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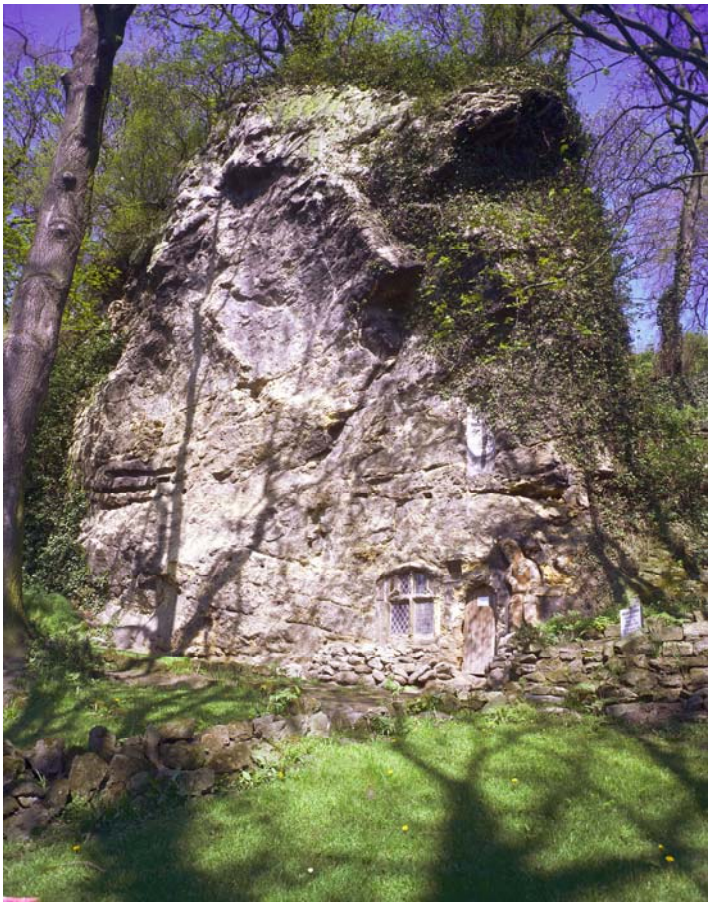
Denys Smith Memorial Trip: The Geology of Knaresborough Gorge - YGS 1st June 2008

Geology Programme

Open Report OR/08/044



BRITISH GEOLOGICAL SURVEY

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Denys Smith Memorial Trip: The Geology of Knaresborough Gorge - YGS 1st June 2008

A H Cooper

Keywords Knaresborough, Permian, Cadeby Formation, dolomite, Carboniferous, unconformity.

National Grid Reference

SW corner 434313,455375
NE corner 436412,457629

Map

Sheet 62, 1:50 000 scale, Harrogate

Front cover Knaresborough. (SE 351 564) Chapel of Our Lady of the Crag hewn from the Cadeby Formation, Sprotbrough Member dolomite of large-scale (5-18 m. sets) of cross-bedded oolite.

Bibliographical reference

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Foreword

This field guide is presented as a memorial to Dr Denys Smith formerly of the British Geological Survey (BGS). It is based on the Yorkshire Geological Society field guide by Cooper (1994 & 2006) with additions from the Harrogate Memoir (Cooper & Burgess, 1993).

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Summary

This guide is dedicated to Dr Denys Smith, expert on the Permian rocks of Britain and Europe.

The field excursion illustrates the Permian and Quaternary geology of Knaresborough Gorge. The Gorge is a marginal glacial feature cut at the edge of the Devensian Ice sheet during the last Ice-Age. The River Nidd has cut down through the Permian and Carboniferous sequence. The Permo-Carboniferous unconformity is exposed revealing a buried relief of low hills. The Permian Cadeby Formation dolomites above the unconformity show massive subaqueous dune bedding and traces of ooids indicative of formation in a Bahamas Banks environment. Tufa-rich spring activity on the west side of the gorge has resulted in the formation of a large tufa screen with a small cave behind where it has partly collapsed; this is Mother Shipton's Cave.

1 Denys B. Smith, 1929-2007– Permian Geologist

For more than four decades Dr Denys Smith and Permian geology were synonymous. His name graces more than 60 eminent publications about Permian geology and he chaired important working groups on the Permian rocks. His enthusiasm for geology and the Permian in particular were illustrated by his roles as both president of the Leeds Geological Association and later as president of the Yorkshire Geological Society. His presidency of the YGS culminated with his presidential address on "The Late Permian palaeogeography of north-east England (Smith, 1986) this and later books drew together his vast knowledge of the Permian rocks and the Zechstein deposits in particular. His merit in the British Geological Survey was rewarded by his senior post and his geological of maps and memoirs will be consulted for centuries to come. Denys enthused students and staff who worked alongside him. John Kaldi (now a professor in Australia) did his PhD jointly supervised by Denys on the sedimentology of the Permian rocks, concentrating on Knaresborough Gorge; this trip examines some of the exposures he studied. As leader of this trip it was my privilege to have worked under Denys when he was in charge of the British Geological Survey office in Newcastle. He presented me with copies of the majority of his papers and I consult them constantly. My understanding of the Permian rocks and the interpretation of much of the Knaresborough district would not have been possible without his considerable help. His publications are his lasting memorial.

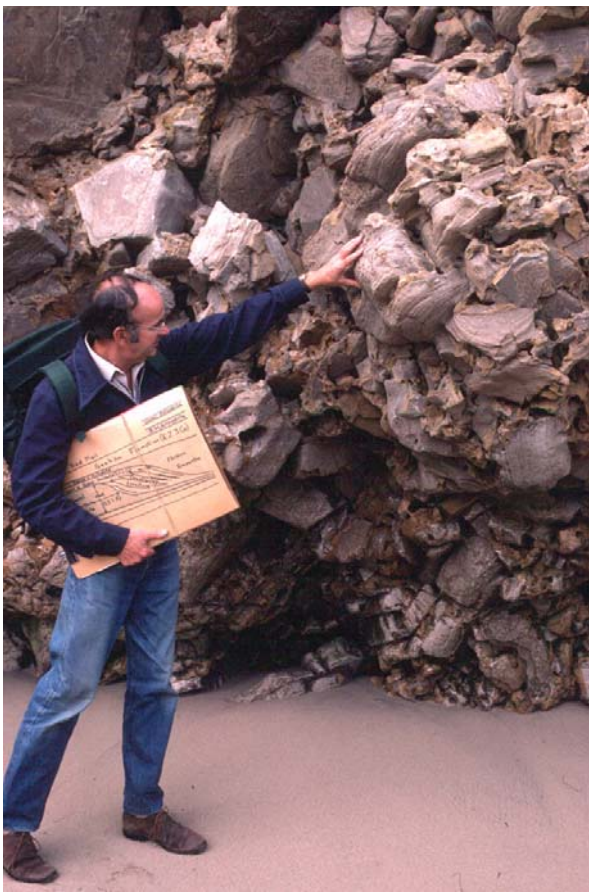

Figure 1 Denys Smith leading a field trip and demonstrating collapse breccia formation due to evaporite dissolution at Marsden Bay, Co Durham in 1984 to mark his retirement from the British Geological Survey.

2 Geological Setting

2.1 TOPOGRAPHY AND GLACIAL MORPHOLOGY

At the start of the last ice-age (Devensian) the topography of the Knaresborough district was different to that seen today (Cooper & Burgess, 1993). The proto River Nidd ran to the north and east of the present town. It deviated from its present course at Nidd (SE 302 608), ran through Brearton and past Farnham (SE 345 605) to the northern outskirts of Knaresborough (SE 363 580) before heading eastwards. During the advance of the Devensian ice-sheet a thick fan of sand and gravel was deposited in this valley emanating from the front of the ice-sheet via glacial channels around Farnham (SE 352 606) and Occaney (SE 352 619); this deposit is currently worked in the gravel pits north of Knaresborough (SE 356 587). If Knaresborough is approached from the north via the B6166 from Boroughbridge the extent of this buried valley, and its associated sand and gravel deposits, can be appreciated from the road. As the ice advanced further to the south and west it overrode the sand and gravel completely blocking the proto-Nidd drainage and diverting the river westwards (Figure 2 and Figure 3). Here the river exploited the lowest, softest rocks and incised the present Nidd Gorge. West of the Nidd Gorge the glacial deposits are generally thin and probably pre-Devensian in age; east of the gorge the Devensian deposits comprise thick hummocky glacial till with moraines, eskers and late glacial lake deposits.

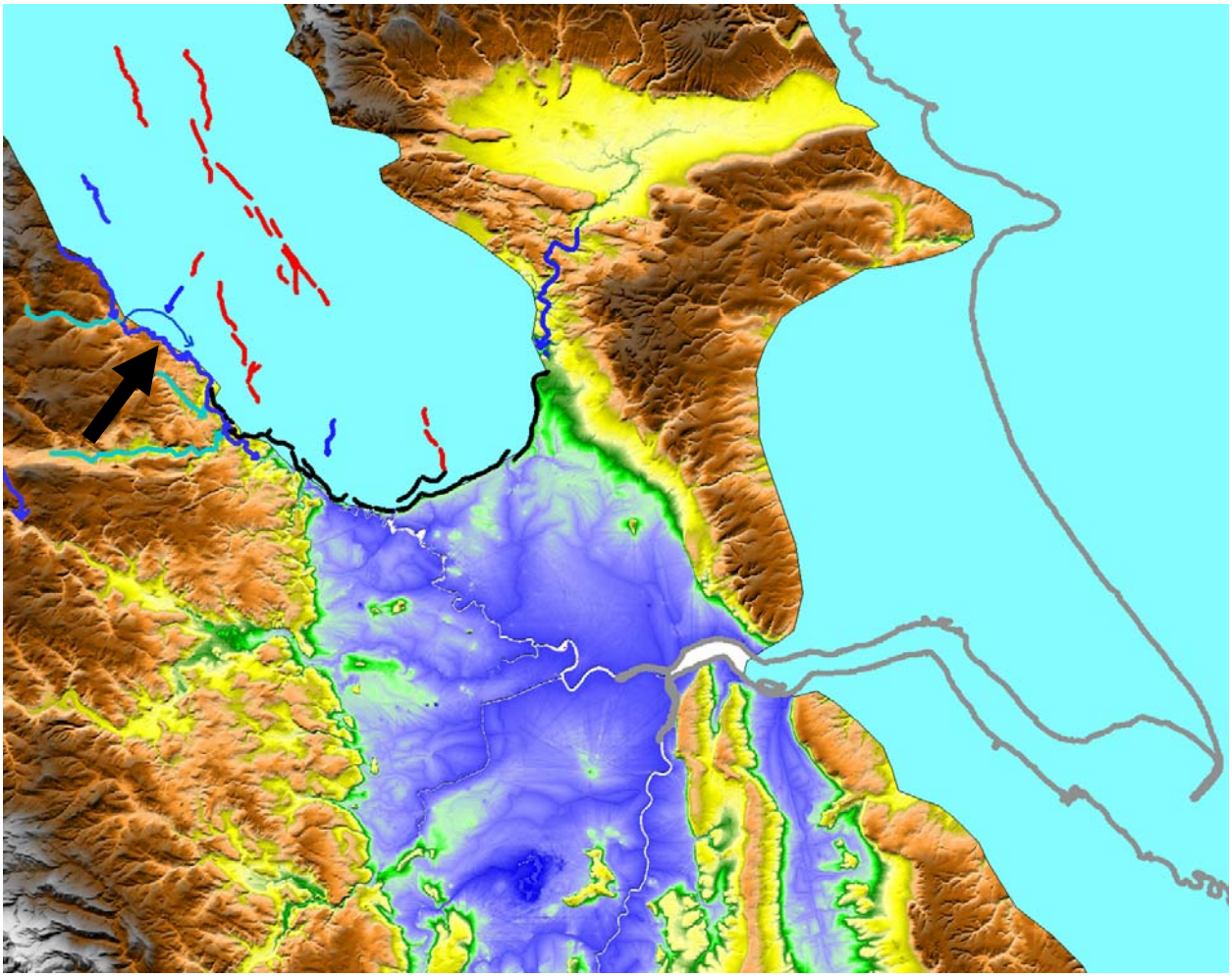

Figure 2. Digital terrain model of the Vale of York (Ordnance Survey and CEH DTM) with the inferred position of the ice at the Devensian maximum. Knaresborough Gorge at the side of the ice–sheet is arrowed. Escrick Moraine in black, eskers in red, glacial diversions in dark blue, ice in pale blue.

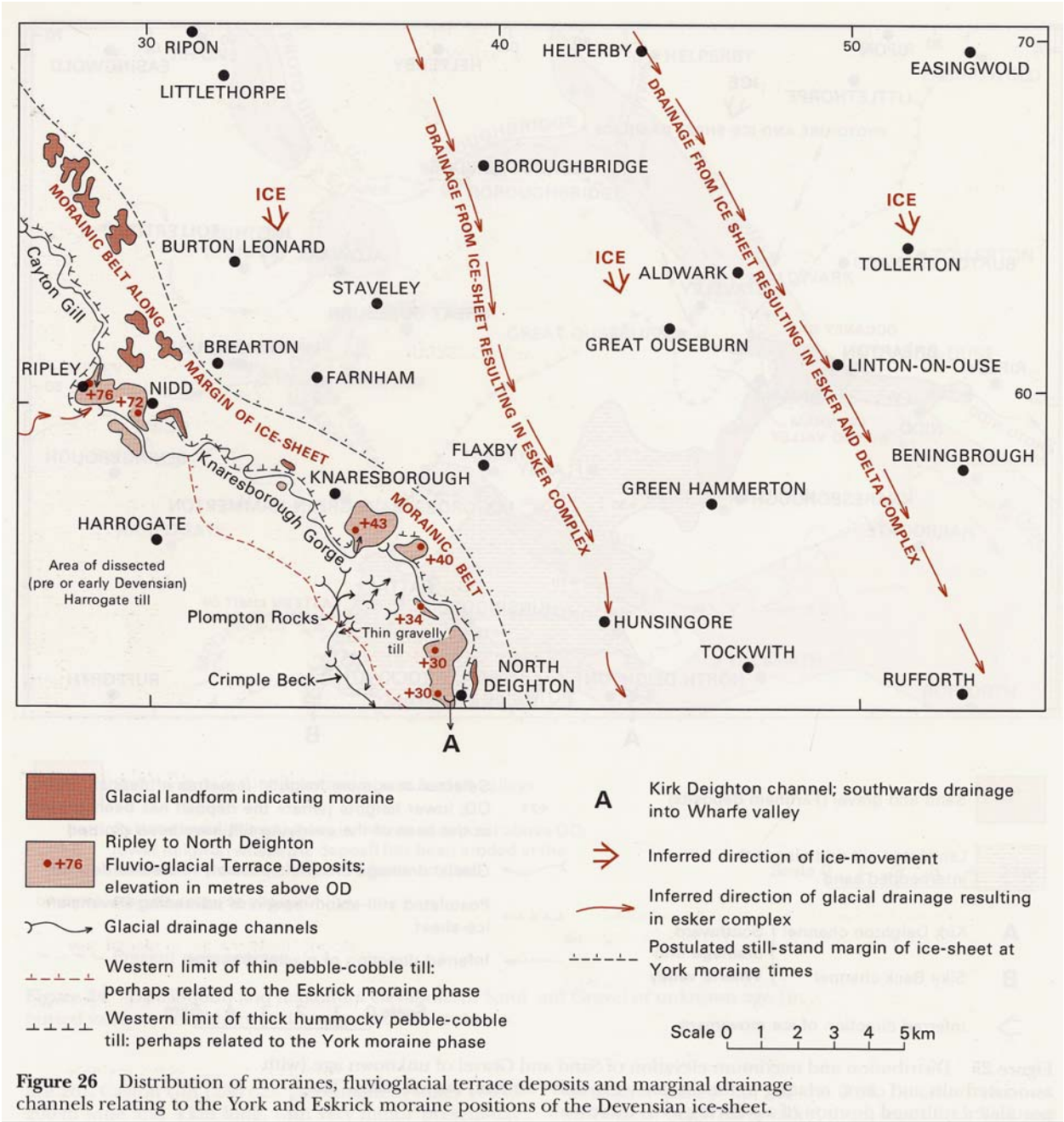

Figure 26 Distribution of moraines, fluvioglacial terrace deposits and marginal drainage channels relating to the York and Eskrick moraine positions of the Devensian ice-sheet.

Figure 3. The glacial geology of Knaresborough Gorge at the Devensian glacial maximum, from Cooper and Burgess 1993, Figure 26.

2.2 BEDROCK GEOLOGY OF THE KNARESBOROUGH AREA

The solid rocks exposed in Knaresborough Gorge are of Carboniferous (Namurian) and Upper Permian age (Cooper & Burgess, 1993). Here the Permian strata overlap onto and submerge a surface of irregular relief eroded in the underlying Carboniferous sandstones and shales. The exposed Carboniferous sequence extends upwards from the Lower Follifoot Grit to the Lower Plompton Grit. At the northern end of Knaresborough the Carboniferous rocks are folded around the nose of the Harrogate Anticline and dip at up to 27 degrees to the east and south-east (Figure 4). This anticline was formed during the Hercynian Orogeny prior to the Upper Permian deposition.

The overlying Permian strata (Table 1) dip gently eastwards and rest unconformably on the Carboniferous rocks (cross-section in Figure 5). The lowest Permian rocks seen here are the Cadeby Formation (formerly Lower Magnesian Limestone). This formation is over 40m thick and subdivided into two members the lower one is the Wetherby Member (formerly Lower Subdivision) and the upper one the Sprotbrough Member (formerly Upper Subdivision). The Cadeby Formation (Sprotbrough Member) forms the ridge on which Knaresborough is built. The ridge consists largely of cross-bedded oolites and is capped by a small outlier of Edlington Formation (formerly Middle Marl). The Knaresborough ridge appears to be a primary depositional feature, for the limestone thins away from it in all directions and depositional dips (Kaldi, 1980; giving the palaeocurrent information on Figure 5) mimic the form of the ridge. The thinning of the formation is best illustrated north-west of the town centre, near Conyngham Hall, where it thins to 1-3m of even-bedded, sandy dolomite; the westward thinning is illustrated by the cross-section in Figure 5. The overlying Edlington Formation comprises red-brown calcareous mudstone with some gypsum and is generally poorly exposed. It overlaps the Cadeby Formation both northwards and westwards to rest directly on the Carboniferous rocks. The Edlington Formation is in turn overlapped by the Brotherton Formation (formerly Upper Magnesian Limestone), a sequence of dolomitic limestone 5-15m thick, which rests directly on Carboniferous rocks at Scriven (SE 345 585) and Rudfarlington (SE 342 543).

Formation and Members	Old Name	Main Lithology	Local thickness (metres)
Roxby Formation	Upper Marl	Mudstone with gypsum	10-15
Brotherton Formation	Upper Magnesian Limestone	Dolomitic limestone	5-15
Edlington Formation	Middle Marl	Calcareous mudstone with gypsum	0-20
Cadeby Formation: Sprotbrough Mem. Wetherby Mem.	Lower Magnesian Limestone: Upper Subdivision Lower Subdivision	Dolomite	0-40

Table 1. The Permian sequence in the Knaresborough area

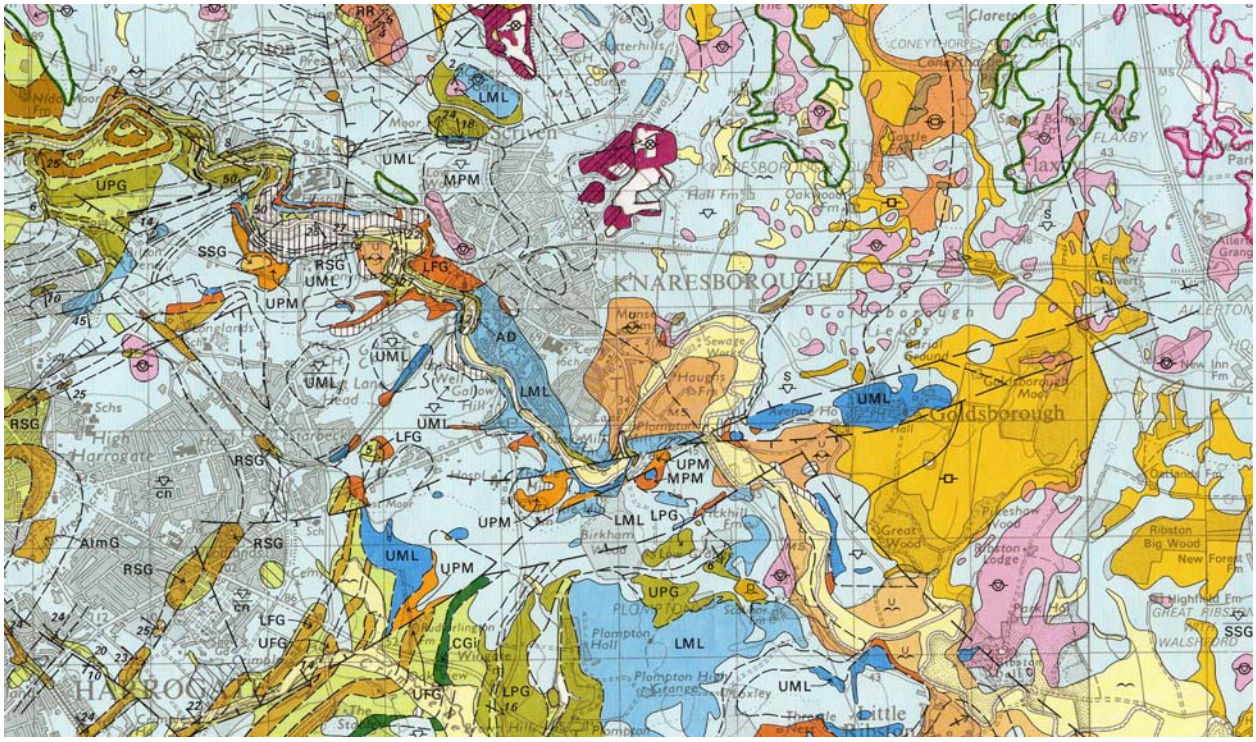

Figure 4. Extract from British Geological Survey 1:50,000 scale geological map 62 (Harrogate – Solid & Drift) showing the geology of the Knaresborough Gorge area.

3 Excursion Details

Starting point. Riverside Car Park (SE 347 567)

Location 1. (SE 348 569) From the car park and head northwards on the east side of the Nidd. Below the Castle the cliff section near the Weir, seen earlier from the opposite bank of the river exposes the unconformity at the base of the Cadeby Formation. The face is vertical about 27m high and not accessible. At road level 2-3m of weathered Addlethorpe Grit is exposed with a fossilised tree-trunk present below an overhang about 1 m above ground level. The remaining 27m of the cliff comprises a basal zone 6-7m thick of reddish-buff sandy dolomite overlain by about 17m of dolomite in large-scale cross-bedded units representing subaqueous dunes.

Location 2. (SE 349 569). An energetic walk up the cliff path, just north of locality 1 to Knaresborough Castle affords an opportunity to examine the Cadeby Formation at close hand and to visit the Castle. The castle was originally Norman though all traces of that period have now disappeared; from 1371 it was a stronghold of the Duchy of Lancaster and used as a barracks. From the castle viewpoint the form of the Knaresborough Gorge glacial diversion channel can be appreciated; return to the riverside walk

Location 3. (SE 3475 5685). Enter `Old Mother Shiptons' park (payment required) and proceed along the Long Walk to the Weir (SE 3475 5685); here Carboniferous sandstone (Addlethorpe Grit) is present in the river, and the sub-Permian unconformity is visible in the cliffs below the Walk. About 12 m of dolomite are exposed, overlain by red siltstones of the Edlington Formation with some slipped deposits of till. On the opposite bank of the river the Addlethorpe Grit and overlying Cadeby Formation form a sheer cliff, the unconformity at the base of the Permian sequence is clearly visible.

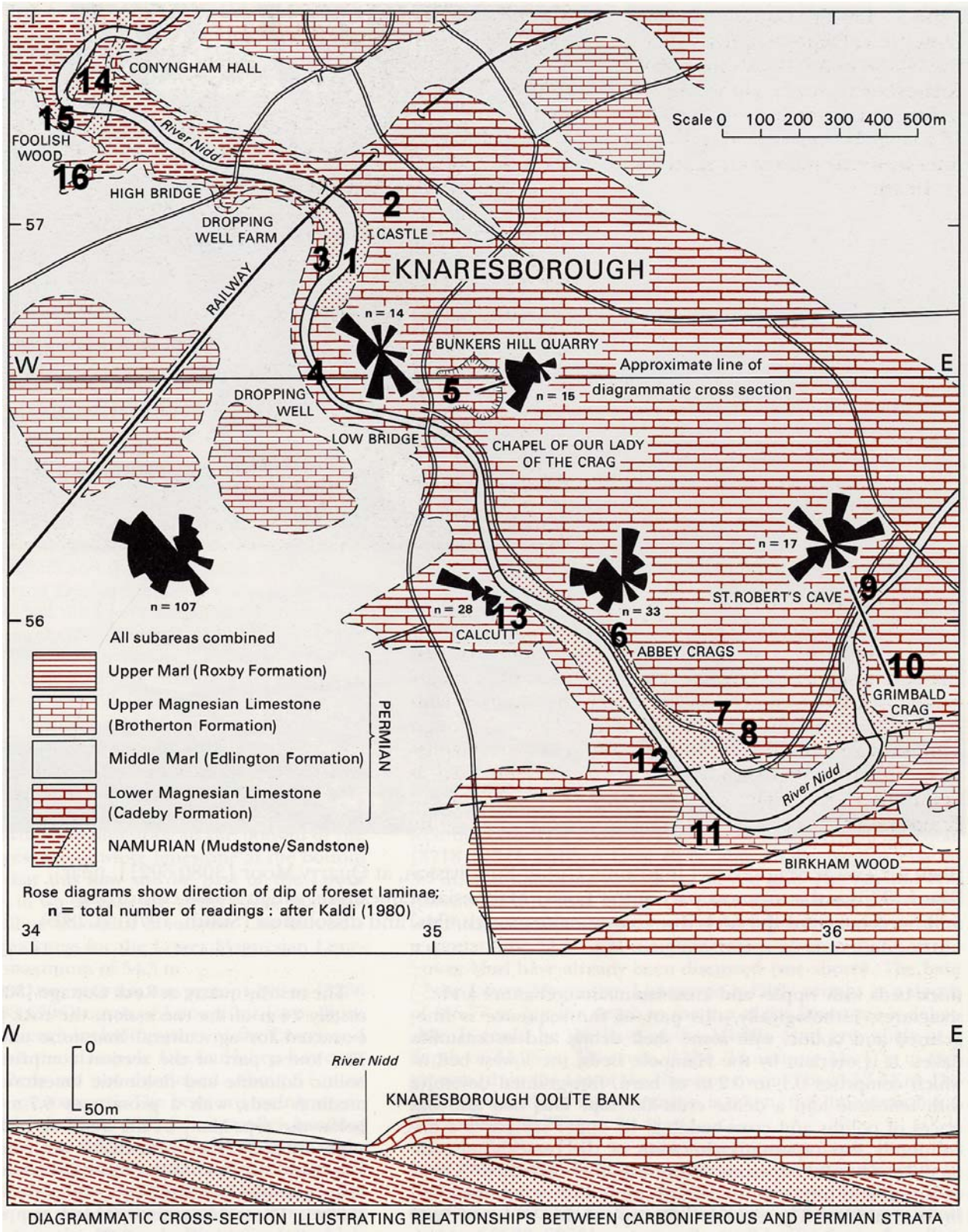

Figure 5. Geological map of Knaresborough Gorge and cross-section through the Carboniferous and Permian sequence. Showing the Cadeby Formation oolite bank thinning to the west (it also thins to the north and south). The Cadeby Formation is overlapped by the Edlington Formation and the Brotherton Formation which rest unconformably on the upstanding Carboniferous strata of the Harrogate Anticline. The localities visited are numbered; those numbered 14, 15 and 16 will only be visited if there is time.

Location 4. (SE 348 565). Proceed southwards to the Dropping Well. Here there are several magnificent tufa screens produced by the carbonate- and sulphate-rich waters of the spring. The Dropping Well spring emanates from the dolomite of the Cadeby Formation, but includes dissolved sulphates (Table 2) derived

from the gypsum of the overlying Edlington Formation. The carbonate is readily deposited from the water forming the Dropping Well screens and petrifying objects placed in its path. `Mother Shipton's Cave' just north of the Dropping Well is situated below an ancient tufa screen. Near this well tradition says that the notorious sibyl of the North, Mother Shipton, was born in the year 1488. Leave `Old Mother Shipton's' by the exit at Low Bridge, cross to the east side of the river and walk south about 50m.

	mg/l
Na	15.5
K	3.5
Ca	633.2
Mg	49.1
HCO,	223.6
SO,	1572.1
Cl	27.1
Sr	4.6
Si	4.9
Fe	1.1
Mn	0.6
Total determined mineralisation	2535.5

Table 2. Chemistry of mineral water from the Dropping Well, Knaresborough; composition in mg/l. Date 1896 (recalculated from Fox-Strangways, 1908; partly after Edmunds et al., 1969).

Location 5. (SE 351 565) At the entrance to Bunker's Hill Quarry (Caravan Park) massive, cross-bedded oolites of the Cadeby Formation are exposed in the cliff along to the `House in the rock' and the `Chapel of Our Lady of the Crag', these may be visited upon payment of an entrance fee. The chapel was formerly known as St Robert's Chapel after the monk who built it (see Locality 9 for further details). To visit the rock faces in Bunker's Hill Quarry (SE 3515 5655) the caravan site owners must be asked for permission. Near the `Chapel of Our Lady of the Crag' the cliffs show rows of post holes from the roofs of houses occupied by weavers up to about 1840. Hereabouts the rock faces show sections of oolitic dolomite which occurs in massive cross-bedded units with sets up to 18 m high; these belong to the Sprotbrough Member of the Cadeby Formation. These units represent massive sub-aqueous oolite sand waves. There is a general westward thinning of the sequence from here to Callcut (see cross-section in Figure 5).

Location 6. (SE 355 539). Proceed southwards along the road to the south end of the garden of the last house (Amtree House) on the east of the road. Please keep out of the garden which is private. Here, looking up at the rock face to the east, the unconformity between the massive sand-wave facies of the Cadeby Formation and the underlying Upper Plompton Grit is exposed. The sandstone is reddened and takes the form of a rounded buried hill with an exposed relief of 8m and a width of 32m (Figure 6). The overlying Cadeby Formation covers the buried hill with subconcentric drapes of beds 0.1-0.15m thick. On the flanks of the buried hill the they pass laterally into large-scale cross-bedding on a scale of 1-10m. The Cadeby Formation here comprises fine-grained crystalline to granular dolomite with sporadic poorly preserved ooliths.

Figure 6. Abbey Crags, Knaresborough. The Carboniferous Permian unconformity at Abbey Crags, Knaresborough. Large-scale cross-bedded oolitic limestones of the Cadeby Formation – Sprotbrough Member (Lower Magnesian Limestone - Upper Subdivision) rest unconformably upon a buried hill of slightly reddened Upper Plompton Grit (Namurian).

Location 7. (SE 357 557). Continue southwards to the car turning point. North-east of here the unconformity at the base of the Cadeby Formation dips down into a buried valley, but reappears in the quarry east of the road. Here 3.6m of Carboniferous sandstone (Upper Plompton Grit) is present beneath 13.5m of Cadeby Formation. The sandstone is very coarse to granule-grained, feldspathic, with quartz pebbles, and occurs in very thick cross-bedded units; the rock is reddened and weathered. At the base of the overlying limestone there is a thin impersistent bed (0-0.1m) of yellow, very coarse-grained sandstone with a dolomitic cement; it is not apparent whether this is part of the Carboniferous sequence, re-cemented with dolomite, or a very sandy bed at the base of the Permian. The overlying thin, medium and thick beds comprise dolomite with quartz grains in the lowest 0.5m or so.

Location 8. (SE 357 557). About 60m south-east of Locality 7 the same unconformity rises to the top of the old quarry in the private grounds east of the road. The section now exposes 10.5m of Carboniferous sandstone overlain by 4m of dolomite. This shows that locally the relief on the unconformity is a least 8m

Location 9. (SE 361 570). Continue along the riverside road to the NNE for about 500m where St Robert's Cave (Figure 7) is situated in the river bank below the road; entry is made through a gap in the wall and a flight of steps. This cave was the former abode of the pious monk Robert Flower of York from Fountains Abbey, AD 1160-1218. He took refuge in the cave and turned another cave into St Robert's Chapel (Locality 5). The cave also gained notoriety as the scene in 1745 of the murder of Daniel Clark for which crime Eugene Aram, a scholar of considerable ability, was hanged at York in 1759. At St Robert's Cave thin sub-horizontal beds of cross-bedded, oolitic dolomite are exposed with a channel structure to the south of the cave entrance. These beds are sparsely fossiliferous and probably represent the Wetherby Member (lower subdivision) of the Cadeby Formation. The member must, however, wedge out rapidly southwards

because it is not present at Grimbald Crag (Locality 10, SE 361 558) only 300 m to the south. From St Robert's Cave proceed northwards along the road, cross the River Nidd by the Wetherby Road, and head southwards on the riverside footpath to Grimbald Crag.

Figure 7. SW of Grimbald Bridge, Knaresborough. Saint Robert's Cave, Knaresborough. The cave believed to be the ancient dwelling place of St. Robert has been cut into the cross-bedded and shelly, oolitic dolomites of the Cadeby Formation. The steps and foundations belong to another dwelling built in front of the cave.

Location 10. (SE 361 558). Grimbald Crag exposes a sequence similar to that found at Abbey Crags and reveals another hill in the pre-Permian topography. About 16 m of massive, cross-bedded dolomite rest unconformably on reddened Lower Plompton Grit with one footpath running along the unconformity. The unconformity was formerly exposed overlain by about 2m of evenly bedded dolomitic limestone; then by massive cross-bedded units typical of the area (Dr Denys Smith, pers comm.). The unconformity is now obscured, but the lowest Permian beds seen contain abundant derived quartz grains. South of Grimbald Crag a fault, down-throwing to the south, brings the Brotherton Formation limestone outcrop against that of the Lower Plompton Grit.

Location 11. (SE 3567 5552). The Brotherton Formation limestone is best seen at the top of the bank west of Birkham Wood (SE 3567 5552). This exposure comprises 1.5m of white and pale grey, thin-bedded, porcellanous, dolomitic limestones which contains fossils. These include small tube-like algal threads of *Calcinema permiana* (King) Podemski which commonly occur in drifts and other concentrations, plus the bivalves *Schizodus obscurus* (J. Sowerby) and *Liebea*.

Location 12. (SE356 556). 100m north of locality 11 the Grimbald Crag Fault crosses the River Nidd opposite the Priory and is marked by a prolific spring. At this locality the Brotherton Formation limestone and Roxby Formation (formerly called the Upper Marl) are thrown against the Cadeby Formation, the fault scarp forming a prominent feature which can be traced to the west.

Location 13. (SE 352 560) North of the Grimbald Crag Fault Calcutt Cricket Ground occupies a quarry excavated in the Sprotbrough Member of the Cadeby Formation. East of the quarry the Lower Plompton Grit is exposed in the river bed while to the south and north the Edlington Formation overlies the dolomite of the Cadeby Formation. East of the Nidd, beneath Knaresborough, the Cadeby Formation is thick and its top rises to 75 m O.D., but at Calcutt it is thin and the top only rises to 53 m. As the regional dip of the Permian rocks is to the east, the westward thinning of the Cadeby Formation at this point is clearly illustrated (see Figure 8 and cross-section in Figure 5). Proceed along the riverside path to Low Bridge,

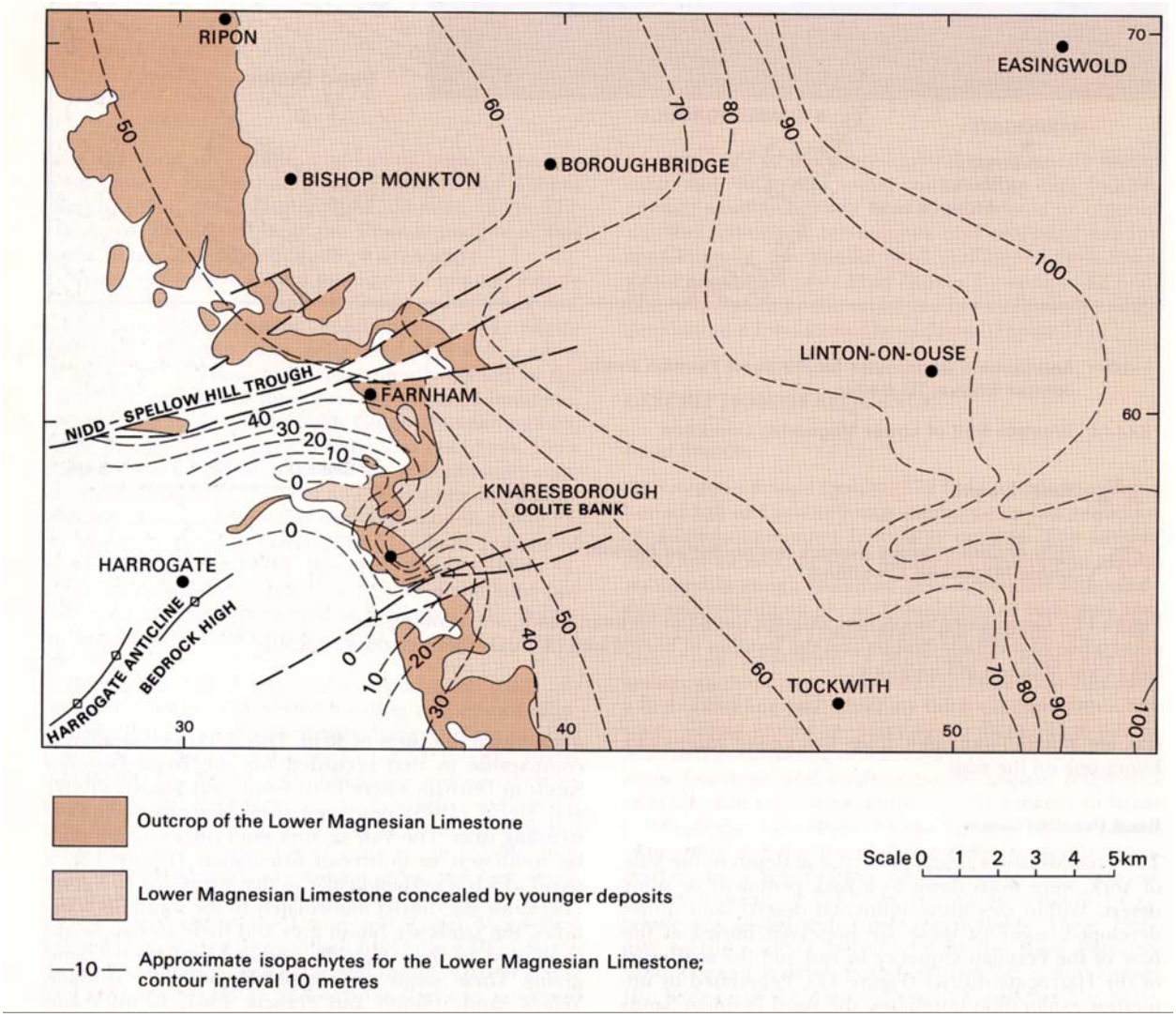

Figure 8. Generalised isopachyte map for the Cadeby Formation in the Harrogate district (Figure 13 from Cooper and Burgess, 1993).

Additional localities included in the YGS trip (Cooper, 1994):

Location 14. (SE 3425 5742). Continue upstream past the High Bridge to Conyngham Hall Farm,where the track crosses the river again. Fifty metres to the east, in the wooded area below Conyngham Hall, the attenuated Cadeby Formation (only 1.2m thick) is seen resting on weathered purple-brown Carboniferous siltstones, and overlain by the Edlington Formation. The exposed Edlington Formation comprises 2.6m of red-brown mudstone and sandstone; it includes sandy and micaceous detritus derived from Carboniferous sandstones similar to those exposed 100 m to the east, where the Edlington Formation rests directly on Carboniferous strata. The N-S cross-section through here is similar to the E-W cross-section shown in Figure 5.

Location 15. (SE 342 575) Near Conyngham Hall Farm the Upper Follifoot Grit crosses the river, forming the foundations of the bridge. The sandstone dips to the east at 27 degrees and comprises some 7m of fine to medium-grained sandstone with subordinate siltstone partings and a thick bed of siliceous ganister with rootlets near the middle of the unit. The Carboniferous rocks here, and at locality 16, dip steeply eastwards around the nose of the Harrogate Anticline. The resistant sandstone units form small escarpments projecting above the general level of the sub-Permian unconformity, and the basal Permian sedimentary rocks are banked against them.

Location 16. (SE 3413 5722) Follow the river southwards to Foolish Wood where in an old quarry the Upper Follifoot Grit dips south-west at 27 degrees. At the back of the quarry, sub-horizontal dolomite, 0.5 m thick, of the Cadeby Formation rests with a basal conglomerate of local material on an irregular sandstone surface, and is overlain by red siltstone. The sandstone apparently formed a ridge on the sea-floor prior to the deposition of the Cadeby Formation. Only a few metres to the north of the quarry, where the dolomite rests on siltstones underlying the Upper Follifoot Grit it thickens to 3 m, forming an escarpment from which large blocks have slipped down to the river bank.

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Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

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