as aggregate in the construction industry lies in the belt of glacial outwash described in the previous section. It extends from the neighbourhood of Tribley [NZ 240 510] through Grange Villa and Low Stanley [NZ 2152] and thence northwards to the vicinity of Beamish

Hall [NZ 211 549].

(ii) Brick clays: The laminated silt and clay of the southwards extension of the buried valley of the River Team have been extensively worked as a source of brick clay for many years; the main workings have been in the vicinity of Birtley, and exploitation continues. The deposits are thick and relatively easily worked and reserves are sufficient for a considerable period at the present rate of extraction. The main constraints on future exploitation of these deposits are posed by their proximity to industrial and commercial premises and to housing developments.

The abandoned brick clay workings have provided cheap local receptacles for domestic and industrial waste and most have now been restored; future workings are likely to be similarly used, although the creation of amenity areas is another possible use for these large water-filled excavations. The deposits in which the pits have been dug are relatively impervious and waste deposited in them is unlikely to cause other than purely local contamination.

## LANDSLIPS

There have been relatively few landslips in the past in the area of NZ 25, and all have been in the drift deposits; landslipping is unlikely to form a major hazard either to existing structures or to future projects but cannot entirely be discounted. The landslips that have occurred are mainly on the steep banks of deeply incised streams, where slopes through interbedded laminated clays, silts and sands have been oversteepened and undercut by stream action. Such slips have been recorded on the banks of the River Wear [NZ 277 503] near Chester-le-Street, on the sides of the deeply incised river valley of the Cong Burn between Waldridge and Pelton Fell Bridge, and on the steep flanks of the Twizell Burn and Beamish Burn. Slipping is a potential hazard wherever slopes cut into these interbedded clays, silts and sands are artificially steepened by the excavation of trenches and cuttings or where previously stable slopes on such deposits are loaded or their natural drainage is impeded or otherwise changed.

## WATER SUPPLY

The water requirements of the area are now met almost exclusively by water piped in from adjoining areas, mainly to the west, and from the River Wear. The natural drainage of the area has been extensively modified by pumping of coal workings and the water table was thereby lowered considerably. With the ending of pumping now that most deep coal mining has ceased, the level of groundwater is gradually rising and it is possible that future supplies might be obtainable from Coal Measures strata (especially the coarse-grained sandstones) that for 200 years or so have not been used for this purpose. The presence of incompletely collapsed workings and infilled shafts may considerably influence the local groundwater flow patterns.

There is no known current extraction of water from the drift deposits of NZ 25, although some of the bedded sand and gravel deposits probably have a small supply potential. Water in the drift deposits is mainly important because of the effect is has on the stability of these deposits in excavations; where, for example, it is present in sands interbedded with the laminated clays in the Team Valley and its southwards extension, the presence of substantial amounts of water within the sequence considerably weakens the clays and sharply decreases their strength in the walls of excavations. Local perched water tables are present in sands of the buried valley-fill, and lie well above the local water table in the Coal Measures rocks.

Because water from Coal Measures strata in the area has not been used in historic times for drinking purposes, it has not been necessary to consider in detail the local groundwater flow as a factor in the choice of sites for the disposal of domestic and industrial wastes; if future use of water from these strata is to be considered, it is essential that future groundwater regimes should be considered when choosing future landfill sites.

## GEOLOGICAL CONSTRAINTS ON PLANNING

Although each potential development site in NZ 25 has its own local problems that need to be assessed and overcome in the planning of future buildings or engineering works, geologically related factors impose relatively few major restrictions on large-scale planning. Details of the main local hazards have been itemised in the text, but are summarised here for convenience:

(a) Mining subsidence

Shallow and deep mine workings have taken place over almost the entire area of NZ 25 at some time in the past, but most of the workings are old and subsidence has long since been completed. Some subsidence is likely to continue over the most recent mine workings for a limited period, especially in the west of the area, but is then unlikely to recur and to remain a problem in the future. The major outstanding problem is the presence of unrecorded shallow workings in a number of places where drift is relatively thin and in the possible future collapse of workings that have hitherto remained open because of the existence of thick but brittle overlying sandstones which may, in time, founder. The possible presence of such workings and of continued episodic subsidence requires that careful examination of the ground conditions at future construction sites is essential in all areas where drift is relatively thin. By contrast, where drift exceeds c 10 m in thickness, it buffers the effects of differential subsidence which thus becomes a less important factor.

(b) Settlement of made ground

Because of the long history of extractive industry in the area of NZ 25, made ground is particularly extensive; much of it is poorly recorded and its character not known in detail and differential subsidence is likely to remain a hazard for many years. It is likely that some areas of fill are not shown on our maps and their possible presence (especially in the sandstone outcrops in the north-east of the area) must be taken into account.

(c) Weak ground

The laminated clays, silts and subordinate sands of the low-lying ground between Team and Chester-le-Street are generally weak and heavy structures founded upon them require special and expensive foundations. These deposits are inherantly unstable when wet and are likely to present considerable engineering problems in the sides of excavations.

(d) Sterilization of ground containing possible mineral reserves

(i) An area where sterilization might be prudent to facilitate the future extraction of sand and gravel aggregate is mentioned in the appropriate part of the text. The information available from surface mapping and from the few boreholes available is not sufficient to make a full assessment of the value of this deposit and a thorough assessment would be prudent.

(ii) Brick clays in the area west and south of Birtley are still being commercially exploited and reserves are adequate for many years at the current rate of extraction. On the assumption that the brick-making industry near Birtley will continue, adequate provision for the protection of the reserves must be made.

(e) Contamination by landfill

Disused brick-clay workings will continue to provide useful receptacles for local waste and the tipping of normal urban and non-toxic industrial waste appears to pose only a minimal health hazard. Wastes of low toxicity would also probably present little hazard. By contrast, the character of waste tipped into former sandstone quarries must be carefully considered in the light of the possible effects on groundwater in the area in years to come, when coal workings have declined further and the groundwater may be needed for domestic and industrial purposes.

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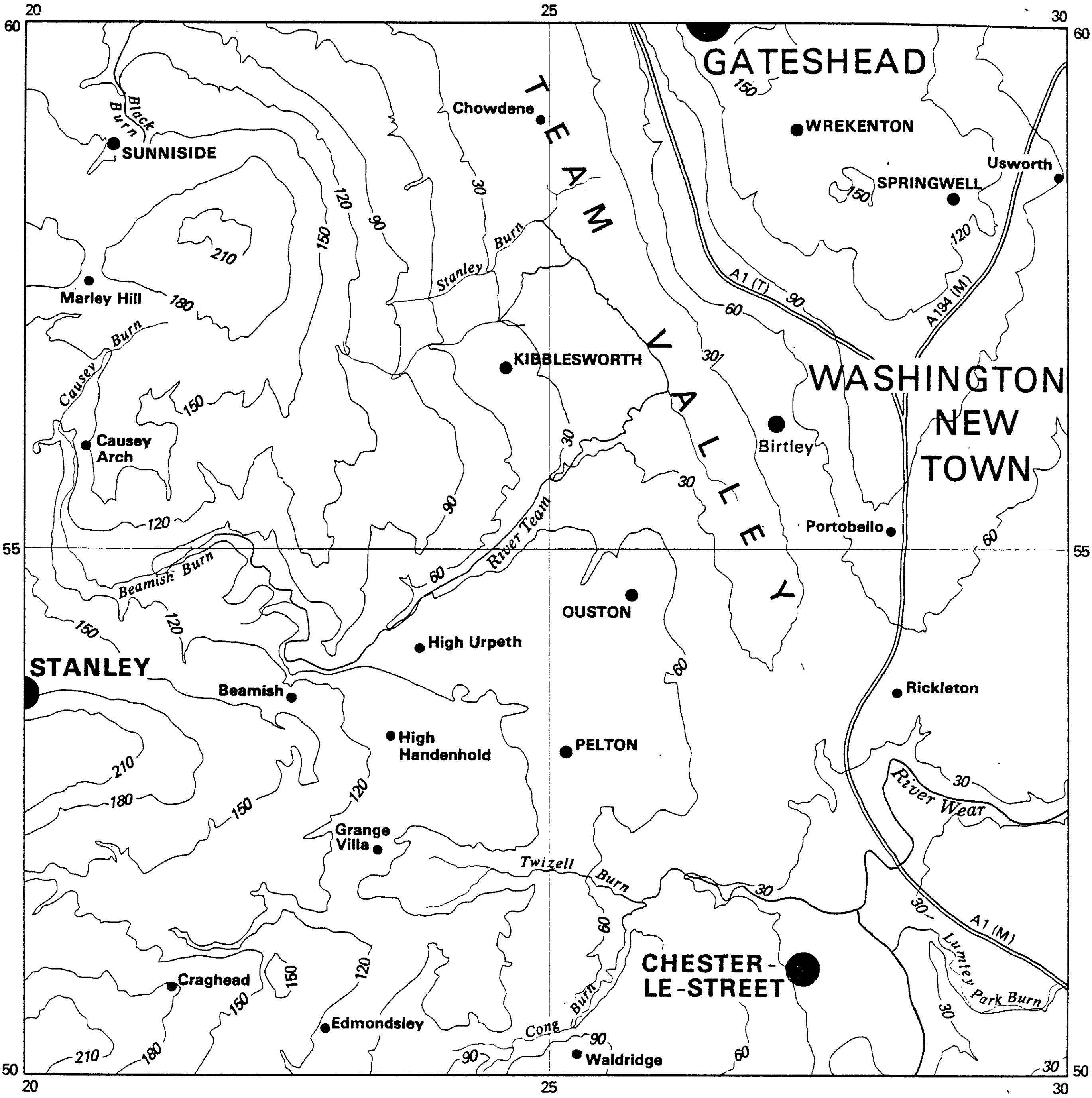
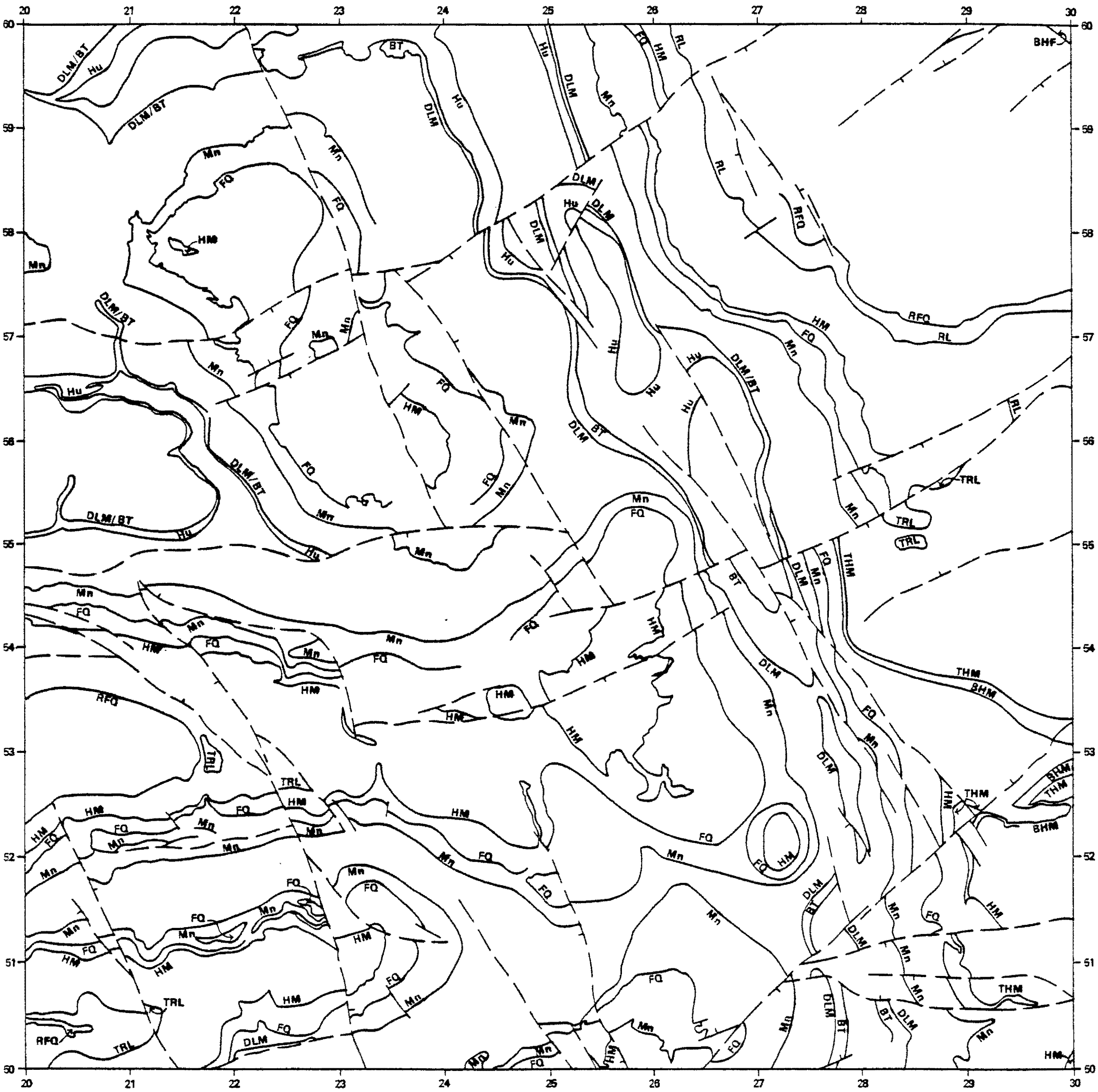



Fig. 1. Outline map of the area showing the main localities referred to in the text.




Faults. Tick mark on the downthrow side

0 500 1 1500 2 2500 3 km

Scale

Abbreviations:

| | | | |
|---|---|---|---|
| FQ | FIVE-QUARTER | BHF | BOTTOM HEBBURN FELL |
| Mn | MAIN | RFQ | RHYHOPE FIVE-QUARTER |
| BT | BRASS THILL | RL | RHYHOPE LITTLE (T & B) |
| Hu | HUTTON | HM | HIGH MAIN (T & B) |
| DLM | DURHAM LOW MAIN | | |

Fig. 2. Sketch map of the solid geology of NZ 25, showing selected coal seams

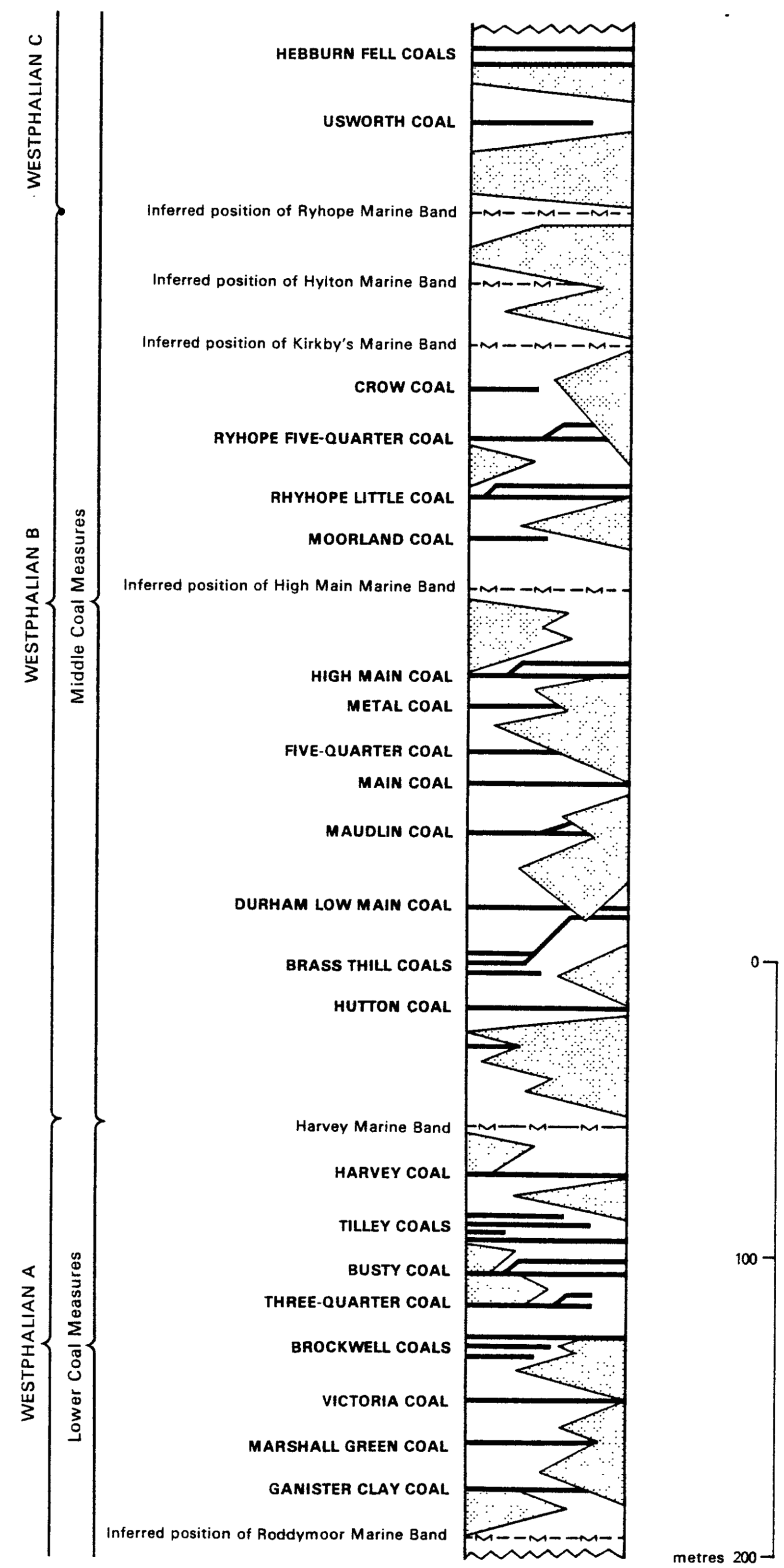



Fig. 3 Generalized sequence of the Coal Measures of NZ 25 showing major sandstones (stippled); for further details see the sections shown on the maps

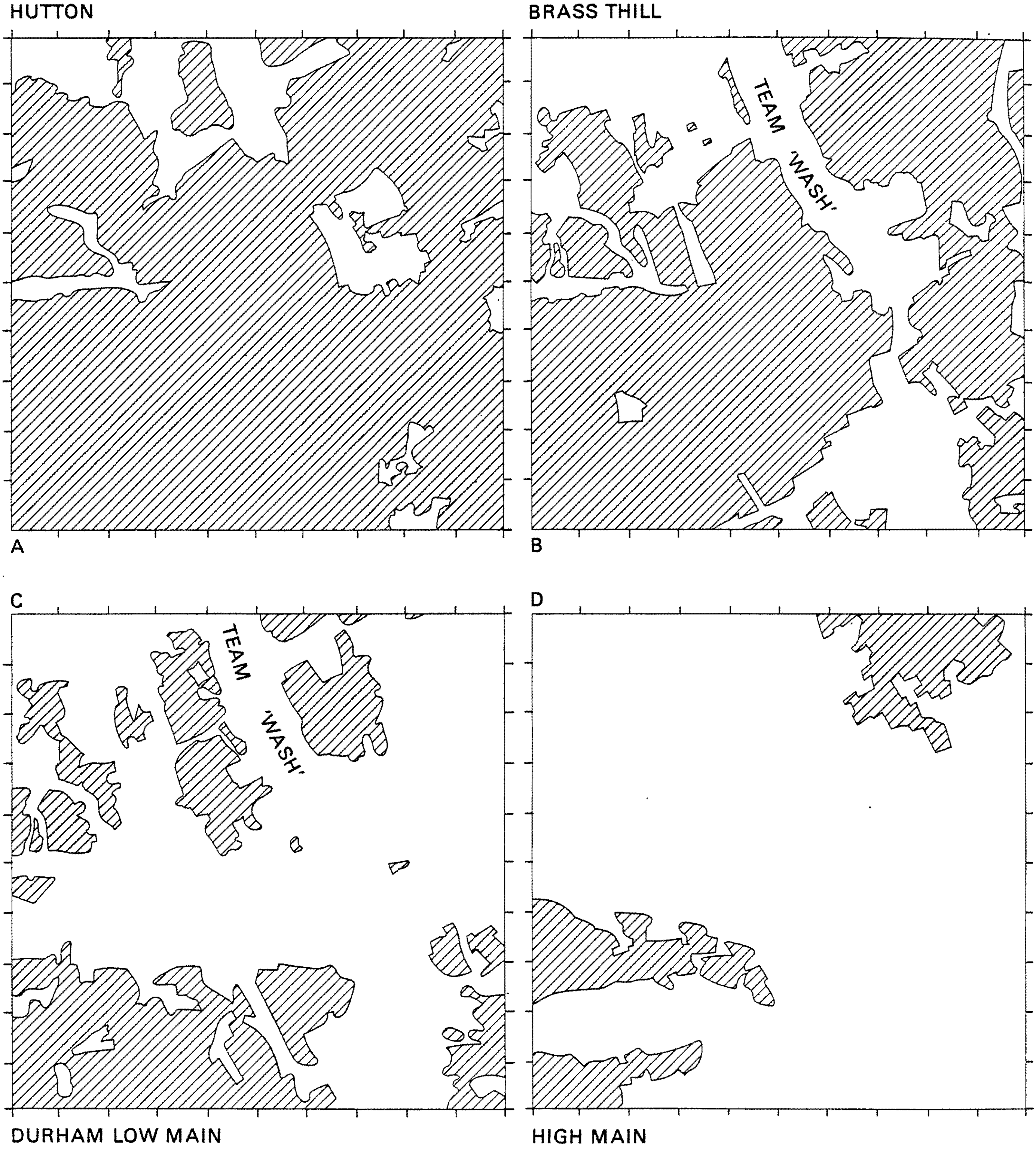



Fig. 4 Distribution of deep mine workings (shaded) in selected main coals. Note that the Top Brass Thill and Durham Low Main were worked together in some western parts of the sheet. For opencast workings see Fig. 7. The position of the deep buried valley between Team and Chester-le-Street is shown by its local miner's name of 'Team Wash'.

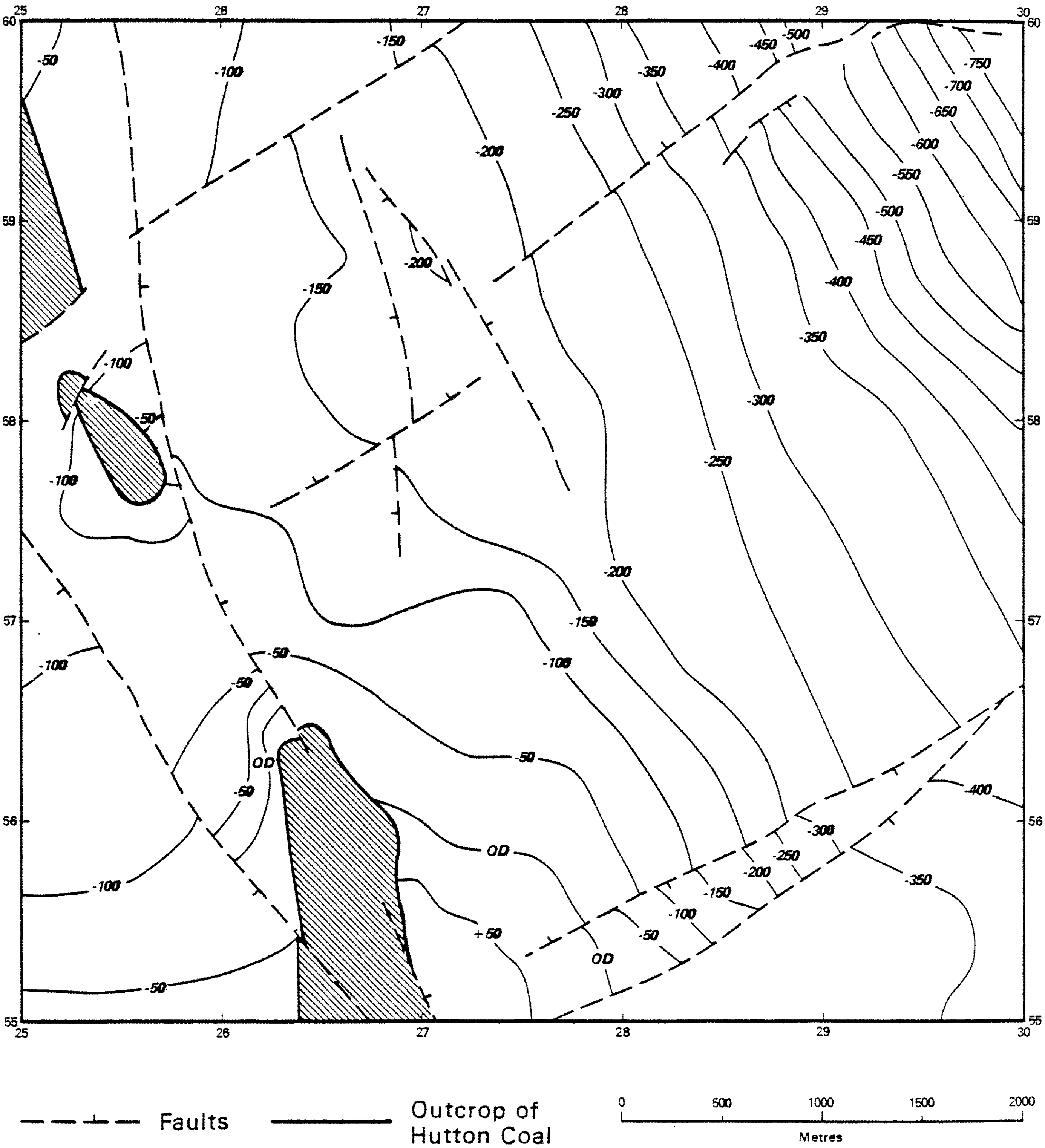



Fig. 5. Generalized structural contours (in feet) on the Hutton Seam of NZ 25 NE; areas where Hutton has been eroded off are shaded.

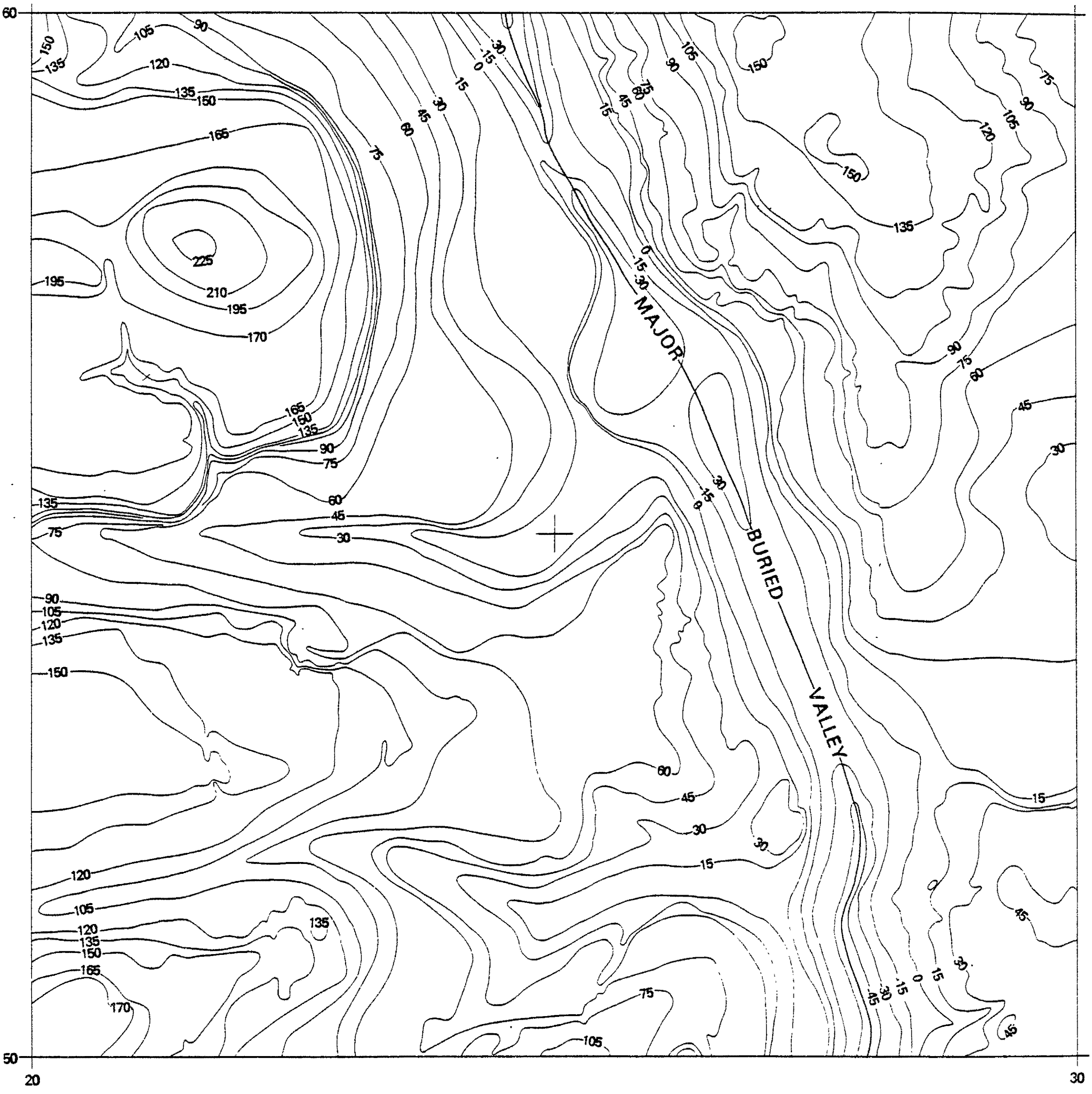



Fig. 6 Rockhead contours of NZ 25 (contours in metres relative to Ordnance Datum)

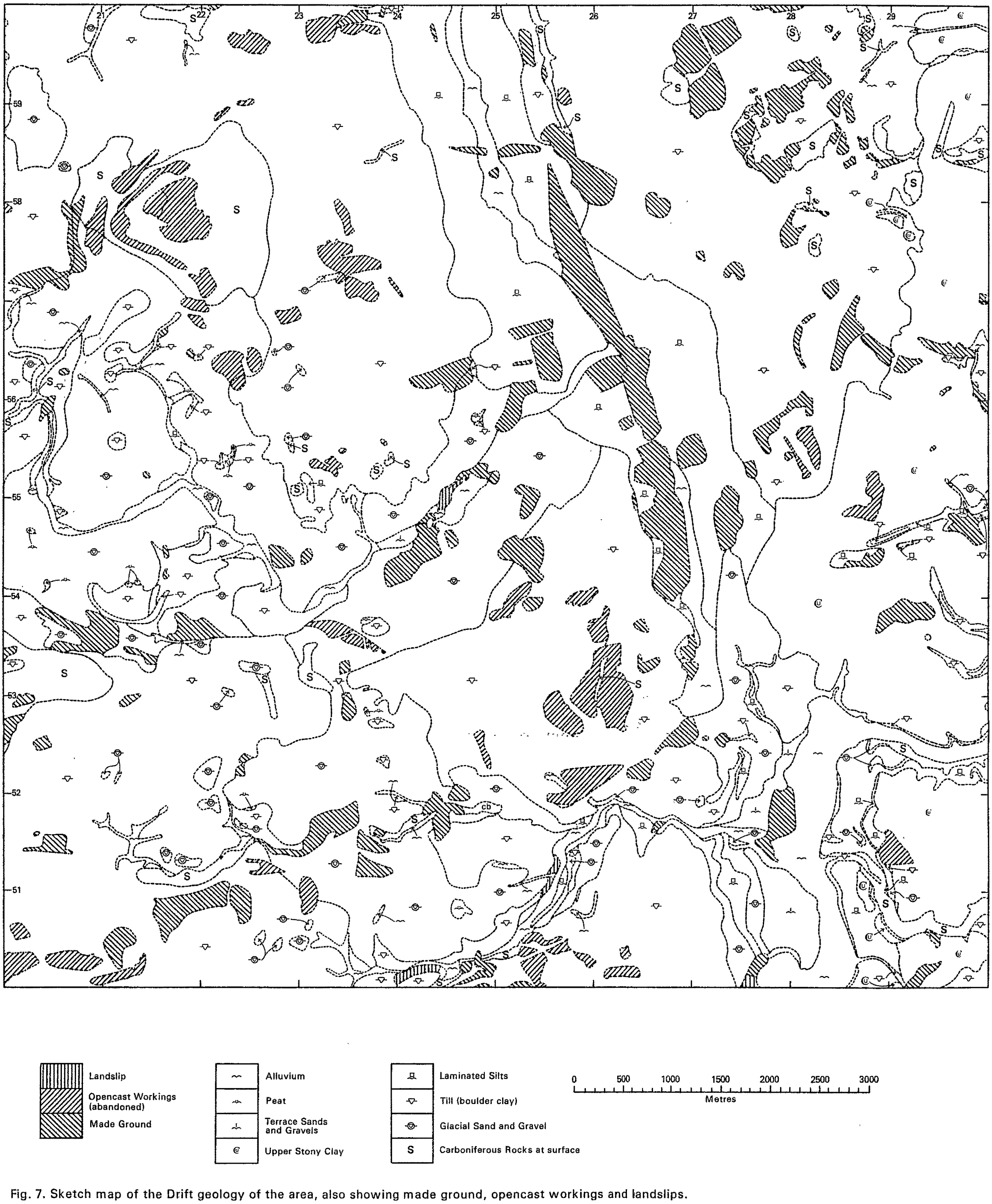



Fig. 7. Sketch map of the Drift geology of the area, also showing made ground, opencast workings and landslips.