Wad deposits in the White Peak

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In the context of the Derbyshire Peak District, wad has been described as a generally black, apparently structureless soil with a chemistry dominated by iron and manganese oxides, including hematite, limonite, pyrolusite, psilomelane and birnessite (Ford, 2006). Closely related, but dominated by iron oxides, umber is browner in colour. Relatively loose and easy to mine, wad and umber were historically viable as minerals for use in pigments, paint drying agents, steel ship hull treatments (mixed with lime), steel alloys, and mixed with hydrochloric acid to form chlorine gas for bleaching. It was mined at Winster, Elton, Brassington and Youlgreave, and Heyspots Mine worked the Portaway Pipe for the largest yield (Ford, 2001).

In Derbyshire, the wad correlates with the boundaries of the dolomitised limestone (Ford, 2001). It has been described in similar settings in the Eastern Transvaal (Hawker & Thompson, 1988), Romania (Ford, 2001), Southern Belgium (Dubois et al., 2014) where it is referred to as alterite, and Maryland USA where it is associated with dolomitised marble (Bourgault & Rabenhorst, 2012).

Unusually extensive exposures of wad were revealed in excavations for the four wind turbines at Carsington Wind Farm (Fig. 1). These wad deposits are associated with the dolomitised southern edge of the Peak District Carboniferous carbonate platform. The site is underlain by dolomitised Carboniferous limestone bedrock and lies within a palaeovalley, with Harborough rocks rising to the north. To the south, riaing ground reflects the Carboniferous palaeogeography, with upstanding, platform-fringing reefs dipping steeply towards the Widmerpool Gulf farther to the south. The Gulf contains more than 1000m of deltaic mudstones, sandstones and gritstones, which broadly coarsen upwards. The Neogene and Quaternary cover of the limestone is patchy (Fig. 2), but includes till and head, and also the Miocene Brassington formation as pocket deposits at Bees Nest Pit, 450m west of the wind farm.

***Figure 1**. Carsington Pasture Wind Farm with Harborough Rocks to the north.*

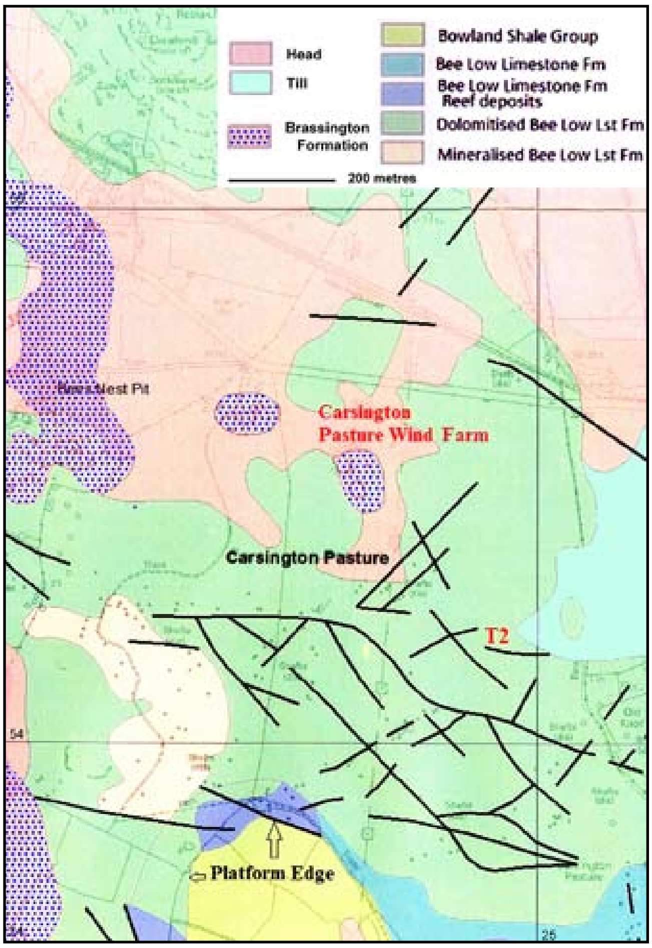

***Figure 2**. Geology of Carsington Pasture (after mapping by British Geological Survey ©).*

The limestones have been heavily dolomitised by diagenetic expulsion fluids (Mississippi Valley-type mineralisation) from the Widmerpool Gulf. They have been leached, to leave zones of uncemented dolomite sand, and were extensively mineralised during subsequent phases of fluid expulsion. The lead-zinc mineralisation occurs as veins (rakes) and flats. Interbedded with the dolomitised limestones are clay wayboards, formed by volcanic activity along with the Bonsall Sill (1100m southeast of the wind farm. The foundation excavation for turbine T2 (Fig. 2) was more than 10m wide and up to 4m deep, thereby providing good exposure for field description, undisturbed sampling (kubiena tin) for moisture replacement and thin-sectioning, and disturbed sampling for physical and chemical analysis.

Though the form of the buried karst at this site (Fig. 3) might indicate that the wad is a form of palaeosol, the loose nature of the wad and locally its angle of rest are such that it could not have been preserved at the surface. Rather, it owes its preservation to the low-energy hydrodynamic regime and trapping by the overlying sediments, and its formation to favourable Eh and pH conditions at the sediment-bedrock interface. Oxidising, low-pH conditions in the vadose zone would favour pene-contemporaneous dolomite dissolution and wad accumulation. Typically this is likely to be

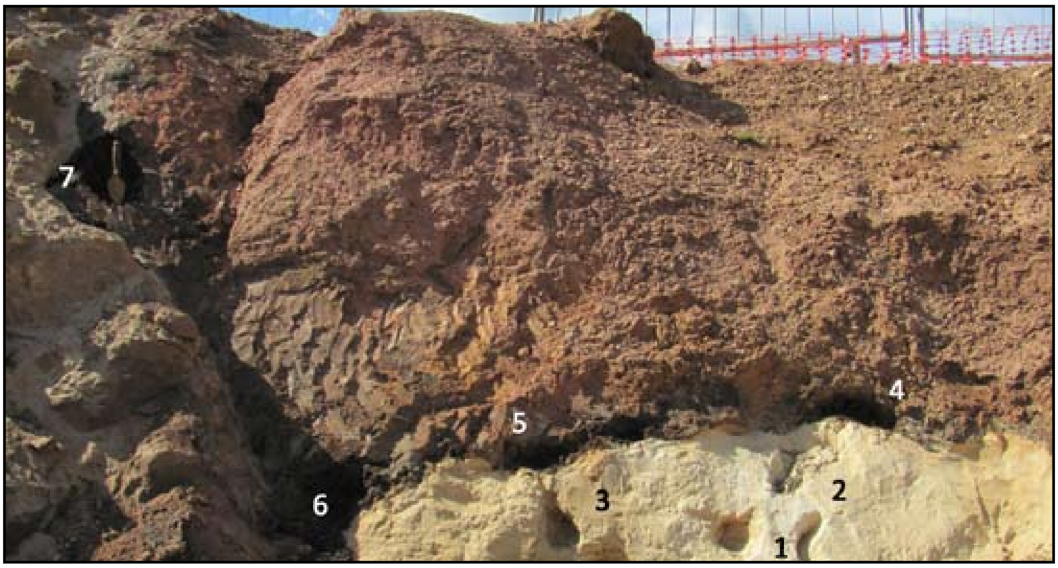

Figure 3. Buried karst, with wad at bedrock-sediment interface. Numbers indicate sampling positions.

Figure 4. Gradation from bedrock of white dolomite sand, (across the base) to wad above the dark contact, to sediment above the diffuse boundary.

the result of mildly acidic, infiltrating, meteoric water focusing on joints in the bedrock. Sources of acidity for the water include organically derived carbon dioxide and sulphides in the overlying sediment.

At the field scale there is a weakly visible, gradational contact between the wad and the dolomite (darker adjacent to the dolomite and lightening towards the overlying sediment) over a scale of centimetres (Fig. 4). In the laboratory, a polished section from a moisture-replaced kubiena tin sample revealed little evidence of compaction, but dissolution was focused on the faces of dolomite crystals; about 3% of the sample comprised euhedral crystals of quartz.

Chemical of the wad and dolomite was compared with the mean of upper continental crust (Fig. 5). The wad showed consistent mineral enrichment over that of the bedrock dolomite except for the depletion of magnesium and calcium. Its enrichment with respect to strongly correlated manganese and phosphorus, and depletion with respect to magnesium and calcium, indicate a single source for this sediment. Silica is poorly correlated with all of the other elements, which suggests that it is from a different source or sources.

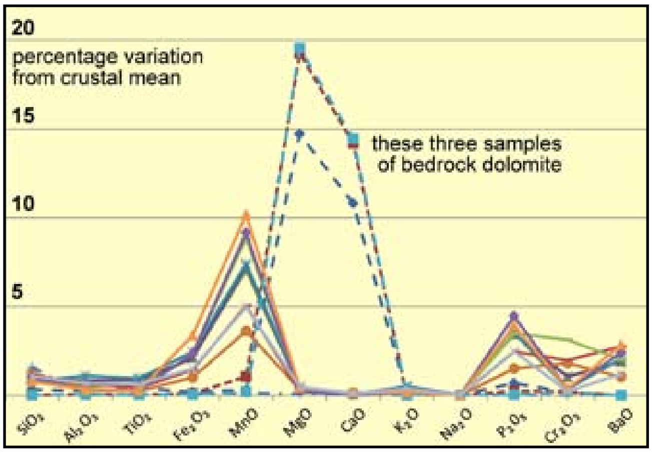

Figure 5. Chemical analyses of ten samples of the wad and three of the dolomite bedrock, compared with mean values for upper continental crust.

Both the field and laboratory evidence support the interpretation of the wad as a residual deposit, resulting from the gradual rotting of the dolomite bedrock beneath the sedimentary infill.

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