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Revisiting the 'reefs' of Black Reef Cave, Ribblehead, North Yorkshire with some observations on cave divers 'chert'

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A restudy of the black materials encountered in Black Reef Cave as sheet cutting across the main passage has shown they have influenced the passage morphology. Upstream of the reefs the passage has a typical phreatic tube like cross section whereas downstream the passage cross section is that of a canyon suggesting the reefs have ponded water resulting the development of small perched phreatic loops. The reefs consist of a core of crystalline calcite surrounded by black manganese/iron material. It is proposed that calcite vein mineralisation along joints caused the ponding of water and the manganese/iron material is a secondary deposit preferentially deposited or preserved on the calcite vein. Other occurrences and possible occurrences in the region are discussed.

Black Reef Cave (NGR SD 774794) is a 550 m long cave system developed in the Lower Carboniferous Great Scar Limestone of the Ribblehead area, Yorkshire Dales (Brook et al. 1991 p120)(Figure 1). The cave was explored in 1959 by the Oxford University Caving Club with only the briefest of descriptions given in the first published record (Crabtree 1960) though a more detailed description is given in Sutcliffe (1963). The cave consists of a stream passage aligned approximately east-west with an active inlet from the north. Cave development in the Ribblehead area is generally characterised by shallow, sub-horizontal low gradient passages usually aligned along the jointing. The passages have a generally 'youthful' feel and there is an overall scarcity of the relict cave passages usually associated with cave development in the Yorkshire Dales. Waltham (1990) attempted to reconstruct landscape evolution of the Ingleborough area and inferred a relatively recent date for the loss of the shale cover for the Ribblehead area thus accounting for the youthful appearance of the caves. However the combination of low surface relief, low hydraulic gradients, well defined sub-horizontal shale beds and a scarcity of small faults and multi-bed joints may also be important factors guiding cave development (Brook & Waltham 2015). Hydrological investigations have been undertaken by Nichols and Shackleton (1977) and Murphy and Hodgson (2016)

Black Reef Cave is unusual for the area being not aligned along the jointing. The stream passage beyond the junction with the inlet is characterised by a series of pools formed where thin sheets of a crumbly black substance cross the passage termed reefs by the original explorers and as such being responsible in part for the cave's name (Figure 2). This material was analysed by Crabtree (1962) and shown to consist mainly of manganese oxide with a subordinate amount of iron oxide. Crabtree described the material as Ferrian Wad rather than the "Bog Ore" of the paper's title. While iron and manganese crusts on cave sediments are well documented in the area (e.g. Murphy 1999) this occurrence is different as observation shows the 'reefs' cut through the rock mass and are left standing proud across the passage where the limestone has been preferentially dissolved (Sutcliffe 1963). They do not form rimstone dams along the stream floor as reported in Hill and Forti (1986). The presence of the reefs crossing the passage has controlled passage development as upstream from them the passage cross section is that of a phreatic tube, whereas downstream of the reefs the passage has a canyon like cross section providing evidence of vadose incision downstream of the reef (Figure 3). This shows water has been ponded behind the reefs maintaining a perched phreas. The caver and stream route through the reefs today is at least in part a result of damage to these features by the original explorers (Crabtree 1962 p361) and presumably later visitors. Having exerted a hydrological control on cave development shows the reefs were therefore present in the rock mass before cave development took place

A restudy of the reefs has shown the black material described by Crabtree and others is not the only material forming the reefs. Within the black material is a core of crystalline calcite (Figure 4). This important observation is not recorded in the original reference or by the astute observer of speleological phenomena Roger Sutcliffe in his description of the cave (Sutcliffe 1963). An alternative explanation for the formation of the reefs is that the crystalline calcite had been deposited along the joints local to the Black Reef Cave area as calcite veins. This resulted in them acting as a hydrological barrier rather than a preferred groundwater flow route as in other caves in the area, crystalline calcite having a relatively low dissolution rate compared with the wall retreat rate of the limestone bedrock. This explains why the cave is the only one in the area to not have developed along the joints. The manganese/ iron is thus a secondary deposit preferentially preserved on the crystalline calcite surfaces rather than on the limestone cave walls. Evidence for a secondary origin of the manganese/iron material being is its occurrence as horizontal layers across the surface of the water when the cave was first explored (Crabtree 1962 p 361). X-ray diffraction analysis has failed to identify any crystalline structure within the black material which is consistent with precipitation as a gel or nanoparticles. The most common origin of manganese oxides is from surface organic matter brought into the cave. Organic matter is regularly encountered in the cave today in part due to the shallow depth of the cave passage so this does seem the most likely source. The processes of formation and deposition are not fully understood but microbiological activity appears to be important (Carmichael and Brauer 2015).

Other occurrences:

Iron/manganese materials are recorded from other caves in the Yorkshire Dales karst, often as a floor covering such as Psilomelane Pot, Penyghent (Walker 1979) and Stake Beck Head Caves, Teesdale (Wood 1986). Vertical screens of hydrated iron oxides have been described from Nirvana and Ibbeth Peril Cave 1 in Dentdale, also in Robins Dub Cave, Deepdale (Allwright et al. 1998, Holmes 2015). The iron rich layer is considered to be a primary feature of the mineral vein having protected the vein calcite from dissolution. Closer to Black Reef Cave water being ponded behind friable barriers was described in Great Bank Gill Cave, Ribblehead (Sutcliffe 1975).

Similar features are often reported by the cave diving community and are traditionally described in Cave Diving Group Newsletter dive reports as chert. Examples have been recovered from Hurtle Pot in the Chapel-le-dale phreas (Hill and Hall 2015 p148) and are iron rich material sandwiching a vein of crystalline calcite. In the Kingsdale phreas a constriction referred to by divers as the osmotic palpitator (Skorupka 1986) proved a significant barrier to continued exploration of the Marble Steps branch of Keld Head (Hill and Hall 2015 pp188-191). In order to pass the restriction chert-like obstructions had to be removed (Skorupka 1996). The area was described in detail as "..cherty tube changes to a clean washed bedding. This sudden change in character typifies the further reaches of this area, where the rock seems to pass through bands of thin, cherty veins, which appear to slow down passage development and cause localised restrictions." (Skorupka 2000) which is reminiscent of the situation in Black Reef Cave where the mineralisation has impeded cave development.

Conclusions

The reefs of Black Reef Cave are mineral veins of crystalline calcite which have acted as barriers to water flow. This accounts for the atypical development of the cave as compared with other caves in the vicinity which are developed along the jointing. The iron rich material described as Ferrian Wad by Crabtree (1962) formed as a secondary coating on the mineral vein protecting it from further dissolution. Similar features commonly occur in other areas of the Yorkshire Dales karst and many of the cave diver's descriptions of 'chert' associated with decreases in passage size may be similar materials to those described from Black Reef Cave.

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Figure Captions

Figure 1: Reproduction of Figure 22.81 of Brook and Waltham (2014) with permission. Additional proven connections from Murphy and Hodgson (2016) are shown in black

Figure 2: A typical reef in Black Reef Cave. Photo: D Ryall

Figure 3: Looking downstream with a reef crossing the passage in the mid ground. Upstream of the reef the passage is a typical phreatic tube shape whereas downstream of the reef the passage has a canyon style cross section. Photo: D Ryall

Figure 4: Although not from Black Reef Cave this shows the typical structure of crystalline calcite surrounded by black manganese oxide. This example is from Joint Hole, Chapel-le-dale. Photo: J N Cordingley