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Recent fissuring in the Magnesian Limestone at Houghton-le-Spring, City of Sunderland

Urban Geoscience and Geological Hazards Programme

Research Report RR/02/03

BRITISH GEOLOGICAL SURVEY

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Recent fissuring in the Magnesian Limestone at Houghton-le-Spring, City of Sunderland

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Foreword

This report describes the results of a field survey, conducted during June 2001, to examine the effects of renewed ground movements in the Magnesian Limestone outcrop at Houghton-le-Spring, City of Sunderland. A detailed field investigation of this area during 2000 revealed widespread evidence of fissuring and structural damage, which may result from reactivation of faults within the Magnesian Limestone and underlying Coal Measures rocks. The features described in this report appeared suddenly during May 2001, causing further damage to land and structures and causing minor injuries to a member of the public.

The investigation was undertaken as part of the British Geological Survey Urban Geoscience and Geological Hazards Programme.

The assistance of the Sheilah Hudson and Harry Husband, owners of Hillside Farm, and of John Ellis is greatfully acknowledged. Northeast Press Ltd are thanked for allowing the use Sunderland Echo Photograph No. 65414 as Figure 13 of this report.

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FIGURES

1 Introduction

Young and Culshaw (2001) described and figured widespread evidence of fissuring in the Magnesian Limestone and underlying Coal Measures rocks of the Houghton-le-Spring area, City of Sunderland (Figure 1). Evidence of structural damage, related to this fissuring, was also described. Whereas local movement along some fissures was noted during the course of this investigation, the dates of initiation of surface features, or of movements associated with them, was possible in only a few localised instances. In their discussion of the possible mechanisms of fissuring, Young and Culshaw (2001) concluded that fissure formation and resultant surface collapse is still active and may be related to renewed subsidence or reactivated movement associated with the Houghton Cut Fault.

In early May 2001 the attention of the British Geological Survey was drawn to ground movements in which a conspicuous belt of open surface fissures appeared suddenly along a strike length of at least 0.5 km. A field investigation revealed evidence of very significant recent fissuring extending for a further 0.25 km along the same line and almost certainly resulting from the same event, which is at least 0.75 km long. The features observed are compared with those reported by Young and Culshaw, during the previous investigation conducted in June 2000.

2 Geology of the Houghton-le-Spring area

Houghton-le-Spring lies near the centre of the Durham Coalfield. The geology is illustrated in Figure 2 which is an extract of BGS 1:10 560 scale Sheet NZ35SW. Much of the town stands on the outcrop of Middle Coal Measures rocks, which here comprise a succession of mudstones, siltstones, sandstones and coals. These are overlain unconformably by a variable thickness of poorly cemented desert dune sands of late Permian age, known as the Basal Permian Sands, or Yellow Sands. These are, in turn, overlain conformably by the marine limestones and dolomites of the Magnesian Limestone, also of late Permian age. The continuity of the outcrops of these units is interrupted by several normal faults, which in the vicinity of Houghton-le-Spring mainly strike between east–west and east-north-east–west-south-west.

Across much of the area the Coal Measures rocks are concealed beneath a mantle of superficial deposits of Quaternary age. The outcrop of the Permian rocks, particularly the Magnesian Limestone, is distinguished by a much thinner coverage of superficial deposits, with wide areas of the limestone vitually free of such deposits.

The edge of the Magnesian Limestone outcrop is typically marked by a prominent scarp feature overlooking the lower lying ground of the Coal Measures. The area described in this report lies on, or close to, the prominent south-facing scarp of the Magnesian Limestone immediately north of the town of Houghton-le-Spring.

More detailed accounts of the geology of the Houghton-le-Spring area include those by Smith (1994) and Young and Culshaw (2001).

3 Field evidence of recent fissuring

In May 2000, the BGS were invited by the owners of Hillside Farm, Houghton-le-Spring, to examine open fissures which had recently appeared within several fields on the farm. Discussion with the owners revealed that these fissures had all appeared suddenly and within a very short period, probably all within one or two days, during early May, though the precise dates involved were not clear. The authors of this report visited the farm on 16th and 21st May to record the features then visible. The results of this visit are summarised below (Section 3.1).

At the time of this site visit the A690 road in Houghton Cut, immediately west of the farm, and which was affected by fissuring described by Young and Culshaw (2001), was examined for evidence of recent movement. Cracking of the carriageway and adjoining ground is described below (Section 3.2).

The results of an examination of the ground immediately west of Houghton Cut, and which is known from Young and Culshaw's investigation to exhibit evidence of significant fissuring, are also outlined below (Section 3.3).

3.1 Evidence of recent fissuring north and north–east of Hillside Farm

Evidence of recent fissuring was abundant in the fields immediately north and north-east of the farm. The sites of fissures and related subsidence features are shown on Figure 3 and brief details of the features recorded during the present investigation are summarised in Table 1. Examples of these features are illustrated in Figures 4–11. Several of the open holes had been fenced to protect farm stock by the time of the field visits (Figures 4 and 5).

Young and Culshaw (2001, p.12 and Figure 12) commented on the presence, in June 2000, of several shallow linear features up to 2 m wide and 0.75 m deep marking the course of fissures within this field, and noted the presence of a recently subsided hole about 1.0 m wide and 0.75 m deep near the eastern extremity of the field. They also recorded that, according to the previous landowner, collapse features of this sort have long been a feature of this field.

At the time of the present field investigation, fissures were evident as linear depressions (Figures 6 and 7) and as discrete open holes (Figures 8 and 9), in some of which fissured limestone was clearly visible. This investigation revealed clear evidence of significant very recent surface disturbance along several of the depressions delineated by Young and Culshaw (2001) (sites A, B, D and G, Figure 3). In addition, several hitherto unrecorded linear depressions, which almost certainly indicate new fissures, were identified (sites C, E and F, Figure 3). Fresh fractures of the soil profile, with disruption and collapse of the present season's grass growth were noted along the courses of these (Figures 6, 7, 9 and 11). These features appear as narrow, generally sharply-defined linear, or slightly curved or faintly sinuous, depressions up to 1.5 m wide and about 0.75 m deep. The outer edges of the depressions are typically bounded by small scars, up to several centimetres high, which exhibit a clear downthrow towards the centre of the depression (Figure 11). The depressions thus take the form of very small-scale graben structures. Their form is consistent with collapse of the surface into a dilated fracture, either a fault or major joint.

Mapping reveals that these fissures crop out as a series of en echelon depressions aligned parallel to, and within a 100 m wide belt within the hangingwall zone of, the surface position of the Houghton Cut Fault.

3.2 Evidence of recent fissuring within Houghton Cut

The sites of fissuring and associated damage within Houghton Cut are shown on Figure 3 and brief details of the features recorded during the present investigation are summarised in Table 2.

The presence of a significant crack across both carriageways of the A690 road, and its relationship to fissures in the Magnesian Limestone, was discussed by Young and Culshaw (2000). In their report (pp.17–18) these authors drew attention to the presence, in June 2000 of two rather sinuous cracks, which had not been visible in April 2000, in the tarmac surface of the north-bound carriageway, approximately 40.0 m south of the original crack. When first observed these cracks were comparatively faint and were confined to the easternmost two lanes of this carriageway. By October the cracking was observed to have extended into the westernmost lane.

During the investigation reported here, this cracking was appreciably more conspicuous than in 2000, and had clearly extended across much of the western lane of the carriageway. No signs of cracking were found in the south-bound carriageway of the road. This cracking appears to align very closely with one of a number of distinct fissures exposed in the western wall of the cutting (Figure 12).

Young and Culshaw (2001, pp.10–11) also described active movements along the fissure exposed in the western wall of the cutting, and which underlies the original crack in the A690 road. Renewed movement on this fissure early in May 2001 resulted in a sudden surface collapse producing a hole approximately 0.5 m across and approximately 0.75 m deep in the pavement (Figure 13). A pedestrian who was passing at the time of the collapse sustained minor injuries (Sunderland Echo, Saturday May 12, 2001, p.3). The hole was excavated and backfilled with concrete by the City Council shortly after this incident (Figure 14).

3.3 Evidence of recent fissuring west of Houghton Cut

Field observations made during the present investigation along the line of fissuring described by Young and Culshaw (2001) west of Houghton Cut are summarised in Table 3 and brief details of the features recorded during the present investigation are summarised in Table 3. The surface features discovered in this area are some of the most striking found in this investigation and include several which present significant problems of public safety.

Table 1 Surface effects of fissuring north and north-east of Hillside Farm, recorded during this investigation.

Letters and numbers refer to sites shown on Figure 3. **Letters refer to linear subsidence features; numbers refer to open holes.**		
A	NZ 34462 50497	Linear depression up to 0.75 m across and approximately 0.5 m deep. Appears to be surface expression of continuation of 1.0 m wide open fissure exposed in limestone cliff immediately west of field. No evidence of recent movement. Appears unchanged from when seen in June 2000.
B	NZ 34458 50479–NZ 34492 50481	Long linear depression up to 0.75 m wide and approximately 0.5 m deep. Abundant evidence of very recent collapse in form of fresh scars in turf and topsoil on either side of depression forming graben-like feature. Observed during June 2000 investigation as a line of linear depressions up to 0.3 m across and 0.5 m deep.
C	NZ 34505 50508–NZ 34609 50521	Long, rather sinuous linear depression up to approximately 1.0 m wide and generally approximately 0.5 m deep. Connects several discrete open holes. Brick rubble locally towards eastern end suggests filling from previous collapse. Not observed during June 2000 investigation.
D	NZ 34628 50539–NZ 34683 50540	Long, rather sinuous linear depression up to 1.5 m wide and approximately 0.5 m deep. Abundant evidence of very recent collapse in form of fresh scars in turf and topsoil on either side of depression forming graben-like feature. Observed during June 2000 investigation as a rather indistinct line of very shallow grassy hollows.
E	NZ 34743 50560–NZ 34766 50562	Rather short linear depression up to approximately 1.0 m wide and approximately 0.5 m deep. Connects several discrete open holes. Not observed during June 2000 investigation.
F	NZ 34772 50555	Short linear depression approximately 1.0 m long, 0.5 m wide and 0.5 m deep. Not seen during June 2000 investigation.
G	NZ 34774 50545–NZ 34794 50548	Linear depression up to 2.0 m wide and approximately 0.5 m deep. Not seen during June 2000 investigation.
H	NZ 34795 50569–NZ 34872 50572	Linear depression approximately 1.0 m wide connecting several discrete open holes. Observed during June 2000 investigation as line of fissures up to 0.5 m wide and up to 1.0 m deep.
I	NZ 3452 5048–NZ 3457 5047	Linear depression up to approximately 1.0 m wide. Observed during June 2000 investigation, though several fresh scars observed during June 2001.
1	NZ 34505 50508	Freshly subsided open hole, up to 1.0 m across, through turf. No limestone seen. Appears to be partly choked with subsided soil. Depth not determined. Hole appears to dip steeply to west. Not observed during June 2000 investigation.
2	NZ 34515 50510	Freshly subsided open hole up to 0.75 m across and up to 3.3 m deep. Roughly east–west orientated open fissure up to 0.75 m wide, vertical or with very steep dip to the north, seen in limestone at base of hole. Not observed during June 2000 investigation.
3	NZ 34544 50518	Freshly subsided, roughly circular open hole approximately 0.5 m across and at least 0.7 m deep. No limestone seen. Not observed during June 2000 investigation.
4	NZ 34565 50515	Prominent roughly circular depression approximately 1.5 m across and approximately 0.7 m deep. Hole appears to be partly choked with limestone boulders. Not observed during June 2000 investigation.
5	NZ 34683 50540	Freshly subsided hole approximately 2.0 m across and 0.75 m deep through limestone-rich soil. Not observed during June 2000 investigation.

6	NZ 34702 50538	Small open hole approximately 0.7 m across and approximately 0.5 m deep. No limestone seen. Not observed during June 2000 investigation.
7	NZ 34706 50539	Freshly subsided open hole approximately 3.0 across and at least 2.0 deep. Only limestone-rich soil and rubble seen in sides. No solid limestone seen. Hole contains old timbers, possibly from filling of previous collapse. Observed during June 2000 investigation as comparatively recently subsided hole approximately 1.0 across and 0.75 m deep.
8	NZ 34761 50561	Freshly subsided open hole up to 1.5 m across and at least 3.0 m deep. East–west orientated open fissure up to 0.3 m wide exposed in limestone walls in base of hole. Brick and limestone rubble within hole suggests filling from previous collapse. Not observed during June 2000 investigation.
9	NZ 34766 50562	Freshly subsided open hole up to 0.5 m across and at least 1.75 m deep. No solid limestone seen. Brick and limestone rubble within hole suggests filling from previous collapse. Not observed during June 2000 investigation.
10	NZ 34811 50571	Freshly subsided open hole approximately 2.0 m across and at least 2.5 m deep. Sides expose limestone rubble. Observed during June 2000 investigation as open fissure up to 0.5 m across and up to 1.0 deep.
11	NZ 34827 50572	Freshly subsided open hole approximately 2.0 m across and up to 2.0 m deep. Sides expose limestone rubble. Observed during June 2000 investigation as open fissure up to 0.5 m across and up to 1.0 deep.
12	NZ 34865 50579	Deep, cave-like hole approximately 2.0 m across and at least 2.5 m deep. Not safely accessible for detailed examination but exposes east–west orientated open fissure up to 0.5 m wide dipping steeply to the south. Not observed during June 2000 investigation, though may have been concealed beneath vegetation.

Substantial evidence of very recent ground movements along the full length of the linear fissure, described by Young and Culshaw (2001), was noted. The investigation in June 2000 revealed evidence of significant dilation of the northernmost fissure exposed at locality 15 in Figure 3. Whereas the present investigation showed little or no further widening of this joint at this point, very substantial recent movement was evident between here and the western edge of Houghton Cut. The fissure here is up to 1.1 m wide, dipping steeply to the south, with freshly exposed walls of limestone and limestone rubble. Over much of this length the fissure is up to 1.3 m deep. However, at the extreme eastern end, immediately above the western wall of the cut an open hole over 1.0 m wide extends to a depth of several metres, though it proved impossible to gain safe access to undertake accurate measurements (Figure 15). Freshly broken soil and turf occur along much of the line of the fissure. A mature hawthorn shrub has subsided almost 1.0 m into the top of the open hole at the eastern end of the fissure.

At locality 16 in Figure 3 a newly opened linear fissure at least 4.0 m long and up to 1.0 m wide is partially concealed beneath shrubby vegetation. The fissure has clean vertical sides in solid limestone and is floored at a depth of approximately 2.5 m with limestone rubble and very recently collapsed blocks of newly grown turf (Figure 16). At its western end the fissure continues downwards beneath the present collapse to depths which could not be accessed.

A similar, though rather smaller open fissure up to 0.5 m wide and at least 1.2 m wide, again almost totally concealed beneath thick vegetation occurs a few metres further west (locality 18, Figure 3) (Figure 17).

Table 2 Surface effects of fissuring and related damage in Houghton cut, recorded during this investigation.

Numbers refer to sites shown on Figure 3.		
13	NZ 34364 50435	Cracking of tarmac surface of north-bound carriageway of A690 road. Observed during June 2000 investigation. Crack more conspicuous May 2001.
14	NZ 34377 50467	Site of subsidence of footpath. Active movement on adjacent fissure recorded during June 2000 investigation. Sudden collapse of hole up to 0.5 m across and approximately 0.75 m deep in May 2001; minor injuries to pedestrian.
21	NZ 34408 50467	Gap between kerb stones widened and with evidence of vertical displacement.

The line of this major fissure can readily be traced further west through very newly subsided ground with abundant evidence of fresh scars in turf and topsoil (Figures 18 and 19).

A similar, though rather smaller open fissure up to 0.5 m wide and at least 1.2 m wide, again almost totally concealed beneath thick vegetation occurs a few metres further west (locality 18, Figure 3) (Figure 17).

The line of this major fissure can readily be traced further west through very newly subsided ground with abundant evidence of fresh scars in turf and topsoil (Figures 18 and 19).

Table 3 Surface effects of fissuring in ground west of Houghton cut, recorded during this investigation.

Numbers refer to sites shown on Figure 3.		
15	NZ 34350 50464	Prominent gully extending several metres west from western edge of cutting. Open fissure up to 1.1 m wide and up to several metres deep at its eastern extremity immediately above cutting. Paired fissures separated by approximately 1.0 m of limestone. Clear evidence of very recent collapse with disrupted soil, turf and displaced mature hawthorn bush. Substantial collapses since June 2000 investigation.
16	NZ 34345 50465	Prominent linear fissure approximately 4.0 m long, up to 1.0 m wide and at least 2.5 m deep. Fissure exhibits clean vertical sides. Adjoining topsoil and turf freshly broken giving clear evidence of very recent collapse. Although this fissure lies along course of depression recognised during June 2000 investigation, this prominent open fissure was not observed at that time.
17	NZ 34308 50461	Very recent collapse of topsoil along small south-facing scar approximately 1.0 m long and approximately 0.5 m high on north side of shallow linear depression. Linear depression observed during June 2000 investigation.
18	NZ 34304 50454	Open linear fissure up to approximately 3.0 m long, 0.5 m wide and at least 1.2 m deep. Clean limestone walls, vertical or locally very steeply inclined to the north. Freshly collapsed turfs in base of opening give clear evidence of very recent collapse. Although this fissure lies along course of depression recognised during June 2000 investigation, this prominent open fissure was not observed at that time.
19	NZ 34285 50445–NZ 34304 50454	Prominent, very recently subsided linear depression bearing 273, up to 2.0 m wide and1.25 m deep. Abundant evidence of very recent collapse in form of fresh scars in turf and topsoil on either side of depression forming graben-like feature. Although this fissure lies along course of depression recognised during June 2000 investigation, this prominent open fissure was not observed at that time.
20	NZ 34199 50430–NZ 34255 50439	Linear depression up to 1.0 m wide and approximately 1.0m deep. Abundant evidence of very recent collapse in form of fresh scars in turf and topsoil on either side of depression. Locally appears to exhibit displacement to south of up to 1.0m, though generally appears as trough, or graben-like feature. Although this fissure lies along course of depression recognised during June 2000 investigation, there is evidence of very considerable recent movement.

4 Discussion

The ground movements which produced the lines of new fissuring, and renewed movement of previously recorded fissures, along a strike length of approximately 0.5 km, north and north-east of Hillside Farm are understood to have developed very rapidly within a very short period of time, perhaps as little as one or two days during early May 2001. It is therefore reasonable to suppose that the features observed at surface may reflect one major coherent phase of movement along a single, or group of very closely related, structures. Random failure of bridging material over isolated concealed open fissures seems unlikely to account for the almost simultaneous appearance of such collapse features along a belt of country of this length.

No eye witness or anecdotal evidence has been obtained to suggest the timing of the obviously very recent ground movements to the west of Houghton Cut. However, their occurrence exactly on line with the belt of fissuring at Hillside Farm, and the obvious freshness of the scars associated with them suggest that they may share a common origin and may have developed at a very similar time.

The sudden collapse of the pavement at Houghton Cut, along the line of fracturing, is consistent with the failure of the tarmac surface several days after renewed movement in the underlying fissures. No major new fracturing of the A690 road surface was revealed during this investigation, though the cracking of the north-bound carriageway which was first noted in June 2000, appears rather more conspicuous than hitherto. It is quite conceivable that the road foundations may presently be effectively bridging any fissures which may lie beneath.

If, as seems likely, the ground movements indicated by the renewed fissuring west of Houghton Cut result from the same event which caused the fissuring at Hillside Farm, the total strike length of ground affected by this recent episode of movement amounts to almost 0.75 km.

The evidence obtained during the present investigation confirms Young and Culshaw's (2001) suggestion that widespread fissuring in the Magnesian Limestone of the Houghton-le-Spring area is still active. Moreover, the observed features and the likely timing of events are consistent with renewed subsidence or reactivation of the Houghton Cut Fault as a causative mechanism.

Although the greatest depth of a fissure measured during this investigation is 3.5 m, several fissures were observed to extend to greater, though indeterminate, depths. Faults within the Magnesian Limestone at surface clearly penetrate the base of the limestone, extending into the Basal Permian Sands (Yellow Sands) and almost certainly the underlying Coal Measures. It is likely that at least some of the major joints within the limestone also extend down to the Basal Sands which, beneath the area of this investigation, may be expected at depths of between 20 and 50 metres below surface. Where widened by renewed movement such fractures may serve as very ready conduits for water into the Basal Sands. As the Basal Sands are an extremely important aquifer throughout this part of north-east England, fissures of the sort described here may have potential to convey contaminants directly or indirectly into this aquifer. This should be regarded as an important consideration when contemplating filling of fissures during remediation works, and should be taken into account in the planning and management of landfill sites.

A number of the fissures observed during this investigation pose significant risks to public safety. This is of particular concern in areas such as that west of Houghton Cut where fissures are present in heavily vegetated ground. In this case the affected ground adjoins, without any fencing, areas of amenity open space much used by children.

The open fissures to the west of Houghton Cut have been fenced by Sunderland City Council.

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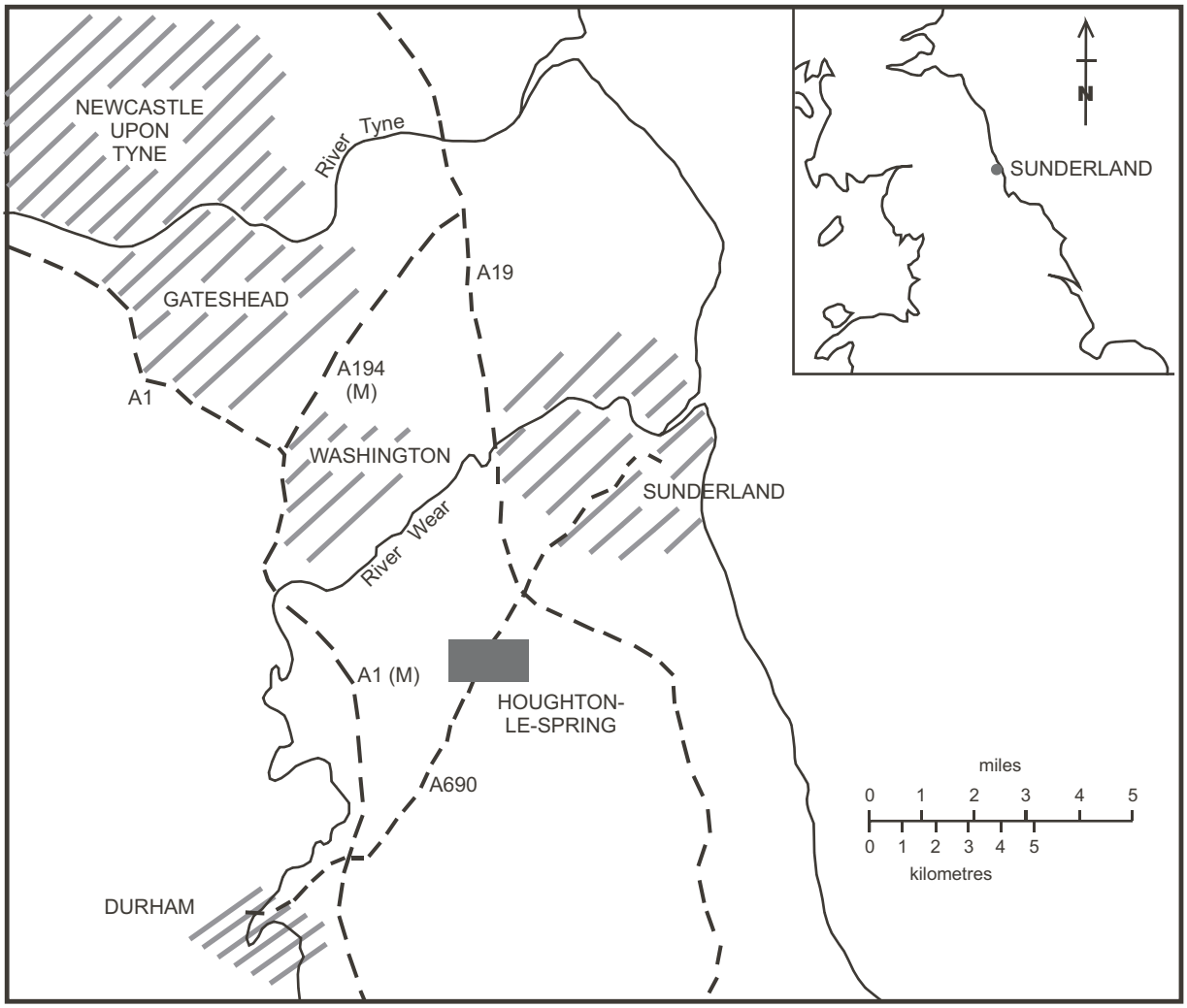
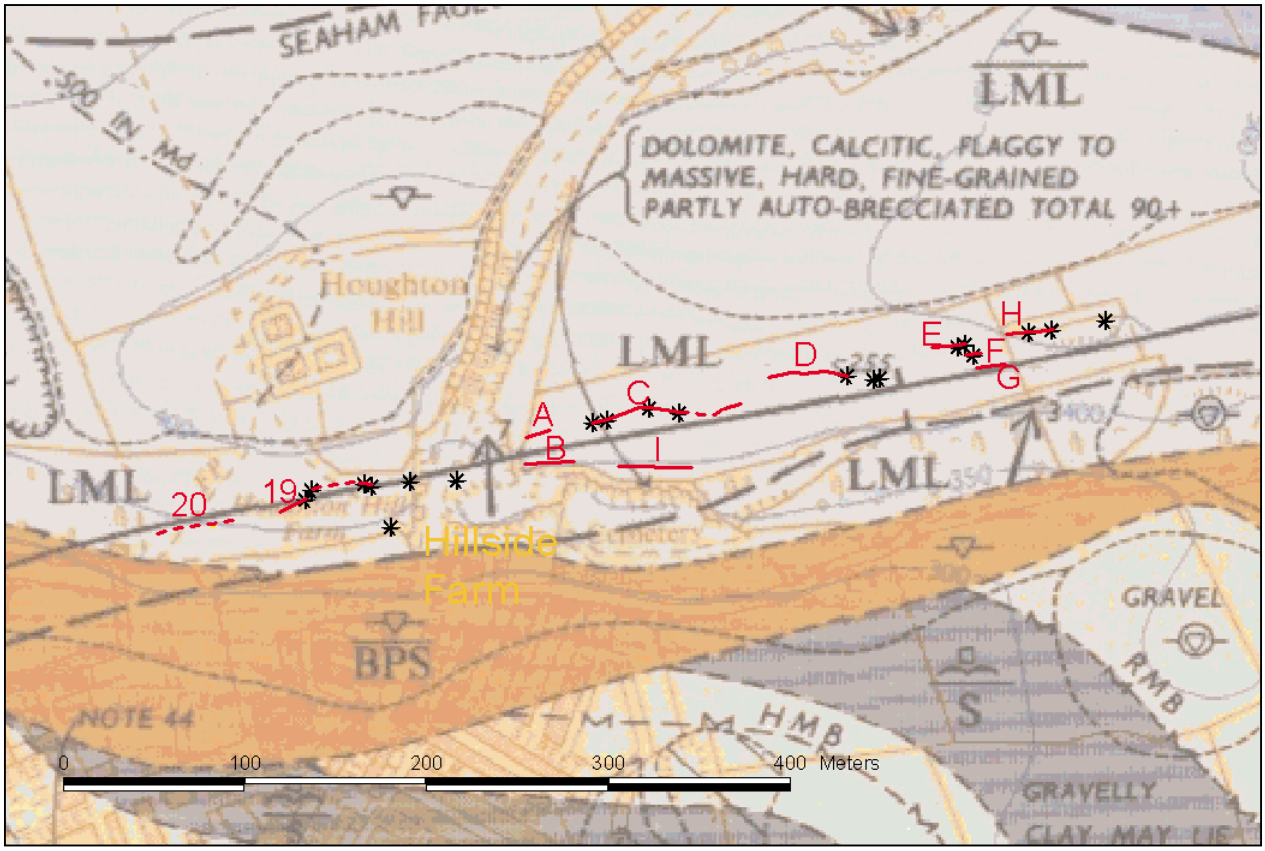


Figure 1 Location map.



DRIFT– Recent and Pleistocene
Glacial Sand and Gravel

Laminated Clay

Boulder Clay

SOLID – Permian

MML — Middle Magnesian Limestone (now known as Ford Formation)

LML — Lower Magnesian Limestone (now known as Raisby Formation)

BPS — Basal Permian Sands

Carboniferous

MCM — Middle Coal Measures

S — Sandstone

Inclined strata, dip in degrees

Geological boundary, Drift

Geological boundary, Solid

Fault at surface

Fault underground in horizon named

Marine Band

Contour or level course in seam

Made Ground

RMB — Ryhope Marine Band

HMB — Hylton Marine Band

Figure 2 Geological map of the Houghton-le-Spring area. (Extract from BGS 1:10 560 scale sheet NZ 35 SW). The position of the main fissures, open holes and depresssions, described in this report are shown. Letters and numbers refer to Tables 1 and 3.

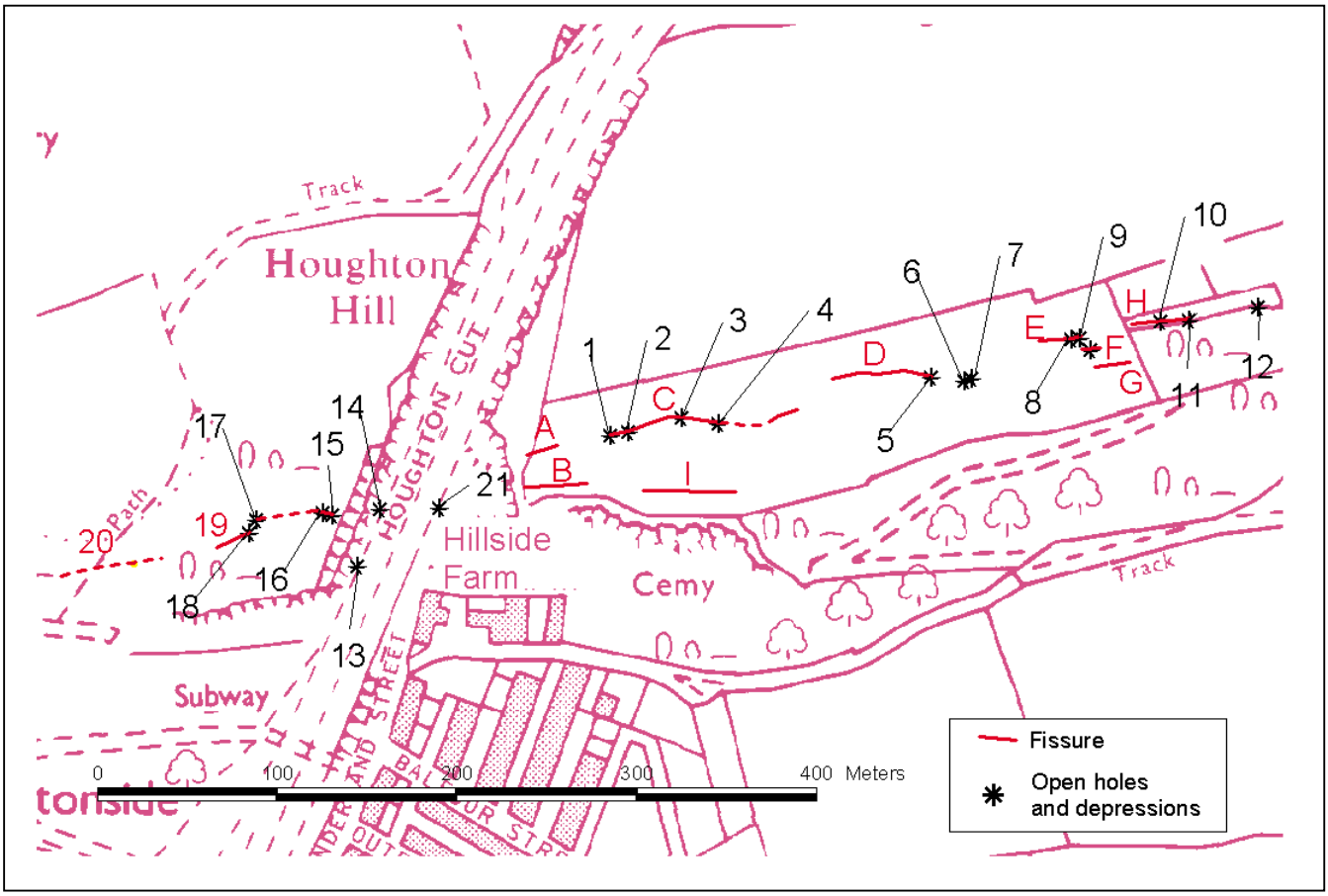


Figure 3 Sites of fissures described in this report.
Linear fissures (letters refer to descriptions in Table 1.)

* Open holes and depressions
(numbers refer to descriptions in Tables 2 and 3.)

Figure 4 Looking west towards Houghton Cut at Locality 2, Table 1. Newly opened surface fissure up to 3.3m deep. A roughly east–west aligned vertical, or steeply inclined to the north, fissure up to 0.75m wide in solid limestone was visible in the sides of the hole.

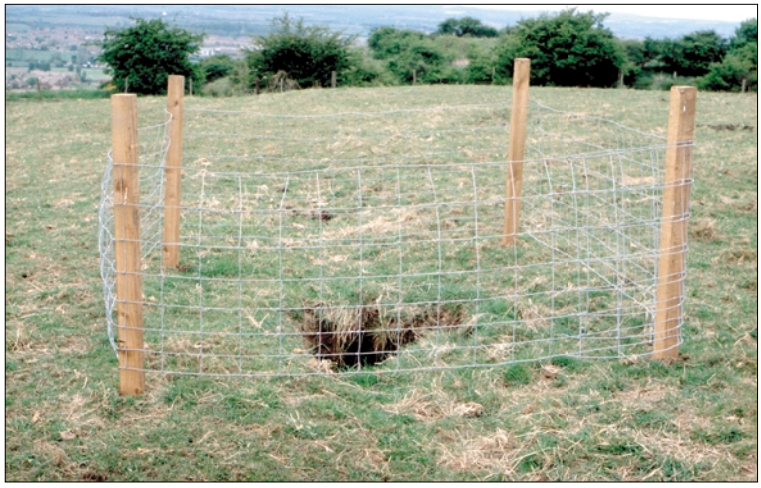


Figure 5 Looking east from near Locality 1 in Table 1. Linear depression marking course of newly subsided fissure with fenced-off deep open fissure.

Figure 6 Looking east along linear depression (D in Table 1).

Figure 7 Looking east along linear fissure (E in Table 1).

Figure 8 Locality 2, Table 1. Recently collapsed recently opened fissure through turf.

Figure 9 Locality 8, Table 1. Looking east along east–west orientated fissure with limestone walls. Brick and limestone rubble in base of depression from previous fillings.

Figure 10 Looking west towards Houghton Cut from hillside at western end of linear fissure (Locality H, Table 1). Fenced-off recently opened fissure in foreground. Other fissures visible in field beyond.

Figure 11 Looking west along linear fissure (Locality B, Table 1). Graben-like form of fissure. Note very fresh scars in turf on either side of fissure.

Figure 12 Looking west across A690 road at Locality 13, Table 2. Cracking in tarmac surface and fissure in limestone cliff behind lamp-post.

Figure 13 Collapse in footpath on west side of A690 road at Houghton Cut, with Mrs S Ellis, who sustained slight injuries by falling into hole. Locality 13, Table 2. Photograph reproduced by courtesy of Northeast Press Ltd, Sunderland Echo, photograph No. 65414.

Figure 14 Collapse in footpath on west side of A690 road at Houghton Cut showing excavation prior to filling and repair. Locality 13, Table 2.

Figure 15 Looking east from Locality 15, Table 3. Wide, newly opened fissure in limestone, with A690 road below.

Figure 16 Looking west along recently opened deep fissure in solid limestone. Locality 15, Table 3.

Figure 17 Locality 17, Table 3. Small recently-formed scar in topsoil.

Figure 18 Locality 18, Table 3. Recently opened linear fissure.

Figure 19 Looking west along linear fissure. Locality 20, Table 3.