PLEISTOCENE SUPERFICIAL STRUCTURES EXPOSED AT WITTERING, CAMBRIDGESHIRE

by

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Summary

Pleistocene superficial faulting and gulls in the Grantham Formation (Middle Jurassic) were temporarily exposed in the Wittering Grange Sand Pit, near Wittering, Cambridgeshire, in 1986. These structures are thought to relate to the mobilisation and outflow of underlying Upper Lias Clay into a valley directly north of the exposure, which set up a tensional stress regime in the overlying competent strata of the Inferior Oolite Series. The significance of the 'Chalky Boulder Clay' glaciation on the formation of such features is discussed.

Introduction

Superficial, or non-diastrophic, mass movement structures of Pleistocene age are widely recognised features in many areas of the English Midlands (Hains and Horton, 1969). The principal structures include cambers, valley bulges, dip-and-fault structures, gulls and landslips. Their formation relates to the flowage of incompetent strata into a valley, causing overlying competent beds capping the interfluves to downwarp valleyward. They are particularly well developed and documented in the East Midlands, where Jurassic Lias Clays overlain by competent interbedded sands, sandstones and limestones of the Inferior Oolite Series frequently form the surface or near-surface strata. Indeed, the first detailed geological observations on cambering and valley bulging were made by Hollingworth *et al.*, (1944) in their classic paper describing and discussing the origin of superficial structures in Northamptonshire. Hollingworth and Taylor (1946), Hains and Horton (1969) and Horswill and Horton (1976) make similar observations on these features involving Jurassic strata in the East Midlands. Since the pioneering work in this region, such structures have been recognised in several other areas of England; for example in Yorkshire (Shotton and Wilcockson, 1951), in the Weald (Worssam, 1963), in Gloucestershire (Ackermann and Cave, 1967), in Somerset (Chandler *et al.*, 1976) and in the Hampshire Basin (Barton, 1984). However, although extensive strong cambering in the Stamford region is shown in cross-sections by Kellaway *et al.* (1978) and noted by Kellaway *et al.* (1961), little has been published on superficial structures in Cambridgeshire. This paper describes a noteworthy temporary exposure of Grantham Formation in north-west Cambridgeshire which shows several splendid examples of superficial features.

Details of the exposed superficial structures

Non-diastrophic Pleistocene mass movement structures are presently seen at Wittering Grange Sand-Pit, south-west of Wittering, Cambridgeshire (N.G.R. 0480 0110). The sand-pit exposes the typical 'white sand' facies of the Grantham Formation (Inferior Oolite Series, Middle Jurassic), which is overlain to the south and west by the Lincolnshire Limestone Formation. Boreholes and interpretive cross-sections of the area show that the Grantham Formation ($\cong$6m) overlies Northampton Sand Formation ($\cong$5m) and a considerable thickness of Upper Lias Clay (>24m).

The 'white sands' (Horton, 1977; Barton *et al.*, in prep.) of the Grantham Formation (Cope *et al.*, 1980), previously known as the Lower Estuarine Series, consist of a variety of pale coloured uncemented sands interbedded with subordinate clay cemented sands, silts and carbonaceous rich sands. The detailed stratigraphy of the sand-pit and petrology of the uncemented sands is described by Barton *et al.* (in prep.).

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The superficial structures are most clearly seen in the north-east of the pit. An accurate diagram of a north-south trending face, as exposed in April 1986, is shown in Figure 1a and 1b. Two principal features are observed in the section:– Fault Structures and Gulls.

(i) *Fault Structures*

Faulting is the most pronounced feature observed. The oblique faults strike 076°–109°, forming a sub-parallel system trending approximately east-west. Fault planes dip steeply (78°–90°) both to the north and south with throws of the order of 10–90 cm. Most faults are 'normal' with step faulting common and some conjugate fault development. This indicates that a tensional stress regime induced the deformation. Occasional reverse faults do occur, however, suggesting late stress relaxation. There is no evidence of major dip-and-fault structures and consequent fault-block rotation—a feature commonly associated with superficial tension faults (Hollingworth *et al.*, 1944; Horswill and Horton, 1976). The lack of observable cambering within the rather limited exposure partly reflects the paucity of fault-block rotation. However, it is postulated that the structures which are exposed in the Wittering Grange Pit, nevertheless probably reflect the presence of a large-scale cambered sheet.

(ii) *Gulls*

Elongate steep-sided narrow open joints, or gulls, are found in close proximity to the faulting. They are commonly only 10–40 cm wide, but up to 200 cm in length. The open joints dissect the Grantham Formation and are filled with overlying poorly stratified, unlithified gravelly sand, of presumed Pleistocene age. On the east side of the pit, quarrying has removed the top soil and the Pleistocene deposit, leaving the uppermost sands of the Grantham Formation exposed on the ground surface. The Pleistocene sands are, however, preserved in the gulls and in plan view delineate the gulls geometry (Fig. 2). These open joints trend east-west parallel to the surface contours of the topography and the strike of the faults. Two types of gull can be recognised. The most common are associated with normal fault movement, where a narrow open fissure has formed on a fault plane. Secondly, simple open joints have developed to accommodate tension within camber blocks.

It is thought that faulting, camber block movement and gull formation were broadly contemporaneous. As the deformation developed, the overlying incoherent (?)Pleistocene sands moved downwards under gravity infilling the gulls and forming occasional drape structures above camber blocks.

Discussion

The faulting and gulls detailed are thought to be relatively minor features which, however, reflect the presence of larger-scale Pleistocene cambering south-west of Wittering. It is suggested that the features observed are examples of deformation within a single large camber block, which itself probably lies within a broadly east-west trending cambered sheet. Figure 3, a cross-section of the area, shows how the features discussed may be related to cambering of the strata south of 'Wittering Grange' valley, which cuts down into Upper Lias Clay. Cambering directly north of this valley is noted by Kellaway *et al.* (1961). Superficial structures including brecciation, internal shearing and valley bulging are recorded by Chandler (1979) in Upper Lias Clay 3 km south-east of this valley at Wansford, suggesting that superficial deformation is common in the general area.

Many mechanisms have been proposed to explain Pleistocene superficial structures. Originally such features of the Midlands were thought to have formed solely as a consequence of the extension, thinning and plastic outflow of susceptible, incompetent horizons, such as Lias Clay, as stream erosion proceeded in a valley (Hollingworth *et al.*, 1944; Hollingworth and Taylor, 1946). According to this theory, valley excavation led to horizontal stress relief in initially highly stressed clay (Vaughan 1976), leading to internal shearing, brecciation and the formation of valley bulges in the deforming clay. Differential stress relief between the Lias Clay and the overlying competent strata of the Inferior Oolite Series therefore developed. A tensional stress regime was induced in the latter strata, which formed the interfluves of 'high' ground adjacent to the valley. Dip-and-fault structures and associated rotation of the camber blocks formed, causing the strata to take on an overall valleywards dip and lowering.

Periglacial conditions were later invoked to help explain the formation of Pleistocene superficial structures. Kellaway and Taylor (1953) suggested the development of ground ice and the thawing of perennially frozen ground (permafrost) were particularly significant in valley bulge formation. Hains and Horton (1969) similarly considered that perennial frozen ground and the movement of melt-water were primary factors in explaining the origin of the superficial deformation features discussed above. Basal

North

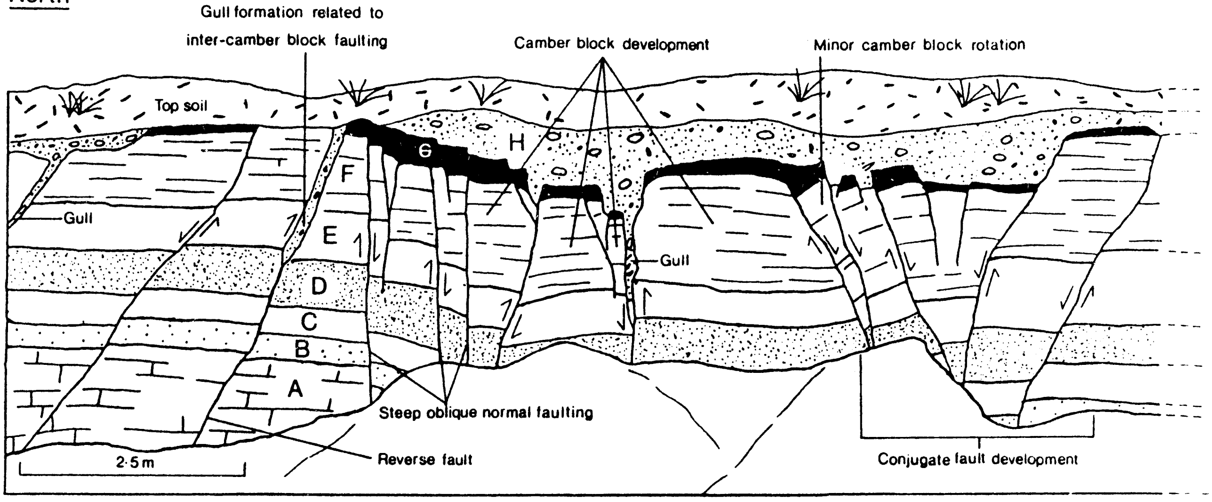

Fig. 1a. Diagramatic sketch of the superficial Pleistocene structures exposed in a vertical face in the north-east end of the Wittering Grange Sand-Pit (N.G.R. 0480 0110).

The sketch shows fault structures, camber blocks and gulls, their formation relating to the accommodation of tensional stresses. See text for details and discussion. Key to lithostratigraphy: Grantham Formation (Beds A–G): A – buff clayey fine sand; B – orange fine sand; C – white clayey fine sand; D – yellow iron cemented fine sand; E – yellow fine sand; F – pale grey fine sand; G – carbonaceous rich pale grey fine sand. (?)Pleistocene deposit (Bed H): H – poorly stratified incoherent gravelly sand.

South

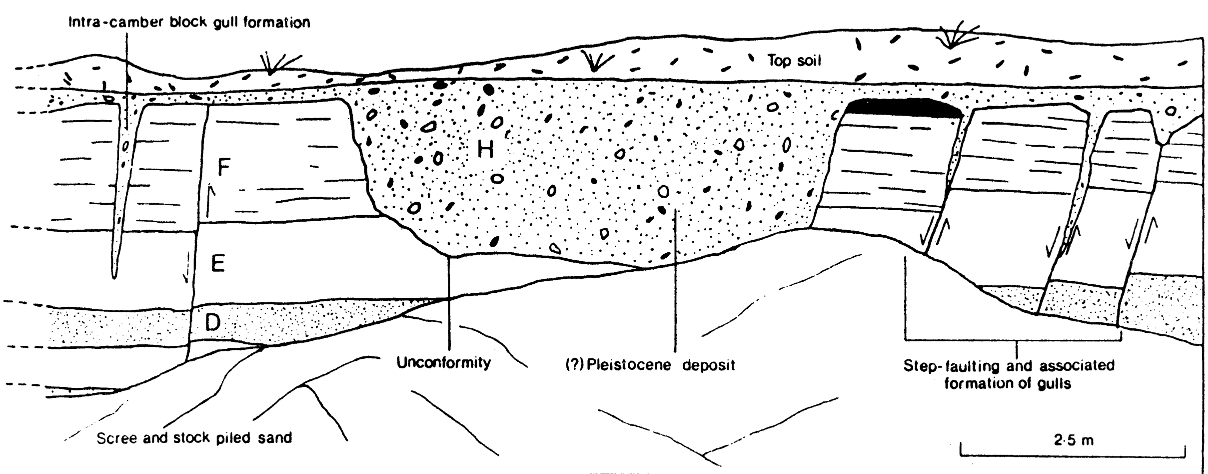

Fig. 1b. Southern continuation of the exposure shown in Fig. 1a, showing similar features. See Fig. 1a caption for explanation and key.

melting of perennially frozen ground may have led to subsidence and faulting of the underlying strata. Resultant melt-water may have caused mobilisation of soft susceptible clay horizons, causing their flowage and intra-deformation. Strata overlying such horizons may undergo structural readjustment in response to this underlying deformation and the load effect. Barton (1984) considered a periglacial regime a significant factor in the origin of superficial structures.

Vaughan (1976) in a very detailed consideration of several possible mechanisms which caused the cambering and valley bulging in the Empingham Valley slope, Rutland, suggested deformation was induced by ground freezing superimposed upon the results of horizontal stress relief by valley formation.

The superficial Pleistocene structures of Central England are thought to have developed during the extensive 'Chalky Boulder Clay' glaciation (Hains and Horton, 1969; Horswill and Horton, 1976). It is possible therefore that the effects of such widespread deep frozen ground and perennial thawing with the consequent passage of melt-water may have augmented any deformation initiated by horizontal stress relief in the Lias Clay.

The deformation observed in the Wittering Grange Sand-Pit, the occurrence of other superficial structures occurring directly to the north (Kellaway *et al.*, 1961), suggest together with cross-sections of the area, that the origin of these Pleistocene features is directly related to horizontal stress relief of Upper Lias Clay by excavation of the 'Wittering Grange' valley (Fig. 3). This may have caused internal shearing and brecciation of the clay, together with valley bulge development, as recorded in Upper Lias Clay 3 km south-east of the pit by Chandler (1979). Although very likely that such structures were formed with respect to the deformation south-west of Wittering, their presence cannot be confirmed because of very poor exposure in the 'Wittering Grange' valley. As discussed, it is considered that a tensional stress regime was thereby induced in the overlying competent Inferior Oolite Series strata. This led to the initiation of the deformation detailed, with faulting and gulls trending approximately parallel to the surface contours of the 'Wittering Grange' valley. The effects of the 'Chalky Boulder Clay' glaciation were later superimposed on the region, possibly significantly effecting the formation and development of the superficial Pleistocene structures observed today.

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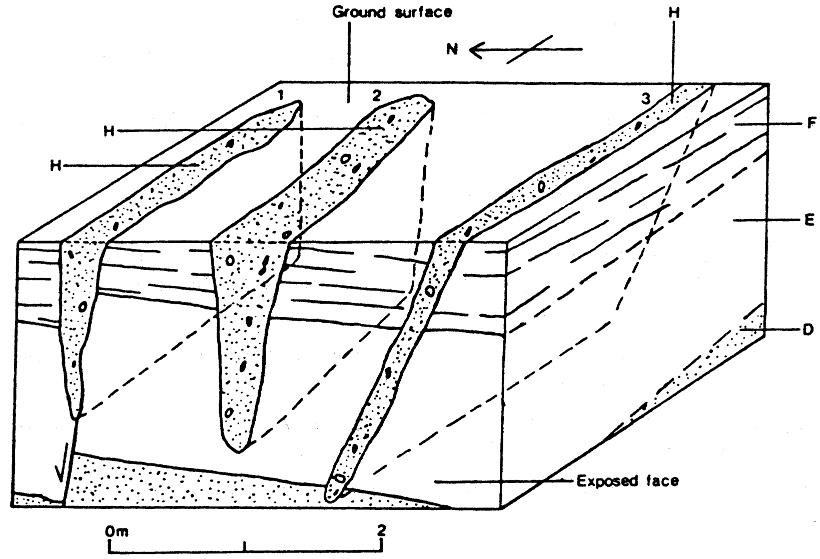

Fig. 2. Block diagram illustrating the three-dimensional geometry of gulls.

The diagram shows the relationship of a vertical and plan view of gulls exposed south of Fig. 1b. The gulls dissect the Grantham Formation (Beds D–F [viz. Fig. 1a]) and are infilled with (?)Pleistocene sand (Bed H). Gull 1 is an example of a fault associated type. Gulls 2 and 3 are simple intra-camber block joint types.

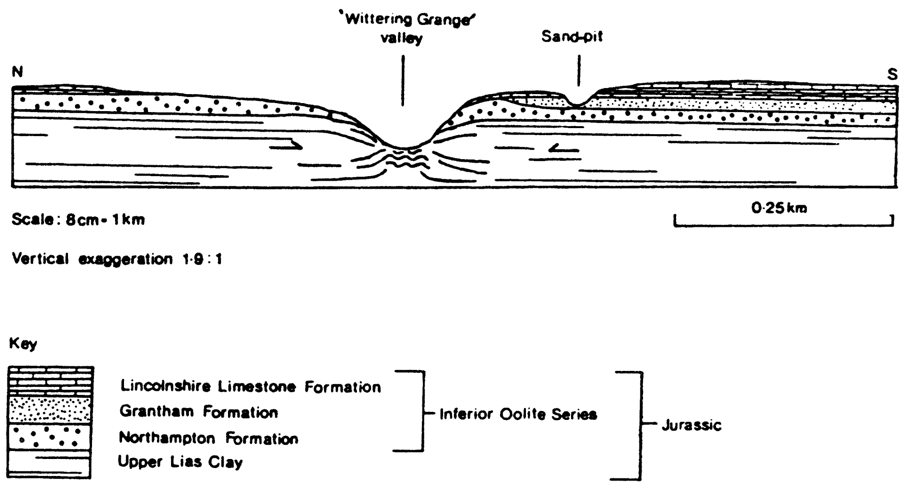

Fig. 3. Generalised north-south cross-section of the area south-west of Wittering.

The diagram shows how the deformation structures observed in the sand-pit may relate to larger-scale superficial features, i.e. cambering of the strata south of the 'Wittering Grange' valley caused by the horizontal stress relief and internal deformation of the Upper Lias Clay flooring the valley. The structures detailed are possibly examples of deformation within a large-scale camber block, itself within a cambered sheet consisting of a series of large-scale camber blocks rotated and lowered towards the valley in the north (individual camber blocks are not shown on the diagram, simply their overall arching effect on the strata).

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