This is a repository copy of **Sediment-filled cavities in the Morecambe Bay karst (UK): Examples from the Warton and Silverdale area.**

White Rose Research Online URL for this paper:
http://eprints.whiterose.ac.uk/96596/

Version: Published Version

**Article:**
Murphy, PJ and Moseley, M (2015) Sediment-filled cavities in the Morecambe Bay karst (UK): Examples from the Warton and Silverdale area. Cave and Karst Science, 42 (3). pp. 144-147. ISSN 1356-191X

**Reuse**
Unless indicated otherwise, fulltext items are protected by copyright with all rights reserved. The copyright exception in section 29 of the Copyright, Designs and Patents Act 1988 allows the making of a single copy solely for the purpose of non-commercial research or private study within the limits of fair dealing. The publisher or other rights-holder may allow further reproduction and re-use of this version - refer to the White Rose Research Online record for this item. Where records identify the publisher as the copyright holder, users can verify any specific terms of use on the publisher's website.

**Takedown**
If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing eprints@whiterose.ac.uk including the URL of the record and the reason for the withdrawal request.
**Sediment-filled cavities in the Morecambe Bay karst (UK): examples from the Warton and Silverdale area**

Phillip J MURPHY¹ and Max MOSELEY²

¹ School of Earth and Environment, University of Leeds, LS2 9JT, UK.
E-mail: P.J.Murphy@leeds.ac.uk

² P.O. Box 69, Poskod 10700, G.P.O. Penang, Malaysia.
E-mail: maxmoseley@hotmail.com

**Abstract:** Various types of sediment-filled natural cavities are exposed in abandoned haematite and copper mines in Carboniferous limestones around Morecambe Bay, northwest England. They range in age from pre-mineralization through to Pleistocene though, because the date of the mineralization is disputed, it has been impossible to propose a confident chronology for many of them. Re-examination of two sites in the eastern part of the district, together with recently published results that point to a Mid Triassic age for the mineralization episode, now make it possible to propose a Neogene age for at least one example. Other, pre-mineralization, cavities and infill sediments probably date from the period of denudation that removed Carboniferous strata in this area prior to deposition of Permo-Triassic red beds. Some unconsolidated sediments are assigned on lithological evidence to being Pleistocene glacial deposits.

**Key words:** Morecambe Bay, palaeokarst, chronology, Carboniferous, Permo-Triassic, Neogene, Pleistocene

Received: 28 April 2015; Accepted: 26 September 2015

The Morecambe Bay karst (Fig. 1) is developed on a series of discontinuous outcrops of Great Scar Limestone. The eastern part of the area is well known for outstanding examples of limestone pavement and other karst landforms (Waltham et al., 1997, 101–112; Gale, 2000; Webb, 2013, especially Fig. 5.26) but there are few explored caves (Holland, 1967; Ashmead, 1974; Brook et al., 1994, 264–281). Local fragments of relict and largely sediment-choked cave passage survive.

Escarpments formed on the limestone now lack impermeable caprocks; drainage is wholly subterranean with little integration of surface flow. Recharge to the limestone aquifers is largely by diffuse flow, but the existence of discrete risings and some restricted active cave development around the bases of the escarpments implies integration of the diffuse-flow inputs within the aquifers.

Haematite ore-bodies emplaced within the limestone strata of the western part of the district were mined extensively from early times until the 20th century, and Furness became the most productive iron-orefield in the world for a time during the second half of the 19th century. The eastern part of the district was much less important as a source of ore but it is known that deposits of haematite and copper carbonate ores were also prospected and mined on a relatively small scale here during the 18th and 19th centuries, and likely earlier. Explorations of abandoned workings in this district found that the miners had intercepted natural cavities at a number of sites. Brief accounts of the known mine workings, natural cavities and infill sediments were given by Moseley (1969, 2010).

The most extensive mine workings are on Warton Crag (Fig. 1), a 163m-high limestone escarpment lying between Silverdale and Warton village. There are a number of abandoned metalliferous mines on the Crag, mostly concentrated in the vicinity of Crag Foot in the northwest, and various types of natural cavities and cave sediments have been reported during investigations of these mines. Palaeokarstic cavities and sediments were also encountered in mines at Silverdale and elsewhere in the district.

Some of the more important of the known exposures of natural cavities and infill sediments have become inaccessible due to sealing of the mines, but several sites (Fig. 1) remain open. Exposures in two of the still-accessible sites, North Level on Warton Crag and Red Rake at Silverdale, have been re-examined and the findings are reported here.

---

**Figure 1:** The extent of the Carboniferous (Great Scar) limestone outcrops in the eastern part of the Morecambe Bay area, showing locations of sites discussed in the text.
North Level

North Level (Fig. 2) of the Crag Foot mine complex is a 100m-long level (NGR SD 48257409) driven through Dinantian limestone, presumably in an abandoned attempt to intersect and de-water mines higher up the Crag. It has been referred to as ‘Grizedale Wood Drainage Level’ by several authors including Holland (1967), Griffiths (1981), Gale (1984), Monaco (1995) and Hill and Hall (2015). Calcareous sand, a haematite-bearing conglomerate overlain by laminated argillaceous sediments, and coarse-grained fills containing chlorite-bearing lithologies are exposed in the level.

Calcereous sand

The adit forehead is at a point where water wells up from a narrow partly-choked natural rift, which has so far proved impenetrable for cave divers (Hill and Hall, 2015). The stream carries a well-sorted bed load of fine-grained, well-rounded calcareous sand grains with a minor component of both black and yellow iron oxide grains. The textural maturity and the presence of the iron oxide grains suggest that this material is being re-eroded from concealed natural cavities beyond the explored limit of the level; iron oxide being usually found as crusts on cave sediments deposited under phreatic conditions.

Coarse fills with chlorite-bearing lithologies

At two points North Level intersects fragments of cave passage characterized by coarse-grade fills that contain pebbles (defined as 2–64mm) and cobbles (64–256mm) of fine-grained chloritized lithologies (points D and A on Fig. 2). The nearest sources of such lithologies are outcrops of Silurian Windermere Supergroup strata to the north. Considering that glacial ice cover in this area was sourced from areas and are distorted by slumping and faulting. XRD analysis reveals to be mainly quartz with subordinate microcline feldspar and muscovite mica. No clasts of chlorite-bearing lithologies have been identified. The overlying banded clays display approximately twenty red–grey alternations and are distorted by slumping and faulting. XRD analysis of this material, both red and grey layers, shows the presence of quartz, microcline, muscovite and haematite, but again no chlorite.

Haematite-bearing conglomerate and laminated clays

Approximately midway along the level (point C on Fig. 2), another sediment-filled palaeokarstic cavity, which differs from the previous examples, is encountered. The deposits are described briefly in Moseley (1969, p.10; 2010, pp 15 and 85, fig.5). The sedimentary sequence is unlithified and consists of a conglomeratic layer 1–2m in thickness overlain by up to 35cm of partly-consolidated red and grey laminated silts and clays that fill the cavity entirely (Fig. 3). The junction between the two units is abrupt. The conglomeratic layer contains both well-rounded and angular fragments, up to cobble grade, within a silty matrix. Clasts consist predominately of limestone and micaceous sandstone along with some haematite. Many of the rounded clasts are composed of a soft, clay-grade material that XRD analysis reveals to be mainly quartz with subordinate microcline feldspar and muscovite mica. No clasts of chlorite-bearing lithologies have been identified. The overlying banded clays display approximately twenty red–grey alternations and are distorted by slumping and faulting. XRD analysis of this material, both red and grey layers, shows the presence of quartz, microcline, muscovite and haematite, but again no chlorite.

Gale (1984) conjectured that the conglomerate layer was deposited under torrential fluvial conditions. The mixture of clast morphologies in the conglomerate does suggest that some material has been subjected to significant fluvial transportation over a significant distance, resulting in high degrees of roundness and sphericity, but the angular nature of some other clasts indicates a more local origin. Such varied morphology is consistent with involvement of mass movement processes (‘slumping’), which are well documented as being responsible for the emplacement of some coarse-grained material into caves (Murphy and Cordingley, 2013). Both of these possible processes imply rapid deposition. This material is overlain by laminated, quiet-water sediments with an abrupt or interrupted chronological hiatus between the two. If the red–grey layers represent annual deposition it is possible that the whole conglomerate and banded clay sequence accumulated very rapidly in just a few years.

These conglomerate and banded clay fills have been interpreted as being derived from surface glacial materials (Gale, 1984), but the suite of lithologies represented does not support this proposal. Glacially-transported materials in the area are sourced from the varied igneous and sedimentary Lake District strata and typically display a diversity of rock types, with the chloritized lithologies that are common among Lower Palaeozoic strata particularly in evidence. As mentioned above, clasts and fine-grained material from such lithologies are absent in the North Level conglomerate and banded clay deposits. The small suite of component rock types and mineralogies that are represented is instead consistent with derivation from younger strata that formerly overlay the area, and they were probably deposited during or soon after denudation of these parent rocks. However, as no strata younger than the Lower Carboniferous limestones now survive on Warton Crag, it is difficult to identify the specific source reliably.

The micaceous sandstone clasts and mineralogy of the argillaceous deposits might be consistent with an origin from Millstone Grit Group strata. Sandstones believed to be mid to late Carboniferous, probably Namurian, in age were formerly exposed a little over a kilometre south of Crag Foot at Ings Point. Alternatively the presence of haematite in the clays points to a possible derivation from the younger Permian conglomerate layer was deposited under torrential fluvial conditions. The mixture of clast morphologies in the conglomerate does suggest that some material has been subjected to significant fluvial transportation over a significant distance, resulting in high degrees of roundness and sphericity, but the angular nature of some other clasts indicates a more local origin. Such varied morphology is consistent with involvement of mass movement processes (‘slumping’), which are well documented as being responsible for the emplacement of some coarse-grained material into caves (Murphy and Cordingley, 2013). Both of these possible processes imply rapid deposition. This material is overlain by laminated, quiet-water sediments with an abrupt or interrupted chronological hiatus between the two. If the red–grey layers represent annual deposition it is possible that the whole conglomerate and banded clay sequence accumulated very rapidly in just a few years.

These conglomerate and banded clay fills have been interpreted as being derived from surface glacial materials (Gale, 1984), but the suite of lithologies represented does not support this proposal. Glacially-transported materials in the area are sourced from the varied igneous and sedimentary Lake District strata and typically display a diversity of rock types, with the chloritized lithologies that are common among Lower Palaeozoic strata particularly in evidence. As mentioned above, clasts and fine-grained material from such lithologies are absent in the North Level conglomerate and banded clay deposits. The small suite of component rock types and mineralogies that are represented is instead consistent with derivation from younger strata that formerly overlay the area, and they were probably deposited during or soon after denudation of these parent rocks. However, as no strata younger than the Lower Carboniferous limestones now survive on Warton Crag, it is difficult to identify the specific source reliably.

The micaceous sandstone clasts and mineralogy of the argillaceous deposits might be consistent with an origin from Millstone Grit Group strata. Sandstones believed to be mid to late Carboniferous, probably Namurian, in age were formerly exposed a little over a kilometre south of Crag Foot at Ings Point. Alternatively the presence of haematite in the clays points to a possible derivation from the younger Permian conglomerate layer was deposited under torrential fluvial conditions. The mixture of clast morphologies in the conglomerate does suggest that some material has been subjected to significant fluvial transportation over a significant distance, resulting in high degrees of roundness and sphericity, but the angular nature of some other clasts indicates a more local origin. Such varied morphology is consistent with involvement of mass movement processes (‘slumping’), which are well documented as being responsible for the emplacement of some coarse-grained material into caves (Murphy and Cordingley, 2013). Both of these possible processes imply rapid deposition. This material is overlain by laminated, quiet-water sediments with an abrupt or interrupted chronological hiatus between the two. If the red–grey layers represent annual deposition it is possible that the whole conglomerate and banded clay sequence accumulated very rapidly in just a few years.

These conglomerate and banded clay fills have been interpreted as being derived from surface glacial materials (Gale, 1984), but the suite of lithologies represented does not support this proposal. Glacially-transported materials in the area are sourced from the varied igneous and sedimentary Lake District strata and typically display a diversity of rock types, with the chloritized lithologies that are common among Lower Palaeozoic strata particularly in evidence. As mentioned above, clasts and fine-grained material from such lithologies are absent in the North Level conglomerate and banded clay deposits. The small suite of component rock types and mineralogies that are represented is instead consistent with derivation from younger strata that formerly overlay the area, and they were probably deposited during or soon after denudation of these parent rocks. However, as no strata younger than the Lower Carboniferous limestones now survive on Warton Crag, it is difficult to identify the specific source reliably.

The micaceous sandstone clasts and mineralogy of the argillaceous deposits might be consistent with an origin from Millstone Grit Group strata. Sandstones believed to be mid to late Carboniferous, probably Namurian, in age were formerly exposed a little over a kilometre south of Crag Foot at Ings Point. Alternatively the presence of haematite in the clays points to a possible derivation from the younger Permo-Triassic red sandstones, in which case the source might have been the equivalent of the Permian Collyhurst Sandstone Formation. These iron-bearing strata crop out beneath a thick cover of till in the Morecambe area (Brandon et al., 1998, p.103) and are suggested as being the probable source of haematite that has resulted in the reddening of Namurian Millstone Grit Group strata in the western part of the Lancaster region (Brandon et al., 1998, pp106–107). However, the occurrence of haematite clasts in the North Level conglomerate indicates that the iron content of the banded clays could have been derived from pre-existing emplaced iron-ore deposits rather than from Permo-Triassic red beds.

![Figure 2: Plan of North Level, Crag Foot (CRG Grade 4, 1970).](image-url)
The mine was excavated on a small northwest–southeast-trending fault plane that can be traced on the surface farther towards the southeast as a shallow valley. The level appears to have been driven at least in part along a cave passage. Mineralized veins and sand-filled and open natural cavities are exposed in the underground workings.

Unconsolidated stratified red haematite-bearing and yellow-brown sand is deposited in natural cavities in the roof and walls of the level. The well-sorted and highly rounded coarse sand consists mainly of quartz with subordinate lithic grains. Sporadic pebbles of water-worn limestone occur in the sand deposit, including some showing the presence of haematite mineralization. The origin of such a texturally mature sand deposit could have been the Permian-Triassic deposits since eroded away. The lack of chloritized grains in the deposits suggests that it is not sourced from the glacial deposits and thus pre-dates the Pleistocene.

Other examples of natural cavities and sediments

Other workings of the Crag Foot mine group exposed a variety of sediment-filled cavities. The fills include lithified argillaceous and arenaceous bedded sediments intimately associated with iron and copper carbonates, oxides and gangue minerals; unconsolidated yellow clays; well-sorted deposits of sand; and gravels and coarse sands containing chloritized lithologies (Moseley, 1969, 2010). Some of the best exposures were in the now inaccessible Crag Foot Mine (NGR SD 48377355) (Fig.2). One section here revealed a sequence consisting of arenaceous haematite-bearing bedded sediments overlain by alternating fine and coarse sand. A sample of the coarse sand showed it to comprise mainly quartz and grains of a chloritized lithology (Moseley, pers. obs.). The succession was capped by speleothem overlain in turn by a deposit of clay with rounded clasts including chloritized lithologies. This sequence implies that the main cavity-fill was deposited either at the arrival of material sourced and transported from Lower Palaeozoic rocks by Pleistocene ice. Elsewhere in the mine examples of haematite ore emplaced within lithified cavity-fill sediments imply a pre-mineralization date (i.e. probably pre-Mid Triassic) for the earliest stage of the sequence, suggesting an origin during the period of denudation that removed Carboniferous strata in this area prior to deposition of Perm-Triassic red beds.

The workings of the Lower Mine at Crag Foot, referred to as ‘Moss House Mine’ (NGR SD 48067380) and ‘Aragonite Band Mine’ (NGR SD 48157380) by Holland (1967) (Fig.1) are still physically accessible and contain some natural cavities and cavity-fill exposures that offer potential for further research in the area. Calcarenous sand is reported to underlie boulder clay in Fairy Hole (Fig.1), a natural cave fragment at NGR SD 49697296 on the eastern side of Warton Crag (Ashmead, 1974, p.221). This material might be similar in origin to calcarenous sand carried by the stream in North Level (see above).

Outside the immediate study area, Ashmead (1974, p.207) reports dissolution pipes filled by “Millstone Grit and sandstone boulders” to the southeast of the study region at Swantley Reef Knoll, near Kellet. Brandon et al. (1998, p.129) describe a sediment-filled cave in a quarry near Nether Kellet, which contained 6m of unconsolidated sediment consisting of brown stony clay with reddish brown and orange-brown clay overlain by brown stony clay, which was overlain in turn by finely laminated grey and pale brown clay. The authors suggested derivation of the cave fill from a temperate interglacial palaeosol for the lowest deposits in the sequence and that the whole sequence might span the last interglacial/glacial cycle. Moseley (2010) reported a surface exposure of yellow sand that appears to be a cavity infill at NGR SD 47338074 near Storth.

Conclusions

There are many examples of sediment-filled palaeokarstic cavities recorded from the mines of Warton Crag and district. These preserve portions of the local stratigraphical record, from pre-mineralization through to Pleistocene, that have been removed in the surface environment by subsequent erosion. Further study to elucidate the stratigraphical and palaeontological age of these sediments could therefore provide important information on both the erosional history of northwestern England and also the still-controversial process of mineralization of the Morecambe Bay haematite ores. The sediment-filled cavity exposed in the North Level of the Crag Foot mine group shows a fill sequence that postdates the emplacement of haematite mineralization and probably pre-dates the glaciation of the region. It might be Miocene or Pliocene (Neogene) in age and, if so, is the only Cenozoic sediment so far known in this vicinity.
Scalloping associated with haematite mineralization at Hodbarrow (West Cumbria) is ascribed on geological grounds to late-Carboniferous or early-Permian karst processes (Murphy and Moseley, 2012). Radiometric dating has shown that by the Mid Pleistocene, clastic and carbonate material was being deposited in caves in the Yorkshire Dales (Lundberg et al., 2010), so there is direct dating evidence that at least some cave formation in northern England pre-dates this. Elsewhere, karst cavity fill deposits of the Brassington Formation of the southern Pennines have also been shown to pre-date the Pleistocene. This latter sequence of sands, gravels and clays contain a Late Miocene (Tortonian) palynoflora (Pound et al., 2012).

Reports of palaeokarstic caves and fill sediments are rare in the British context. Thus, in the future these features merit full consideration when geoconservation measures are being reviewed for the area, which is renowned for its limestone pavements but possesses little known underground karst development. It is unfortunate that some of the most important exposures have already become inaccessible due to the sealing of mines.

Acknowledgements

Our thanks are due to Mrs Lucy Arthurs (Estates Manager, Leighton Hall Estates) and Mr Chris Alty (Moss House Farm, Crag Foot) for permission to access and investigate the Warton mines; to Tony Waltham for producing Figure 1 and Jerry Wooldridge for preparing the figures for publication; to Andrew Walsh for assisting in the field, and to an anonymous BCRA reviewer for a constructive critique of the draft text.

References
