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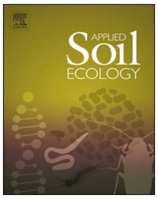

Short communication

An early carboniferous humus from South Wales preserved by marine hydromorphic entombment

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ABSTRACT

Irregular, sub-metre scale occurrences of a highly unusual calcified peloidal (pelletal) limestone are described from a polygenetic paleosol from the sub-Arundian landsurface (Carboniferous, 343Ma) of South Wales. The pedogenic origin is supported by a suite of pedogenic features, and the textures in the peloidal carbonate mimic those of modern mull-like humus indicating the likelihood that the original soil biota was diverse. The occurrence of such material, normally with such a poor preservation potential, is explained by it being partially cemented and entombed by a brackish dolomite petrocalcic horizon, both formed as the landsurface was flooded by marine waters.

1. Introduction

The preservation potential of humus in a geological context is extremely low as such material is readily eroded or oxidised, and distinctive textural features are rapidly lost by compaction during burial by later sediments. Organic horizons can be in part preserved in strongly hydromorphic settings to produce lignites and coals but are prone to major textural alteration. This paper is a report of a calcified humus from an exposure surface within the thick, early Carboniferous limestone succession in South Wales. The material has been briefly described previously (Wright, 1987) but is here documented in more detail, and additional information is provided as to how the topsoil material was preserved.

2. Materials and methods

The material described in this study is found in the Heatherslade Geosol (Wright, 1987) in the Miskin area of South Wales (Riding and Wright, 1981; Wright, 1987). This Geosol is found at a number of localities in the Bristol district and across South Wales capping the Chadian (early Carboniferous) Gully Oolite (syn. Caninia or Caswell Bay Oolite) which represents a carbonate sand strandplain (Burchette et al., 1990), and is overlain by the Arundian transgressive back-barrier lagoonal and tidal flat unit, the Caswell Bay Mudstone. Globally the Chadian-Arundian boundary is dated at around 343Ma (Schmitz and Davydov, 2012), but the duration of the exposure interval is unknown except that as many as six stacked petrocalcic horizons have been identified at a comparable level (Tyle'r Bont Pedocomplex) elsewhere in South Wales (Wright, 1982).

The peloidal material is not present at all outcrops of the Geosol and has only been found at two localities near Miskin. The first example, an outcrop now buried by road construction (51°30′58.50″N 3°23′22.47″W) was described by Riding and Wright (1981) and Wright (1987), and a new locality was found at a nearby working quarry, Fforest Fawr (51°30′ 30.37″N 3°25′14.76″W).

Samples were collected from freshly exposed active quarry faces, and slabbed. Over 100 standard petrographic thin sections and acetate peels were made from this Geosol at the Miskin localities, and will be curated at the National Museum of Wales during 2017. Etched samples were also examined under SEM.

3. Results

Regionally the Heatherslade Geosol is comprised of several, commonly over-lapping units representing at least three different phases of soil development. Initially, soil development involved the extensive calcretisation of the oolitic sand-grade parent material, producing a range of calcified organic textures including needle fibre calcite (calcite associated with fungal mycelial masses; Wright, 1986a), associated with rhizocretions and fungal grain coatings, and calcified root mats (Wright et al., 1988). The polyphase profile also has both calcitic and dolomitic petrocalcic horizons (Wright et al., 1997), the latter having formed in brackish hydromorphic conditions associated with the marine transgression which subsequently deposited the Caswell Bay Mudstone. Interpreting the complex relationships in this polygenetic profile is made more complex in the Miskin area by later dolomitization

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which has over-printed some parts of the profile and some of the overlying Caswell Bay Mudstone. While the complex lateral and pedostratigraphic relationships seen in outcrop are characteristic of palimpsest polygenetic profiles found at subaerial exposure surfaces, the complexity of this material was especially challenging. In contrast, the paleosols formed at the same stratigraphic level further inboard near a large contemporaneous land mass to the north, developed largely on alluvial substrates where allogenic drainage systems deposited floodplain siliciclastic sediments characterised by locally stacked compound profiles (Wright, 1982).

The peloidal material at Miskin is patchily exposed in metre-wide pockets, up to 0.3 m thick, laterally equivalent to an illitic clay with heavily calcretised lithoclasts of the underlying oolitic limestones (Riding and Wright, 1981; Wright, 1987, Fig. 17.1). The Fforest Fawr material was more patchily preserved and is not included in this study. At Miskin the peloidal material and clay-equivalent are overlain by a 0.3 m thick dense horizon (petrocalcic horizon), at least locally made of finely crystalline ferroan dolomite with pyrite. Pyrite is prominent throughout the Miskin profile, and has a variety of morphologies interpreted by Wright (1986b) as evidence of marine hydromorphism caused by the subsequent flooding of the landscape by marine waters during the Arundian transgression. Subsequent work on a range of paleosols in the Carboniferous has shown that before complete immersion in marine waters these paleosols underwent alteration in brackish waters (as confirmed by stable isotope analysis by Wright et al., 1997) which produced the strongly cemented (petrocalcic) horizons of ferroan dolomite.

The overall texture consists of a mass of small peloids, within which are larger compound grains, cemented by calcite sparite cement with a large volume of now calcite cement-filled pores (Fig. 1).

The peloidal material constitutes a peloidal grainstone in the standard terminology of carbonate sedimentology, and the term peloid is defined in carbonate sedimentology as a sand-sized grain composed of largely micritic carbonate (micrite referring to crystalline components < 4 μm in diameter). Such grains are very common in shallow marine limestone successions (Tucker and Wright, 1990). The term peloid is used here and not pellet as the fecal origin cannot be fully established in mineralised material of this age. The peloidal grains range from 20 μm to 4 mm in diameter, thus technically smaller that sand-sized and the term micro-peloid might be more suitable. The main mass of the unit, which constitutes 50–60% of the fabric, consists of grains 20–100 μm in diameter but mainly in the range 50–100 μm (average 40 μm) (Fig. 2), of rounded, spherical to sub-spherical grains. The second component consists of compound structures comprising the same grains as the groundmass, but very closely packed, and arranged in 0.5–4 mm diameter aggregates (Fig. 2). These have mainly smooth margins and are not simple aggregates (crumbs), and include clay material, ooids like those from the underlying Gully Oolite, and scattered pyrite aggregates and crystals up to 30 μm in size. Locally the finer grains have been compressed into a denser matrix (Fig. 3) which also shows evidence of likely desiccation with fine irregular cracks (see below).

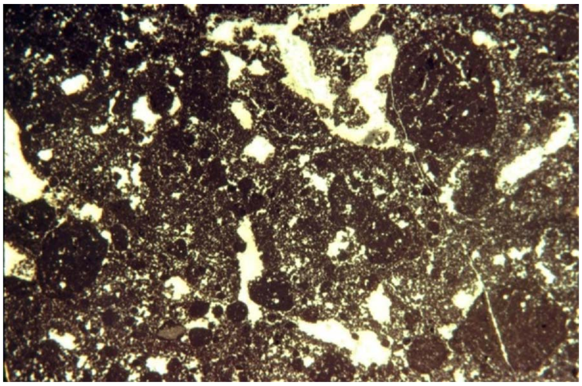

Fig. 1. Mull-like texture in the Heatherslade Geosol showing finer peloid groundmass with larger aggregates and range of calcite (white areas) cemented channels and vugs. Field of view is 16 mm wide.

The gross texture is also atypical of marine peloid-bearing limestones and consists of an open-packed spongy structure with mm-to sub-mm-sized compound-packing voids, zig-zag and curved planar voids (in sense of Bullock et al., 1985), channels, vughs and vesicles. The spongy overall texture contrasts with the areas of denser grains and suggests that compaction took place locally while the grains were soft. The localised nature of this compaction suggests it was not caused by burial compression. The various voids are filled with an initial rim cement, 20–26 μm thick (resembling early marine rim cements), and filled by drusy, non-ferroan calcite cement. However, some are filled with a dense micron-sized mass of carbonate crystals (Fig. 4) with several percent pyrite crystals like those in the larger peloidal aggregates. Whereas pores of this size are found in many intertidal and shallow subtidal limestones and are termed fenestral limestones (e.g Tucker and Wright, 1990), the former pores in the Geosol are elongate (channels) and randomly oriented unlike the either horizontal or vertical pores that characterise fenestral limestones.

Also present are mm-sized fragments of reworked rhizolite crust (calcified root mats; see Wright et al., 1988), and examples of needle-fibre calcite forming alveolar-septal structures (Wright, 1986a), representing calcification within mycelia. Centimetre-sized clasts of the underlying Gully Oolite also occur.

4. Discussion

In dealing with material of such extreme age many criteria used in interpreting modern soil features are not applicable. In particular organic remains will not have survived processes of lithification. These peloids and aggregates differ markedly from those typically found in marine limestones generally. Marine peloids, modern and ancient are sand-sized, less well rounded than those seen in the Geosol, and where a matrix is absent, occur in grain-supported textures, not the range of complex open textures present in the Geosol. Crucially, this range of grain types and sizes is not recorded in the overlying or underlying marine strata. However, the groundmass grains resemble those recorded in the Arundian Darrenfelen Geosol by Wright (1983) from elsewhere in South Wales, and interpreted as a moder-like calcified humus from a paleo-rendzina.

Similar peloids have been described from modern calcareous soils (for example Klappa, 1978; Calvet and Julia, 1983) and resemble fecal pellets. The exact means by which fecal material becomes calcified in some recent calcareous soils is unknown but is a widespread feature of marine sediments, both modern and ancient (Tucker and Wright, 1990), where the role of heterotrophic bacteria in triggering carbonate precipitation is widely suspected.

The fact these textures and grain types were only recorded in association with pedogenic features, and are atypical of associated marine limestones strongly supports the view that the material is soil-formed. The overall texture is strikingly similar to a mull humus and the larger aggregates (fecal pellets), now calcified, which incorporated mineral grains (clays and ooids), resembles a pelleted mullicol in the sense of Barratt (1969) and by virtue of being immediately on a rock surface, an Entimull in the sense of Zanella et al. (2011). However, the horizon exceeds 5 cm in thickness. There is no direct evidence the humus actually formed sub-aqueously and is considered a Terroform (Terromull).

The aggregates could represent the products of isopods, diplopods, myriapods, earthworms or larval insects. Although there is no doubt that a variety of soil mesofauna existed by the early Carboniferous, the material described here is proof that humus fabrics, directly analogous to modern forms, were being produced as far back as c. 343Ma, in what was a near-Equatorial setting under likely semi-arid and seasonal conditions (Wright, 1990). Furthermore, this occurrence contrasts with the