LARGE-SCALE PARTIAL DISSOLUTION OF THE CHALK OF THE DEVON COAST AND ITS ENGINEERING SIGNIFICANCE

R.W. GALLOIS

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Numerous site investigations have described 'reconstituted', 'putty', 'soft' and 'rubbly' chalks which have generally been grouped together for geotechnical description purposes as 'structureless', to distinguish them from 'structured' (bedded and jointed) *in situ* chalks. Structureless chalks have mostly been assumed to be redeposited materials or materials that have been intensely mechanically reworked in place. They include sludge (Head), partially water-sorted (Coombe), fluvial (Dry Valley and Nailborne) and cryoturbation (Head) deposits.

Recent surveys of the east Devon coast have shown that an extensive, thick chalk deposit, which in small exposures or in cored boreholes could be mistaken for redeposited material, has formed *in situ* by the partial dissolution of a particular type of chalk. The best exposures, in the cliffs at and adjacent to Beer, Devon [SY 230 890], show a 15 m- to 30 m-thick layer of partially decalcified, nodular chalk that is underlain and overlain by intact clay-rich chalks. The boundaries of the decalcified unit are stratigraphically controlled and sharply defined. It contains angular to rounded, granule to boulder sized litho-relics in a degraded, chalk-fines matrix. Blocks of intact, largely unweathered chalk up to tens of metres thick occur as detached masses 'floating' in the partially decalcified unit, and even larger masses have settled down into it. Some of these contain the youngest Chalk preserved in Devon.

92 Stoke Valley Road, Exeter, EX4 5ER, U.K.
(E-mail: gallois@geologist.co.uk).

INTRODUCTION

Throughout much of the east Devon coastline between Salcombe Regis [NGR SY 151 877] and Devonshire Head [NGR SY 332 914], the Chalk crops out in the highest part of the cliffs, above the relatively stable Upper Greensand. Few major cliff falls have been recorded in this area in recent years, and none was initiated in the Chalk. Between Beer Head and Beer the Chalk is brought down to sea level in the core of a syncline and gives rise to a 1.2 km-long coastal section of vertical and near-vertical cliffs that are mostly 40 to 70 m high. Collapses of up to 50,000 tonnes have been common after prolonged periods of high rainfall (Figure 1). All the larger falls have been initiated in, and been largely confined to, a thick (up to 30 m) layer of partially dissolved chalk that is substantially weaker than the underlying and overlying intact chalks. Collapses of the type described by Mortimore *et al.* (2004a) as 'plane', 'wedge' and 'toppling' failures that involve complex sets of conjugate joints have also occurred in this area, but have involved much smaller volumes of material.

The Chalk exposed in the east Devon cliffs is the most westerly preserved in the Anglo-Paris Basin. It contains evidence of shallower water environments than its more easterly correlatives in Dorset and Hampshire and is laterally more variable. Although lithologically different in detail from more easterly successions, many of the lithologies and individual marker beds used to divide the Chalk Group into formations (Mortimore *et al.*, 2001) can be recognised throughout the east Devon outcrop. These enable the group to be divided on gross lithology into the standard southern England formations (Figure 2).

Much has been written about the close relationship of the stratigraphy of the Chalk to its properties and engineering performance with respect to slope and cliff stability, notably by Mortimore (2001) and Mortimore and Duperret (2004). The chalk cliffs at and adjacent to Beer provide a good example of the relationship between stratigraphy, bulk lithology and cliff profiles.

EXPOSURES IN THE PARTIAL DISSOLUTION BED

Beer Beach

The Chalk exposed in the cliffs at the back of Beer Beach can be divided on gross lithology into three parts (Figure 3). At the base, strong, widely jointed Holywell Nodular Chalk forms stable cliffs that rest on a hard wave-cut platform of Upper Greensand calcarenites. Above this, the more closely bedded and jointed, marl-rich New Pit Chalk forms near vertical cliffs that give rise to relatively infrequent block and toppling failures in which steeply dipping and sub-horizontal bedding-related joints combine to produce collapses. Two laterally persistent marl-rich beds, the 2-ft and 4-ft bands of Rowe (1903), give rise to prominent ledges and commonly form the termination of steeply dipping joints. The highest part of the cliff, steep (mostly 40° to 60°) and largely vegetated, is composed of partially decalcified Lewes Nodular Chalk. This material consists of angular to rounded litho-relics of chalk that range from granules to boulders, in a matrix of degraded chalk fines (Figure 4). The larger blocks are commonly joint bounded with solution-rounded edges. The smaller clasts are mostly well rounded, strong kernels of hard chalk (the nodular part of the original material) that could be mistaken in small exposures or borehole cores for fluvial gravel. Its high porosity (locally >50%) and lack of interstitial cement have given rise to bulk failures on the Devon coast when the unit was saturated.

The partial dissolution process is almost certainly related to the marked differences in physical properties of the nodular and matrix components of the Lewes Nodular Chalk and lithologically similar chalks. In an extensive study of the physical properties of the chalks exposed along the Sussex and French coasts, Mortimore *et al.*, (2004b) recorded typical values of 2.0 Mg/m^3 for the Intact Dry Density (IDD) and 10% for the Natural Moisture Content (NMC) of the 'kernels' (mostly mineralised burrow infills) in the Lewes Nodular Chalk, and 1.5 Mg/m^3 IDD and 30% NMC for the matrix.