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CONTORTIONS IN THE BOVEY BEDS (OLIGOCENE), SW ENGLAND

Abstract

Small anticlinal disturbances of the Bovey Beds appear to be confined to beds within 25 ft (8 m) of the ground surface. Some are sharp piercement structures but the majority are irregular domes of lignitic ball clay. It is suggested that they are produced by some form of periglacial process (congeliturbation) similar to that responsible for the involutions now recorded in many superficial and other soft deposits in southern England.

INTRODUCTION

The Bovey Beds are well known as a thick sequence of sands, gravels, clays and lignites occupying the „Bovey Basin" in South Devon. Of Oligocene age (Chandler 1957), they are restricted to the lower ground between Bovey Tracey, Newton Abbot and Kingskerswell and have been regarded as the infilling of a possibly fault-girt basin or valley (Jukes-Brown 1908; Ussher 1913). During the period of their accumulation the floor of the basin subsided far below the outlet, and the natural „sediment trap" so formed received an immense volume of sand and clay derived from the weathering of the Dartmoor granite. Sands and gravels of granite debris dominate the sequence at the margins of the basin while the kaolinitic finer sediments are most abundant towards the inner region. The base of the Bovey Beds has yet to be plumbed near the centre of the basin; a borehole at Heathfield failed to reach it at 526 ft (156 m) below the surface (Jukes-Brown 1909).

Sections through the Bovey Beds are virtually limited to those in the sand and ball-clay pits between Newton Abbot and Bovey Tracey and are located on the outcrops of the „Potting Clays", „Ball Clay" and the „Stoneware Clay" (Scott 1929, fig. 1). These expose the uppermost 50 ft (15 m) or so of the more argillaceous strata. Since the earliest days the irregular and disturbed character of the bedding in the clays and lignites has been known, but no particular investigation of it has been carried out.

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It is usual for the beds overall to dip at a few degrees towards the centre of the basin, this being to the west, the area north of Newton Abbot. Locally, however, they are thrown into small sharp anticlines or domes with dips of 50—60 degrees, a fact which was commented upon by Pengelley in 1863. Over the period 1951—1959 the author has observed nine of these structures in detail as the pit faces have been worked for clay. From these observations it seems reasonable to suggest that the contortions in the Bovey Beds are periglacial disturbances of Pleistocene age.

The continued kindness of Messrs. Watts, Blake, Bearne & Co., the Bovey Pottery Co., and other local pit owners in allowing the writer access

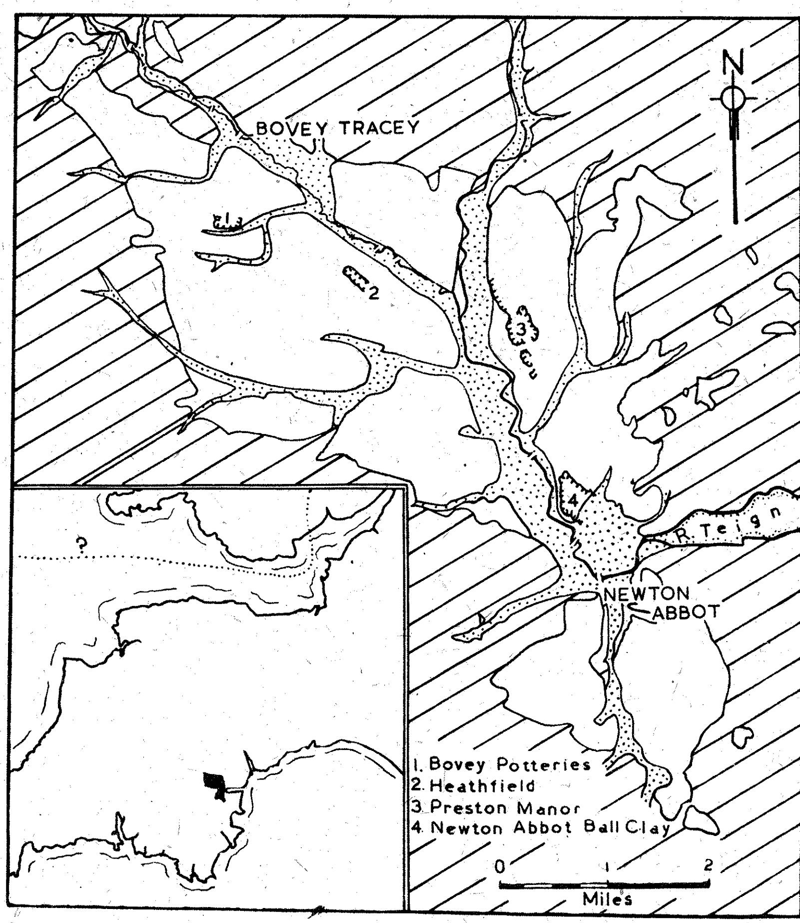


Fig. 1. Sketch map of the outcrop of the Bovey Beds

Pre-Bovey formations shaded, Bovey Beds unshaded, alluvium stippled; principal exposures of clays numbered. Inset map shows position of Bovey Beds outcrop and southern limit of the Older Glaciation in the Bristol Channel area

to the clay pits and mine shafts at all times is gratefully acknowledged. It is also a pleasure to thank Mr. R. S. Waters for his helpful discussions in the field and for kindly reading the manuscript.

DESCRIPTIONS OF SECTIONS

The pits on the western side of the Chudleigh-Kingskerswell road (o. s. grid ref. c. 20/854755) have in recent years been worked most actively and it is in these that the structures described below are observed. Comparable but smaller phenomena were also found at the other localities numbered on the map but have not been revealed so readily by clay-digging and in consequence have received less attention.

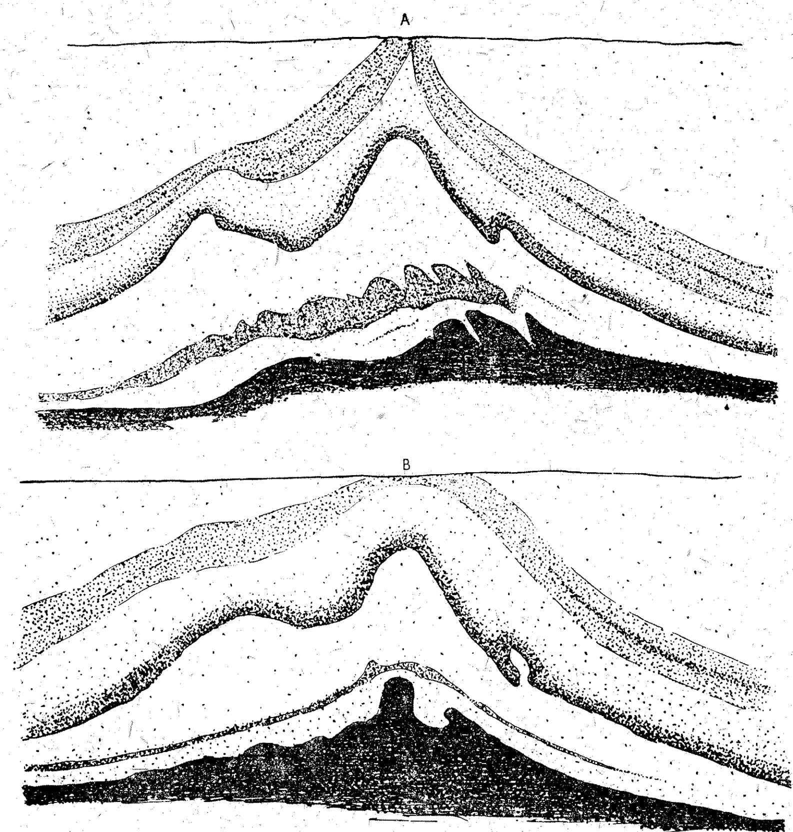
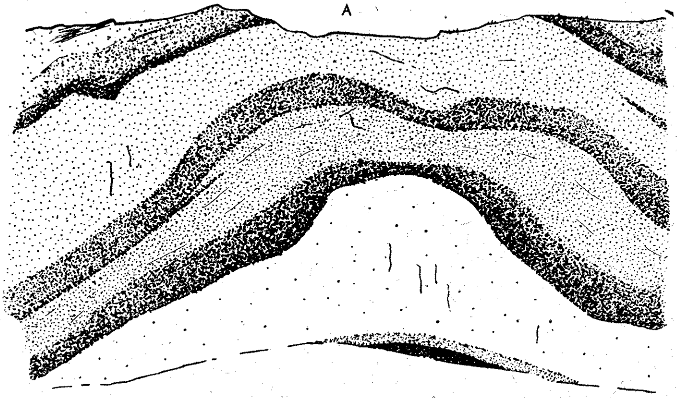


Fig. 2. Sections through contorted ball clays and lignite in the Bovey Beds at Preston Manor pit, near Newton Abbot

Height of section approximately 7 ft (2,0 m). Section A was cut parallel to and approximately 4 ft (1,2 m) from section B during the working of the pit face

A



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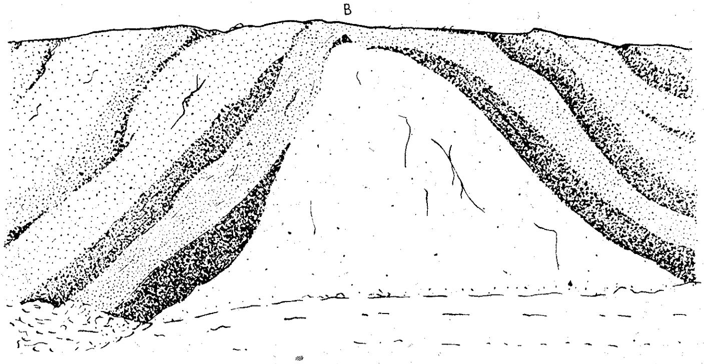

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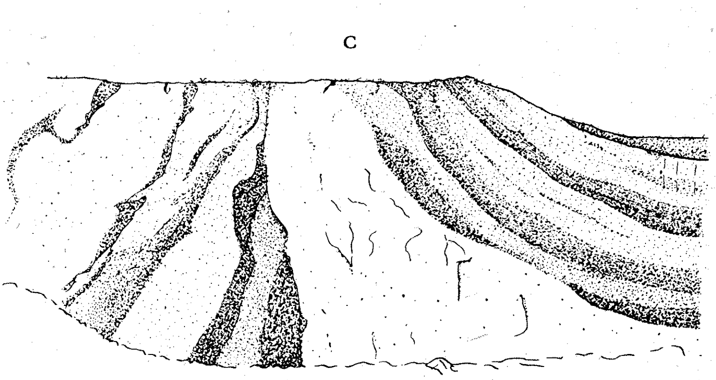

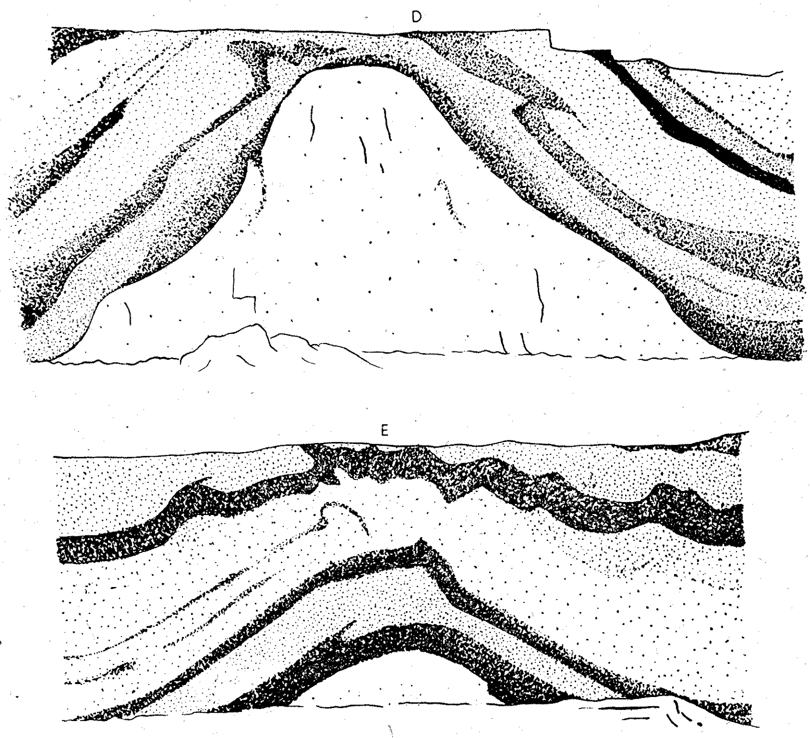

Fig. 3. A typical anticlinally disturbed mass of ball-clay bands in the Bovey Beds at Preston Manor pit, near Newton Abbot

The sections (A, B, C, D, E) were exposed when the pit face was successively cut back at intervals of approximately 4 ft (1,2 m) and are parallel. Height of sections approximately 10 ft (3,0 m). Though the form of the disturbance is characteristic, this example is slightly larger than most. Redrawn from photographs and field sketches

A deposit of river alluvium and coarse gravel up to 15 ft (5 m) thick covers the Bovey Beds in the vicinity of the R. Teign near Newton Abbot and below it the beds are generally fine to silty and lignitic clays, white, grey and even black in colour. Very small quantities of lignitic debris incorporated in the clay give dark colours. The presence of 15 per cent or more of fine lignitic material may produce a virtually black clay. The alternation of these dark bands with purer clays is usually effected with abrupt changes in colour and the sequence produced is often of bands 2 to 15 ft (0,6—5 m) thick. Beds of unadulterated lignite occur but are not common. They are often extremely discontinuous and usually less than 2 ft (0,6 m) thick. Where undisturbed, the strata are almost horizontal.

In the lowest reaches of the clay workings the thicknesses of these bands retain a constancy which is missing in higher levels. The topmost

25 ft (8 m) or so of strata exposed in the various pits often exhibit a most striking lateral thickening and thinning. Frequently the clays at lower levels show small slickened and polished surfaces but it is difficult to locate evidence of tectonic movement in the uppermost beds.

The disturbances affecting the highest 20—25 ft (6.6—8 m), and especially the topmost 10 ft (3 m), of the exposed clays may be said to comprise relatively simple anticlinal structures or domes ranging from gentle undulations to sharp diapiric or piercement structures with vertical sides. In the cores of these structures thickened masses of pale clays are usually encountered occasionally with detached masses of lignitic clay „floating" in them. The core clays often seem to be disrupted, almost shattered, parts yielding at some past stage by flow, other parts yielding by fracture. The most perfect domes are strikingly laccolite-like in shape, the core of clay being usually about 10 ft (3 m) thick. Examples of these structures are illustrated. Several of the anticlines or domes were truncated by erosion before the overlying gravel and alluvium was deposited (see figure 3).

As the excavation of the pits proceeded it was possible to observe the areal extent of several of the individual contortions. In the plan they appear to be more or less circular or quadrate. No elongation or preferred orientation of the structures has been detected nor does there seem to be any undoubted significant faulting within their vicinity. Also, the domes seemed to be separated by several score yards of relatively undisturbed beds.

Large exposures are not sufficiently widespread to give any indication of the overall distribution of the anticlines within the outcrop of the clays. Though the marginal sand and gravel outcrop (not covered by river alluvium) shows many signs of congeliturbation on a minor scale, no disturbances on a scale comparable with that described here have been noted.

THE ORIGIN OF THE CONTORTIONS

Deformation of soft, relatively even-bedded sediment may take place penecontemporaneously by slumping or sub-aquatic mass movement or later by differential compaction, tectonic agencies, superficial (gravity collapse) movement or periglacial processes.

There is little direct evidence to suggest that the contortions are of tectonic origin. It is true that the Bovey valley lies on the line of the Lustleigh Fault (Blyth 1957) and that the Bovey Beds are to some extent affected. There is a displacement of that Dartmoor granite margin near the extreme northern end of the Oligocene outcrop and the fault passes under the Bovey Beds possibly to continue southeastwards under the axis of the basin.

Smaller parallel faults may occur along or near the margins of the basin and may similarly have suffered Tertiary movement. Their effect upon the Bovey Beds would probably be greatest in the lower parts of that formation; the anticlinal disturbances described above, however, fade away at no great depth from the surface. In such poorly consolidated sediments it is impossible to detect any small-scale reliable indication of movement of the basement, and the structures dealt with here are essentially superficial.

Mass movement of these fine-grained and water-saturated materials during the existence of the lake cannot be ruled out entirely. Indeed, it seems likely that some of the features encountered in the mines may possibly be due to sub-aquatic sliding of the material deposited near the shore of the lake towards the deeper reaches. There are, however, none of usual signs of directional movement usually found in such phenomena and it is obvious that the movement post-dates consolidation of the clays and the „lignification" of the vegetable debris.

During and after the deposition of this complex of sands, clays and lignites differential compaction must have had a considerable effect upon the stratification. The marginal sandy beds (doubtless) thin rapidly towards the centre of the basin and upon compaction lose but little of their volume. The clays no doubt thin out marginally and will, with the development of an overburden, experience compaction to a greater or lesser degree. The transformation into lignite of vegetable debris of the character likely to have been present involves compaction to a ratio of perhaps 5 to 1. Such loss of volume during later Tertiary times may well have had a considerable effect upon the stratification of the enclosing lacustrine deposits, especially since there is also much lignitic material in many of the clay beds. Nevertheless it seems unlikely that such a mechanism as differential compaction can be responsible for the contortions described above. It is of course more probable that it contributes to the undulating character of the bedding in the somewhat deeper parts of the succession as seen in the shafts.

It is not thought likely that these comparatively shallow structures have been produced by lateral movement of the type giving rise to „valley bulges". The local geology and gentle topographical relief rule this out.

In all essentials these contortions are remarkably similar to some of the involutions noted by Te Punga (1957) in the Mesozoic and Tertiary rocks and superficial deposits of southern England. Disturbances produced in perennially frozen ground are in places known to extend several hundred feet below the surface. It is, however, within the active layer, confined to a comparatively few feet near the surface, that the most intense structural disturbances are produced. During Quaternary times this region of Britain experienced periglacial conditions, doubtless most intense during the early glacial phases but effective over a considerable part of the Pleistocene epoch. The ice-front during the early glaciation stood for a time at a point only 50 miles (80 km) to the north of the Bovey basin. Striking periglacial features are now known in many parts of Devon, affecting many different kinds of material. The flat terrain of the Bovey outcrop, coupled perhaps with poor drainage and the water-absorbent character of the lignitic clays, lignites and sands would seem to offer an ideal situation for the development of involutions and „polygonal structures".

Te Punga (1957) noted that the superficial deposits of southern England contain innumerable contortions and involutions, each being more or less symmetrical about a vertical axis and often showing a progressive development from simple anticlinal „bulges" to mushroomshaped and even branching intrusions from lower to higher levels. So far in the Newton Abbot area none of the more complex forms has been found. The shape of the Bovey disturbances is strongly suggestive also of that of pingos and the somewhat disrupted character of the pale clay in the cores of the domes may have been acquired from the presence of bodies of ice within it. Müller's (1959) interpretation of the (much larger) East Greenland pingos is attractive as an at least partial explanation of the present structures. „The East Greenland pingos develop where sub- or intrapermafrost waters penetrate into the permafrost zone, forced up by hydrostatic pressure, with a relatively small temperature difference between this water and the frozen ground and at a low rate of flow. Within the upper part of the permafrost zone the uprising water produces a hydrolaccolith *sensu stricto* which, with further reduction of the temperature, will become an ice body. The crystallisation pressure of this process together with the hydrostatic pressure will exceed the pressure and force of cohesion of the overlying layers of frozen or unfrozen clays, gravels, or even bedrock. As the upward forces are concentrated within a relatively small area, the resulting pingo-heave will be of volcanic shape" (Müller 1959, p. 116). The necessary hydrostatic pressure in the Bovey occurrences could perhaps come from the surrounding higher ground, especially to the east where the gravels of the Bovey Beds rise to about 200 ft (66 m) above the floor of the valley. However, the permeability of the clays is low, and it is not easy to envisage the movement of water through them at anything except a very slow rate. The life cycle of Müller's East Greenland pingos is held to be related to an open system, gaps in the permafrost linking the atmosphere with the sub-permafrost zone. Gaps in the Bovey Beds permafrost may have existed but their location is not apparent. There is no evidence to suggest that the structure arose under the sites of lakes as

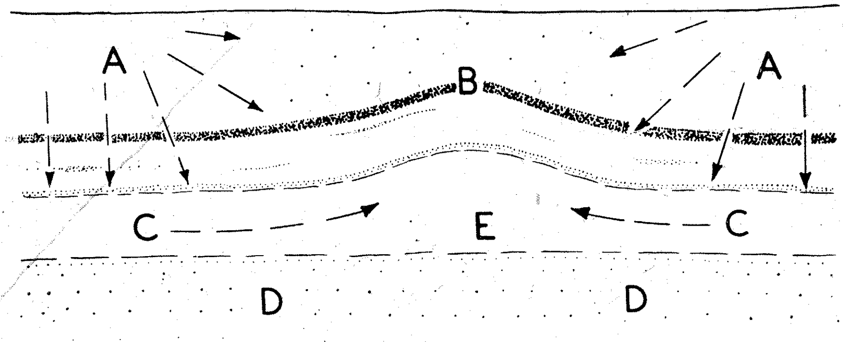

Fig. 4. Possible origin of anticlinal disturbances in the Bovey Beds

A — regions of expanding permafrost, arrows denote directions of growth of frozen ground; B — region of pressure release due perhaps either to (i) difference in weight or strength of overburden, or (ii), absence of permafrost, or combination of (i) and (ii); C — stratum of pale ball-clay subjected to pressure of overburden and or permafrost of regions A, and resting on D, a substratum of comparatively unyielding, perhaps frozen, darker clay. At E plastic clay accumulates in laccolitic form by flow from surrounding areas C. Depth of section approximately 20 ft (6,0 m)

in the case of the MacKenzie pingos. On the other hand, the pressure which produced the Bovey disturbances seems probably to have developed by the expansion of the permafrost into an unfrozen stratum. It might even be the case that the disturbances were produced at a late date following a phase of thawing of the top 20 ft (6,6 m) or more of the low-lying Bovey--Teign valley.

Black (1951) pointed out that the depth of thaw under periglacial conditions is at a minimum in peat or highly organic sediments and increases with the grade of clastic material. Also it is less in poorly drained ground. It is not surprising, therefore, that the sharp disturbances in the Bovey Beds do not extent to a greater depth. Periglacial disturbances in superficial and even solid formations in other parts of southern England are known to reach considerably deeper than 20—25 ft (6,6—0,8 m).

Lignite may contain 25% to 48% water and the clay may commonly contain lignite to as much as 40% of its total volume. Thus the ground suffering permafrost activity would contain a very large volume of water and cryoturbation on a large scale might be expected. It is, however, in clay in which the lignite debris content is not particularly high (i. e. light coloured) that the greatest movement seems to have taken place. Though the degrees of plasticity shown by the various beds or types of clay do not seem to vary much, the lightest clays may be the most plastic under cold wet ground conditions. This perhaps being so, it is not then surprising that where this type of clay occurs within the active zone or mollisol it suffers most disturbance. In the structures described the light coloured clay initially rises from a layer between 20 and 25 ft (6,6 and 8,0 m) below the surface and this depth may have been near the base of the mollisol. Such a highly plastic stratum subjected to permafrost pressure would tend to flow towards points of release. Where the cover of this stratum is of uneven thickness or strength flow may be expected to take place towards the area where it is thickest or weakest. The somewhat undulating surfaces and uneven thicknesses and composition of the beds may have presented such regions of thin or weak cover and towards these the movement would take place.

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