A periglacial ground-ice structure in the Upper Greensand (Cretaceous) at Lyme Regis, Dorset, UK

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Disturbed bedding structures in the Upper Greensand at Lyme Regis are interpreted here as indicative of the growth and subsequent thawing of ice masses in permeable sediments in a periglacial climate. The processes involved are similar to those of the present-day formation of closed-system pingos in northern Canada and Siberia. In east Devon and west Dorset the Cretaceous Upper Greensand Formation comprises a lower part of weakly calcareously cemented glauconitic sandstones overlain by glauconitic calcareous sandstones and sandy calcarenites. Throughout much of east Devon and west Dorset, the upper part of the formation was partially or wholly decalcified, probably during the Palaeocene. As a result, the thickness of this part of the formation is reduced by up to 60%. Where well exposed over a distance of several hundred metres at Black Ven, Lyme Regis, the decalcified beds have subsided more or less evenly and have retained their bedding features and stratigraphical integrity except in a small area where the presumed ground-ice structure is present.

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Introduction

In east Devon and west Dorset, where the Upper Greensand Formation caps an extensive dissected plateau, the upper, more calcareous part of the formation, is much affected by dissolution (Gallois, 2004a). At Black Ven, where this part of the succession is continuously exposed over a distance of 600 m in the back scarp [SY 3491 9344 to 3558 9334] of the Black Ven landslide complex, the thicknesses of the Whitecliff Chert and Bindon Sandstone Members are reduced by up to 60 % in comparison with the unweathered sections west of Lyme Regis in Ware Cliffs [SY 237 916] as a result of the loss of calcium carbonate clasts and cements by dissolution (Figure 1). The dissolution process appears to have taken place slowly and evenly throughout the section with the result that the bedding remains more or less horizontal and the stratigraphical succession is maintained (Figure 2).

Black Ven cryoturbation structure

A westerly expansion of the scarp face as a consequence of renewed landslide activity in 2012 exposed an area in the upper part of the scarp face where the boundary between the Whitecliff Chert and the Bindon Sandstone is disturbed and appears to have locally subsided by up to 4 m over a distance of *c.* 50 m (Figures 3a and b). The base of the Whitecliff Chert is not exposed in the disturbed area, but comparison with the undisturbed outcrop 100 m east, shows that it has also been displaced downwards by up to 4 m. Within the disturbed structure, the glauconite-rich sandstone at the base of the Bindon Sandstone (here weathered to a clayey, fine-grained glauconitic sand) shows marked lateral variations in thickness and appears to have behaved as a fluid. In the unweathered exposures in Ware Cliffs and elsewhere on the east Devon coast, the cherts in the Whitecliff Chert and Bindon Sandstone occur as regular lines of nodules and lenses (Gallois, 2004b, figure 3). The cherts are fractured in the disturbed structure, but have mostly retained their relative stratigraphical positions (Figures 3b and d). The Upper Greensand sediments involved in the structure can be divided into three broad types on the basis of bulk permeability. The clayey fine-grained sands at the bases of the Whitecliff Chert and Bindon Sandstone act as an aquitard; where partially or wholly decalcified at outcrop or at shallow depths the fine-grained Foxmould sands are moderately to highly permeable; decalcified calcarenites and calcareous sandstones of the Whitecliff Chert and Bindon Sandstone are highly permeable.

The Black Ven structure resembles some of those caused by the repeated growth and melting of ground ice in the near-surface, active permafrost layers that form in periglacial climates. The most common and best documented of these structures are ice wedges and pingos. Geomorphological features and sedimentary deposits have been described from Dartmoor (Evans *et al.*, 2012) and Exmoor (Harrison *et al.*, 1998; 2001) that have been interpreted as evidence for local ice sheets, but there is no published evidence for the presence of an onshore continental ice sheet in South-West England. However, periglacial conditions were present throughout southern England for periods of tens of thousands of years during the cold phases of the Pleistocene, ending *c.* 10,000 years ago (Williams, 1965). These gave rise to a wide range of erosional and depositonal cryoturbation features (Te Punga, 1957). There are extensive deposits attributed to the action of multiple freeze-thaw cycles of ground ice in the SW region, notably sandy and gravelly Head Deposits up to tens of metres thick in many valleys, frost-shattered scree debris and block fields adjacent to the outcrops of harder rocks, and creep folds in Jurassic mudstones (Hutchinson and Hight, 1987;