Karst and Caves of Great Britain

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Chapter 8

Karst in Scotland

INTRODUCTION

Karst is a very minor component of Scotland's landscape. Only at Assynt has underground drainage left significant lengths of dry valley floor and limestone solutional features on a scale where they create distinctive landforms. Elsewhere, the very small outcrops of various limestones are almost lost in landscapes dominated by erosional and depositional products of Pleistocene glaciations on a grand scale.

The Assynt karst

A narrow belt of carbonate outcrops extend north–south through the hills immediately east of Inchnadamph, at the head of Loch Assynt; the outcrops are discontinuous due to complexities of the geological structure, and are nowhere more than 3 km wide. The main karst features and caves are in the Traligill and Allt nan Uamh basins, both close to Inchnadamph (see Figure 8.2), but there are also caves in the Knockan basin 10 km to the south and on the Achmore plateau 3 km to the north (Lawson, 1988).

All the carbonates are in the Durness Group, a sequence of grey, bedded dolomites, 100 m thick, of Cambrian and Ordovician age (Johnson and Parsons, 1979). They are underlain by Cambrian quartzites. These rocks lie within a zone of major Caledonian thrusts, of which the Moine Thrust is the highest. Thrust planes have left klippen of Eocambrian sandstones forming the summit outliers of Beinn an Fhuarain and Beinn nan Cnaimhseag on top of the Durness carbonates. Curvature of the thrust planes creates a broadly basinal structure within the dolomites south-east of Inchnadamph, but bedding planes within the thrust sheets dip at various angles. Many of the caves are formed on the planes of the thrusts and faults, and groundwater flow is also constrained by a number of igneous intrusions.

Each Pleistocene glaciation covered the area with ice and largely removed earlier karstic landforms (Atkinson *et al.*, 1995). Glacial till, glaciofluvial debris and blanket peat bogs mask much of the carbonate outcrop, and periglacial weathering during the Loch Lomond Stadial created areas of frost-shattered debris and solifluction flows. A few rocky gorges expose the carbonates and there are a few high crags (Figure 8.1), but there are no extensive doline fields. There are few limestone pavements, because the complex geological structure has not allowed the glacial stripping of extensive stratimorphs.

The sinks, dry valleys and risings are the most conspicuous features of the karst. Allogenic

Figure 8.1 The limestone crags of Creag nan Uamh containing the Bone Caves, south of the Allt nan Uamh, seen from Beinn nan Cnaimhseag, with the Claonaite valley on the left. (Photo: T.J. Lawson.)

drainage is from the higher ground of Breabag and Conival in the east, and most of it sinks where it crosses onto the dolomite. Both the Traligill River and the stream of Allt nan Uamh flow entirely underground, except in very wet weather, though some streams maintain surface courses over the dolomite, mainly supported on mantles of glacial till. The associated caves carry water in postglacial stream trenches and flooded passages, and they also contain many passages which pre-date the last glaciation.

Outlying limestone areas

The Durness dolomites extend both north and south of Assynt, but with fewer karst features. Smoo Cave lies beneath a raised beach platform on the north coast; it has a large entrance chamber at the head of a tidal inlet, and an inner chamber with a stream cascading though its roof; the karstic passages and chambers were modified by wave action when sea levels were higher (Ford, 1959). Many small sinks and caves occur in the Durness dolomites just east of Loch Slapin, on the Isle of Skye; they include the stream cave of Uamh Cinn Ghlinn where the Allt nan Leac flows underground for 350 m (Ryder, 1974). The same carbonates have more small caves in the hills around Kishorn and some caves and limestone pavements in Glen Creran (Jeffreys, 1975, 1984).

Thin Jurassic limestones contain several small caves around Broadford, on Skye, and also the cave of Uamh nan Breagaire which has over 500 m of rift and bedding plane passages beneath a small limestone gorge at Applecross (Ryder, 1982). The mountain of Schiehallion, south-east of Loch Rannoch, is formed in Dalradian quartzites and phyllites with thin bands of marble; short caves have been formed where these are crossed by streams (Jeffreys, 1984). Uamh nan Uachdar is a cave with 60 m of passage in a Dalradian marble at an elevation of about 900 m in the Grampians south of Glen Spean (Young, 1992). There are no significant, recorded karst features in the thin limestone units in the Carboniferous of the Midland Valley.

Limestones are poorly represented in Scotland, and this short list of karst features is unlikely ever to become much longer. Pleistocene and Holocene sediments have been excavated from many caves and rock shelters, but these are mostly marine features preserved in fossil cliff lines behind raised beaches, and are not in limestone.

TRALIGILL VALLEY

Highlights

The Traligill Valley contains Scotland's finest karst scenery and is Britain's most recently deglaciated karst area. Its fine surface glaciokarst and its well documented underground drainage, developed in the Durness Limestones, provide a detailed record of landform development through the Pleistocene.

Introduction

The Traligill Valley karst lies just to the east of Inchnadamph, on the dolomites of the Durness Group, which crop out along a narrow and structurally complex belt. Drainage from the impermeable quartzites of Ben More Assynt in the east flows underground on reaching the dolomites, resurging several kilometres further down the valley. A spectacular variety of rock scars, pavements, blind valleys, dry valleys and dolines represents the progressive development of the karst drainage.

The geology of the Assynt karst and caves has been discussed by Ford (1959), Johnson and Parsons (1979) and Lawson (1988). The cave geomorphology is more fully described by Lawson (1983, 1986, 1988), and the later cave discoveries are recorded by Taviner (1993), Jeffreys (1994) and Mulholland (1994). The karst hydrology has been assessed through quantitative dye tracing (Newson and Atkinson, 1970; Smart *et al.*, 1986; Lawson, 1988), and stalagmite studies have yielded chronological and environmental data for the late Pleistocene (Lawson, 1982; Atkinson *et al.*, 1986; Baker *et al.*, 1993, 1995a).

Description

The Traligill River drains a section of wild moorland terrain dominated by the glaciated landforms which typify the Scottish Highlands. Karst features are not overly conspicuous, but a cave drainage system underlies the valley floor and distinguishes the morphological landforms of the site. About half of the 17 km^2 catchment is underlain by the Durness Carbonates (Figure 8.2). The upper basin extends onto quartzite outcrops and is an undulating plateau at elevations around 300 m, extensively mantled by peat and thick fluvioglacial sands. In contrast, the lower valley is narrower

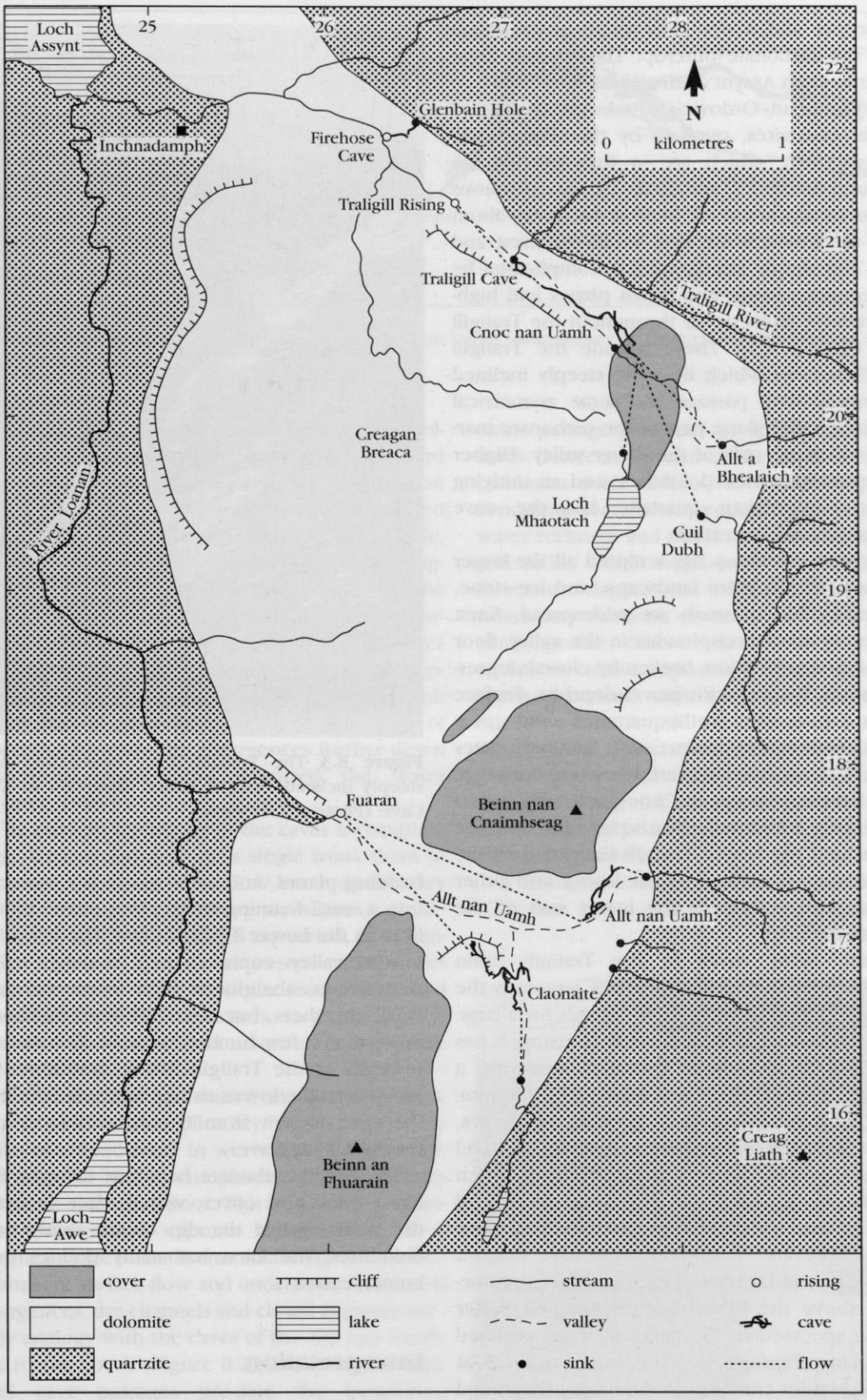

Figure 8.2 Geological map of the main karst belt in Assynt, containing the caves of the Traligill and Allt nan Uamh Valleys. The dolomites belong to the Durness Group and are underlain by the Lower Palaeozoic quartzites. The cover rocks are klippe of Cambrian quartzite and Eocambrian sandstone lying over major thrust planes.

and steeper and is dry over much of its length across the carbonate outcrop. The Traligill River flows into Loch Assynt at an elevation of 70 m.

The Cambrian–Ordovician rocks are composed of basal quartzites, overlain by the 'Pipe Rock' orthoquartzites, which are in turn overlain by shales and dolomites, and finally by the calcareous Durness Group; these are bedded dolomites about 100 m thick which are host to all the karst and caves. The simple stratigraphy is complicated by later tectonic events, and thrust planes and high-angle reverse faults occur throughout the Traligill Valley (Figure 8.3). These include the Traligill Main Thrust, on which lie some steeply inclined segments of cave passage and some asymetrical subaerial ravines along part of the carbonate margin on the north side of the lower valley. Higher thrust planes cap the dolomites, and an outlying klippe of Cambrian quartzite has the cave drainage passing beneath it.

Recurrent glaciation has sculpted all the larger features of the modern landscape, and ice striae, till, erratics and outwash are widespread. Karst features are most conspicuous in the valley floor where it is dry for 2 km, broken by closed depressions, some floored with gravel deposits. Surface streams from the orthoquartzites and peat deposits sink at the contact with the carbonates (Figure 8.2), and ten sinks are known to converge on the cave streamway in Cnoc nan Uamh (Smart *et al.*, 1986). Additional input is provided from the sinks around the Lower Traligill Cave, and all the water resurges at the Traligill Rising and other adjacent risings towards the lower end of the dolomite outcrop.

Of the many caves in the Traligill basin (Jeffreys, 1984; Lawson, 1988), the largest is the Cnoc nan Uamh system which extends for a large part of the drainage line from sink to rising. It has over 2200 m of mapped passages, covering a depth range of nearly 100 m (Figure 8.4). A complex high-level series of phreatic passages, oxbows and collapse chambers, with thick gravel deposits overlain by stalagmite, has been breached at the Uamh an Tartair entrance, and upstream the water emerges from two active phreatic sections. Downstream the cave is again breached at the Uamh an Uisge entrances, immediately above the Waterslide, where the water forms a spectacular cascade down an inclined thrust plane (Figure 8.5). Short sumps at the foot of the downdip cascades lead to a gently graded streamway almost along the strike. This has sections of beautifully decorated high-level phreatic

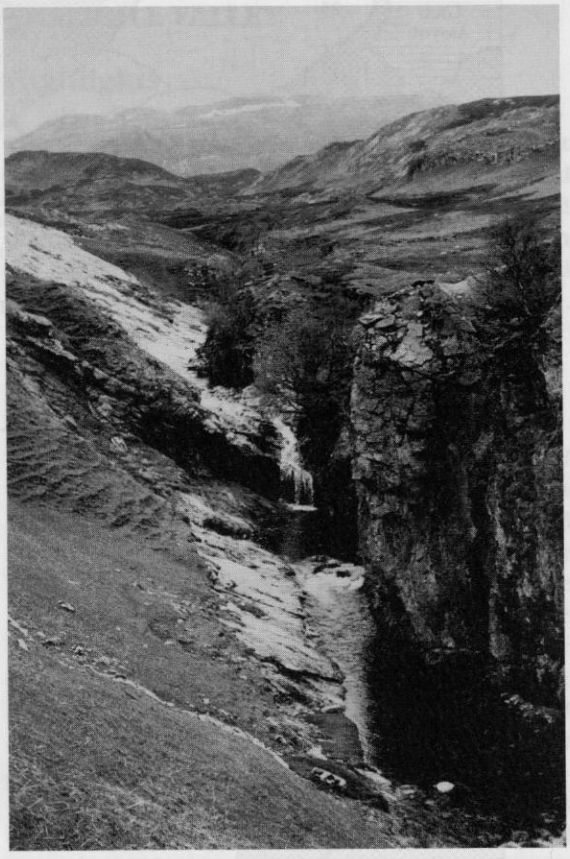

Figure 8.3 The Traligill River entrenched on the steeply inclined Traligill Thrust, upstream of Traligill Cave. (Photo: T.J. Lawson.)

bedding planes, and ends where the water roars into a small foaming sump close to the upstream limit in the Lower Traligill Cave. The lower caves in the valley contain steep, vadose, tributary streamways, abandoned high levels and various small chambers, but none has been explored for more than a few hundred metres. The main flow resurges at the Traligill Rising, but some water escapes to the lower risings where it is joined by the cave stream from Glenbain Hole resurging from Firehose Cave.

The broad carbonate bench of Creagan Breaca has a thick peat cover, with surface drainage to the west, against the dip of the thinly bedded dolomites; the karst has many dolines but no known caves.

Interpretation

The karst landscapes of the Traligill Valley demonstrate the effects of complex geological structures

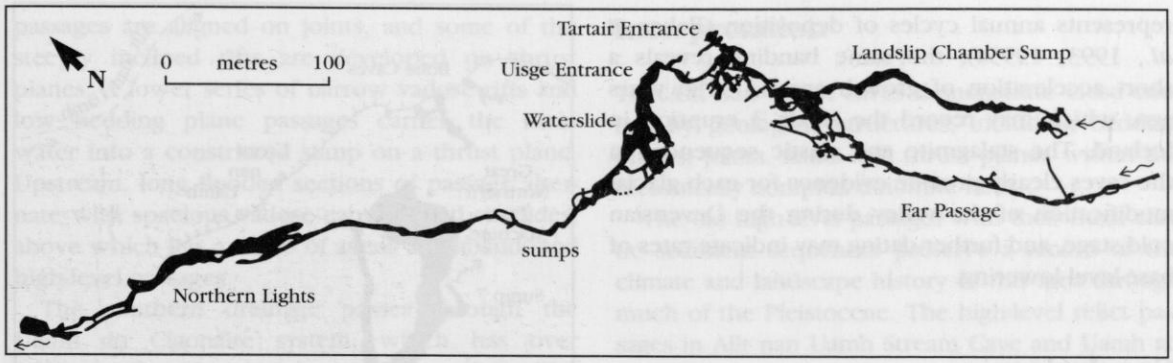

Figure 8.4 Outline map of the cave system of Cnoc nan Uamh (from survey by Grampian Speleological Group).

and multiple glaciations on the surface morphology. Several knickpoints along the valley record the surface lowering and subsequent rejuvenation of the valley after each glacial event. This has led to a progressive lowering of the local water table, causing a series of underground drainage captures. The structurally complex nature of the limestone is reflected in the rather irregular morphology of the caves, with joints, bedding planes and thrust planes all influencing cave development. The drainage below Cnoc nan Uamh follows the Traligill Main Thrust, and a series of successive downstream resurgences further down this thrust plane have captured the water (Taviner, 1993).

The modern hydrology of the caves is complex; large streams converge on a single trunk drain in Cnoc nan Uamh, and then flow into a distributary system feeding several resurgences (Smart *et al.*, 1986). Passage morphologies are varied, and abandoned high-level passages represent earlier stages of development. The multiple resurgences and many flood overflow channels may indicate the immature and constricted nature of many of the lower conduits.

Cave underflow has caused the partial desiccation of the lower Traligill valley, which is now only active as a flood route in wet weather. Higher up, the valley is almost completely dry and dolines punctuate the valley floor. This process of progressive underground capture had resulted in a complex range of landforms, including valleys with permanent surface flow and underflow, abandoned resurgences, dry channels and closed depressions.

By analogy with the caves of the Allt nan Uamh, just to the south (Figure 8.2), many of the high-level cave passages pre-date the Ipswichian interglacial, and were abandoned as the drainage occupied the modern streamways. Within these older passages, calcite stalagmites have yielded dates between 38 and 26 ka, or less than 9 ka (Atkinson *et al.*, 1986). The older dates show that conditions were warm enough to permit groundwater recharge and solutional activity between 38 and 26 ka, which suggests that there was a mid-Devensian deglaciation of the valley; subglacial water may excavate caves but normally lacks the exchangeable carbon dioxide which permits extensive calcite deposition. These caves clearly survived beneath their temporary glacial covers, but how much of the older systems were destroyed is not known. Their extensive clastic fills are interpreted as the product of flooding during some stages of the glacial events, with the main influx of coarse gravels and sands probably during deglaciation.

A Holocene stalagmite from the upper level of Cnoc nan Uamh, has luminescent banding which

Figure 8.5 The Waterslide in Cnoc nan Uamh. (Photo: A.C. Waltham.)

represents annual cycles of deposition (Baker *et al.*, 1993, 1995a); the same banding reveals a short acceleration of growth around 3150 years ago, which may record the Hekla 3 eruption in Iceland. The stalagmite and clastic sequences in the caves clearly provide evidence for each glacial modification of the valley during the Devensian cold stage, and further dating may indicate rates of base-level lowering.

Conclusions

The Traligill valley contains Scotland's finest glaciokarst landscape. Its cave drainage is well documented and provides an excellent example of a complex network dominated by structural rather than lithological controls; the thrust plane caves are particularly unusual. Some of the caves are immature, but sediments in the abandoned caves provide a unique record of underground drainage during a warmer phase of the middle Devensian. The dry valley morphology has evolved in response to sequential lowering of base levels and associated underground captures.

ALLT NAN UAMH CAVES

Highlights

The site contains two of the most extensive cave systems in Scotland, developed in structurally complex Durness dolomites, and containing sequences of calcite and clastic sediments related to the Pleistocene glacial events.

Introduction

The caves are located in the upper basin of the Allt nan Uamh valley, south-east of Inchnadamph (Figure 8.2). Ten caves have been explored, all of which are developed in thrust sheets of Cambrian–Ordovician Durness Limestone. Allogenic streams drain from outcrops of the underlying Cambrian quartzites in the east, as well as from an overlying klippes of Torridonian sandstone both north and south of the valley. The two main cave systems transmit water from sinks in the upper part of the Allt nan Uamh valley towards a common resurgence at Fuaran Allt nan Uamh. The mapped cave passages cover only a small part of the 2000 m horizontally and 150 m vertically between the sinks and resurgence. They have been described by Ford (1959), Jeffreys (1984) and Lawson (1988).

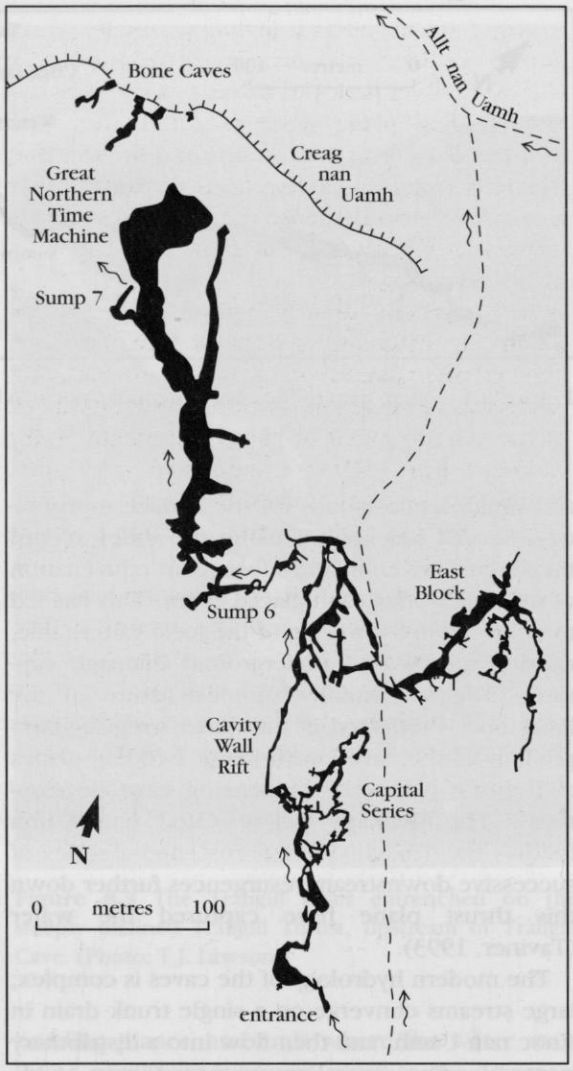

Figure 8.6 Outline map of Uamh an Claonaite; the survey beyond sump 6 is only a preliminary drawing (from surveys by Grampian Speleological Group).

Description

The Allt nan Uamh Stream Cave drains the northern sector of the basin. More than 1500 m of mapped passages are developed at two levels. The upper series of large, abandoned phreatic passages contains extensive clastic deposits and areas of collapse, but has few speleothems. Many of the

passages are aligned on joints, and some of the steeply inclined rifts are developed on thrust planes. A lower series of narrow vadose rifts and low bedding plane passages carries the main water into a constricted sump on a thrust plane. Upstream, long flooded sections of passage alternate with spacious vadose canyons and cascades, above which lies a series of avens and abandoned high-level passages.

The southern drainage passes through the Uamh an Claonaite system, which has over 2600 m of explored passages (Figure 8.6). The modern cave stream flows along the western side of the system; much of its known length is in a vadose canyon, with several cascades, interrupted by flooded sections. Cavity Wall Rift is a fault-guided section where the stream descends gradually along two sections of solutionally enlarged thrust planes which separate two lithologically distinct limestones. The streamway turns south-west through a series of sumps, and then north-west below high-level chambers to a cascade into another sump. Off the main streamway, there are three series of abandoned passages, all at altitudes of 300–340 m. Capital Series consists of a series of largely abandoned, oxbow passages, partly filled with sediment from past periods of ponding. East Block is another high-level series of large phreatic passages, partially blocked by collapse and thick deposits of clastic sediment. The Great Northern Time Machine and other wide chambers above the far streamway are choked very close to the Bone Caves. The old passages contain suites of clastic sediments and calcite deposits which have yielded 22 dates (Atkinson *et al.*, 1995).

The remaining short caves include the Bone Caves which are truncated fragments of old passage in the cliffs of Creag nan Uamh, high above the modern valley floor; the sediments in these caves have provided an important source of Quaternary faunal remains (Lawson, 1993, 1995a). The sinks are choked, except for one shaft 7 m deep into a narrow fissure, and the resurgences are immature.

Interpretation

The Allt nan Uamh caves demonstrate close control by geological structures, including bedding planes, joints, faults and thrust planes within the tectonically complex dolomite beds.

The old high-level passages with their thick clastic sediment sequences preserve a record of the climate and landscape history of this area through much of the Pleistocene. The high-level relict passages in Allt nan Uamh Stream Cave and Uamh an Claonaite, and the truncated passages of the Bone Caves, are the remains of a series of conduits formed close beneath a palaeo-water table at about 340 m. They were abandoned when the main streamway of each cave formed at its present lower level, in response to glacial rejuvenation of the resurgence site. Flowstone from the abandoned passages in Uamh an Claonaite has been radiometrically dated to ages of 12–192 ka (Lawson, 1981, 1988; Atkinson *et al.*, 1995). These results suggest that the main phase of cave development was no later than the Hoxnian, since when the resurgence level has been lowered by about 130 m, probably by three stages of glacial erosion.

The glacial rejuvenation drained the phreatic passages and created the sites for Ipswichian deposition of the oldest stalagmites. The Devensian clastic sediments within the caves include subglacial silts, proglacial sands and gravels, and lag gravels and cobble beds left by meltwater scour during deglaciation (Atkinson *et al.*, 1995; Lawson, 1995b). There was also at least one phase of solutional activity and stalagmite deposition within the Devensian.

Conclusion

The Allt nan Uamh valley contains two of Scotland's most extensive and complex cave systems, as well as some of Britain's longest caves developed in non-Carboniferous limestone. These caves provide excellent examples of the nature of karst hydrology and geomorphology in structurally complex thrust sheets of dolomite, and their high-level passages contain a valuable sedimentary record of Pleistocene events.