SLUMP-SHEAR STRUCTURES AND MASS-FLOW DEPOSITS IN THE CRETACEOUS SEDIMENTS OF SOUTH-EASTERN ALEXANDER ISLAND

By R. R. Horne

ABSTRACT. In the Cretaceous sediments of south-eastern Alexander Island, mass-flow diamictites and intraformational slump-shear structures have resulted from the re-mobilization of unstable accumulations of sediment. This instability appears to have been related to the morphology of the trough, the rate of sediment accumulation and the seismic activity of the trough framework.

THE Cretaceous trough in which the sedimentary and volcanic rocks now exposed in south-eastern Alexander Island were deposited was established as a back-deep of a broad geanticlinal ridge formed on the site of the present Antarctic Peninsula during an early Mesozoic orogenic episode. On the basis of lithofacies variations, fossil distribution, and syn-depositional and post-depositional structures, the general morphology of the trough can be established with some confidence. The western shoreline, marked by a zone of deltaic and inter-deltaic deposits, was close to the present linear east coast of Alexander Island (Fig. 1). It therefore trended north–south, approximately parallel to the cordilleran axis. Westward of these inshore rocks is a zone of sediments that was deposited in moderate water depths on a marginal shelf sloping gently to the west. The west-facing scarp edge of this shelf is marked by typical mass-flow deposits such as pebbly mudstones and breccias. Turbidite sandstones with inter-bedded pyroclastic and effusive volcanic rocks accumulated in the deeper water along the axis of the trough west of the shelf edge. This trough may have been bounded to the west by a volcanic landmass or an island arc (Horne, 1967). Intermittent instability, resulting from rapid sedimentation combined with tectonic activity in the basement, caused extensive re-mobilization of the accumulating sediment. This paper describes the resulting intraformational slump-shear structures and deposits within the shelf sediments and the mass-flow diamictites deposited at the base of the scarp.

INTRAFORMATIONAL SLUMP-SHEAR STRUCTURES

Several different patterns of intrastratal convolute bedding result from various stress distributions, which in turn are a function of the time of formation of the structure relative to the progressive deposition and lithification of the enclosing sedimentary sequence. A study of available descriptions in the literature reveals that convolute bedding can possibly be divided into three genetic groups. The first can be described as essentially syn-depositional and is claimed to have resulted from selective deposition and erosion under turbulent conditions of sedimentation (ten Haaf, 1956; Dzulynski and Smith, 1963). The folds are typically sharp tight anticlines separated by broader open synclines. Erosion of the top of the convolute bed before the deposition of the succeeding one can result in strong angular discordance at the contact. This structure is extensively developed in certain turbidite sequences and, unlike the other types, it is not fundamentally controlled by components of the gravitational force acting on sediment resting on a slope. Some types of finely laminated, intricately convolute intrastratal folds, which are frequently developed in the sandy siltstones of the inter-deltaic facies of this trough, may represent true syn-depositional convolute lamination modified by subsequent load and compaction deformation. The second type of structure, to which the term "slump folding" is widely applied, results from the *décollement* and down-slope movement of the uppermost and therefore unloaded and unenclosed plastic layers of a sedimentary sequence under the action of a down-slope component of gravity. Fold structures of this type have not been recognized in the Alexander Island sediments. Where surface slumping has been initiated in this trough, the high mobility of the sediment has resulted in texturally homogeneous mass-flow deposits such as the pebbly mudstones described on p. 17.

The vast majority of the soft-sediment convolutions in these sediments belong to a third group of pre-diagenetic folds, which are essentially intraformational and are generated when certain strata intercalated within a pile of sediments act as a lubricating zone for the overlying beds to slide down-slope under gravitational forces. Consequently, the folds are the result of shear and they generally have a distinct monoclinic symmetry, being overturned towards the

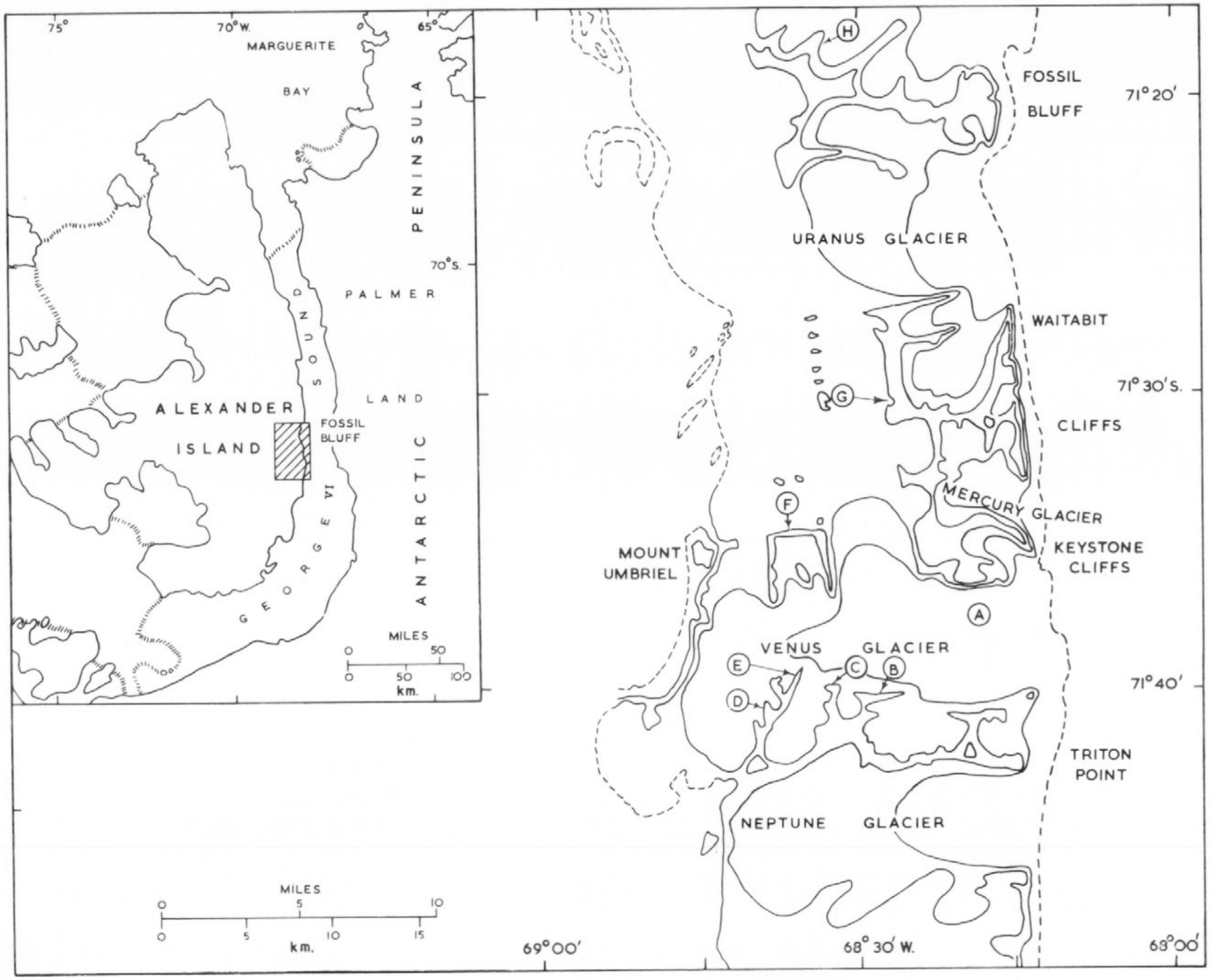


Fig. 1. A general map of Alexander Island showing the area surveyed and the localities (A–H) referred to in the text.

down-slope direction. The upper parts of the folds here do not usually exhibit sharp angular discordance with the overlying beds, and even when this occurs it is a consequence of intense localized shear and not erosion. At locality A (Fig. 1), intraformational fan folds (Fig. 2) are defined by a more cohesive bed of sandstone surrounded by re-mobilized sandstone which has been squeezed into the axial zones of the folds. The relative rigidity of the strata above and below these folds, and the subsequent load-flattening by the thick overburden, has resulted in the flattening of the noses of the folds against the enclosing beds. The compression of the fluid sand in the axial space of the best-defined fold near the centre of Fig. 2 has resulted in depression of the underlying stratum.

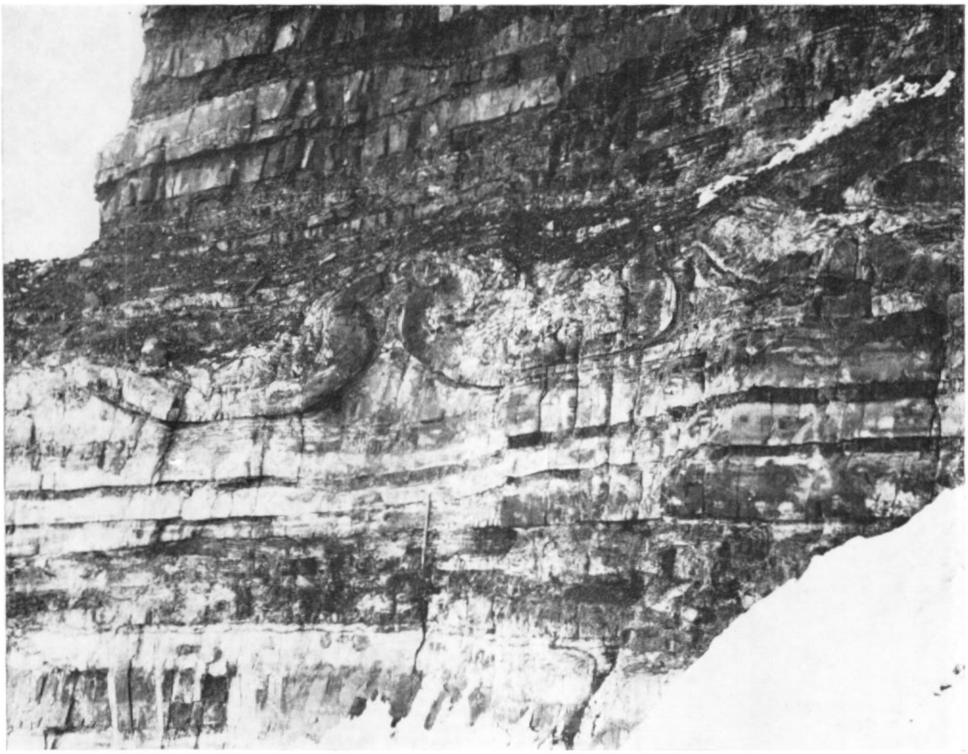


Fig. 2. Tightly involute slump-shear folds at locality A. The shaft of the ice-axe near the centre of the picture is 1 m. long.

At locality G (Fig. 1), which is approximately 10 km. along the sedimentary strike from locality A, the structure shown in Figs. 3 and 4 was recorded. Here the lowermost 32 cm. of an interbedded sequence of thin sandstones and silty mudstones, which have a sharp lower contact with a thick series of massive mudstones, underwent intraformational deformation while the sand laminae were in a semi-fluid state and the argillite bands in a plastic condition. One sand layer in the disturbed zone has been sheared into discrete involute folds, which, as a consequence of their down-buckling, have been impressed into the arenaceous layer below and mobile sand from this layer has been forced upwards in the form of fine stringers in the plastic mud between the folds. The upwelling of this sand between the folds is paralleled by a slight uparching of the laminae overlying the main shear surface, and this observation supports the hypothesis that the upper beds had been deposited before the shear convolutions were produced. A similar effect has been recorded in relation to the fan folds at locality A.

These structures are therefore essentially intraformational and post-depositional rather than surface phenomena and syn-depositional (Nagtegaal, 1965). The axial planes of these folds are

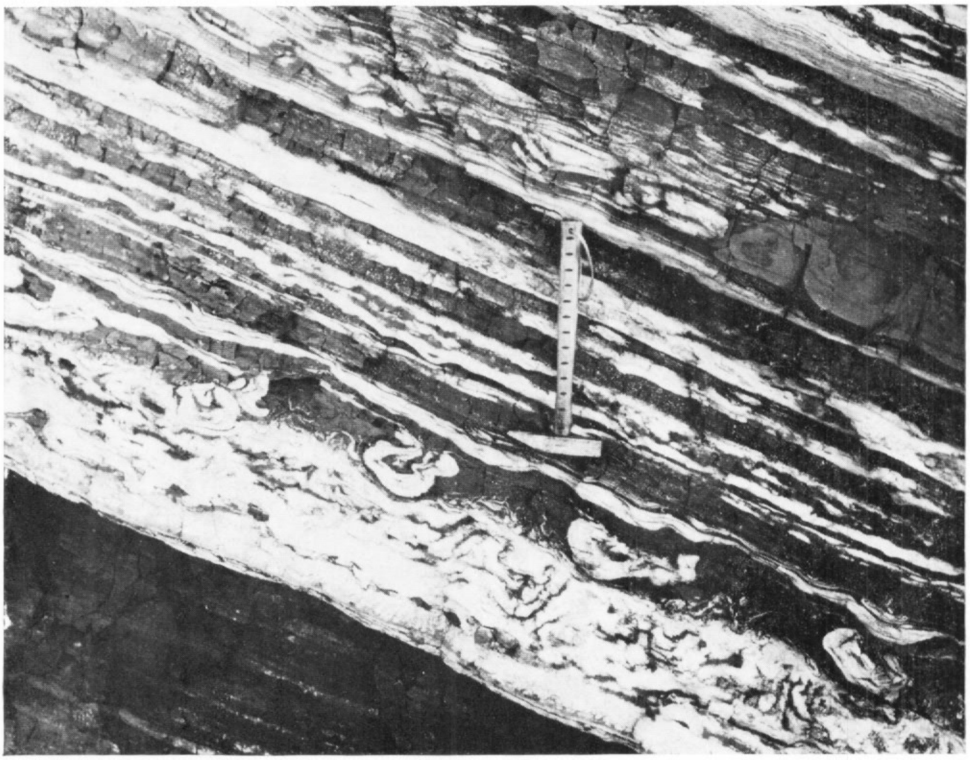


Fig. 3. Intraformational slump-shear folding at locality G. The hammer shaft is 0·35 m long

Fig. 4. A close-up photograph of one of the folds in Fig. 3, showing the detail of the structure. The scale on the hammer shaft is in 2·5 cm. units.

invariably overturned towards the west. This is consistent with the westerly down-slope direction derived from other criteria.

Repeated small-scale slump faulting of interlaminated clays is exposed at locality D (Fig. 5) in sediments overlying the pebbly mudstones there. To the right of the photograph the finely banded sand layer involved in the slump faulting has been folded back and drawn out into the enclosing mudstone.

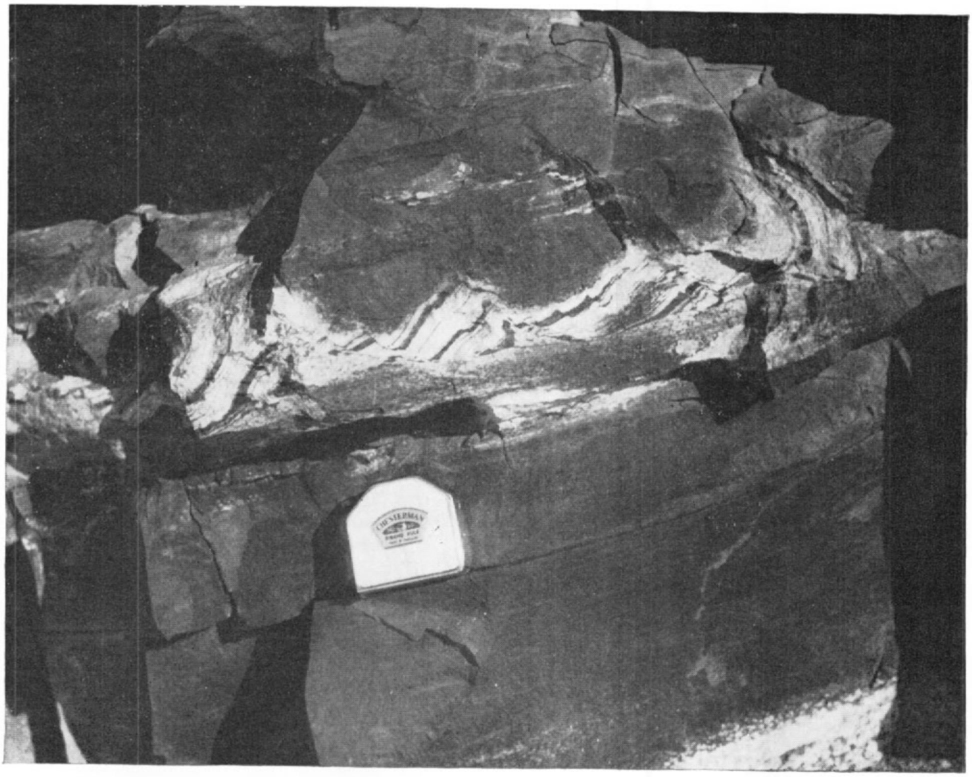
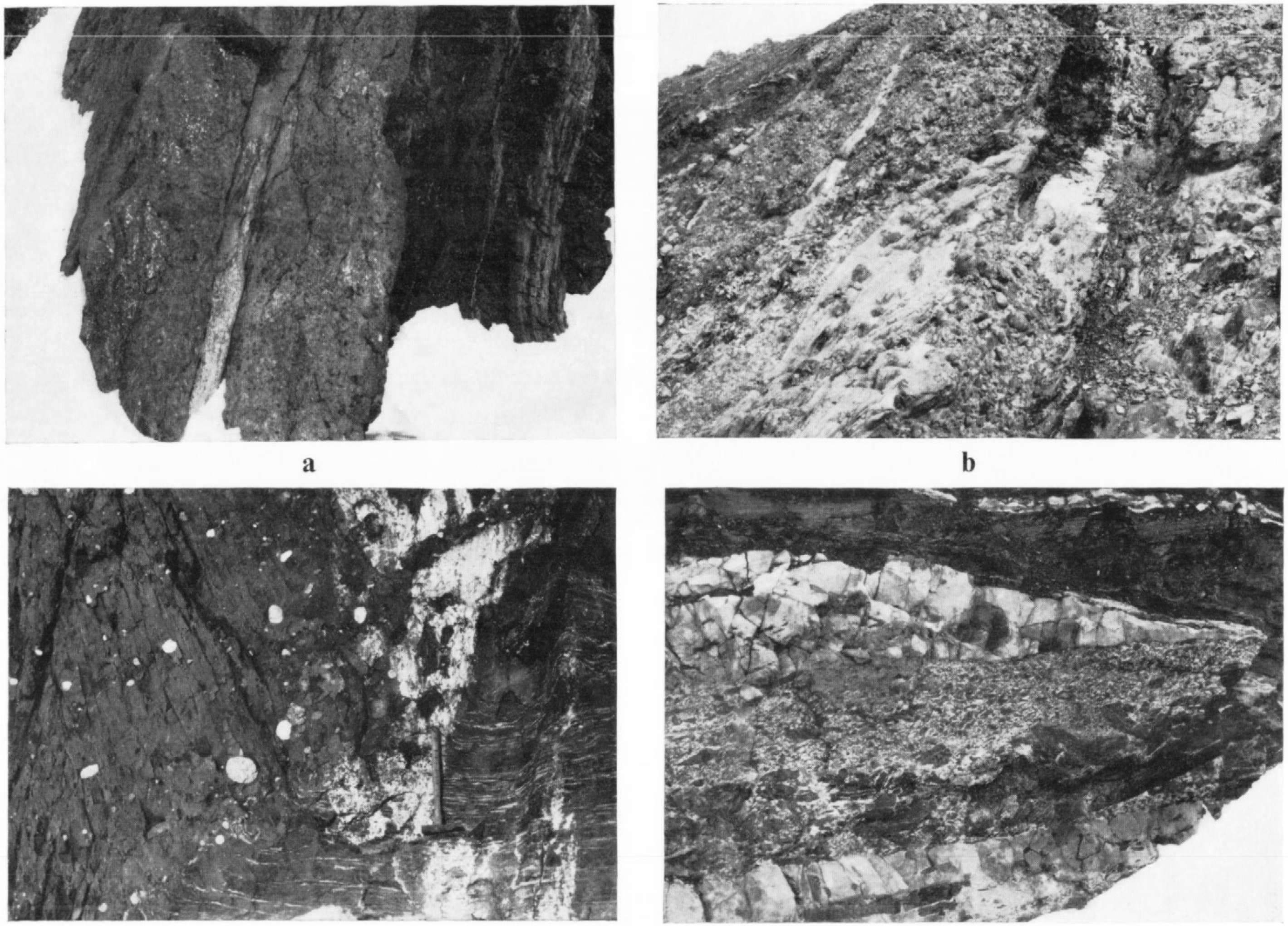


Fig. 5. Repeated small-scale slump faulting at locality D. The scale is 5 cm. across.

Pebbly Mudstones and Breccias of the Shelf Edge

The base of the marginal shelf of the trough is marked by a narrow zone of pebbly mudstones and breccias resulting from submarine mass-flowage on the steep scarp face of the shelf (Crowell, 1957; Dott, 1963). As the edge of the shelf is approached there is a gradual transition from regularly interbedded pebble and cobble conglomerates, sandstones and mudstones at locality B (Fig. 6a) through similar beds whose external morphology has been distorted by incipient flowage at locality C (Fig. 6b) into actual mass-flow deposits at localities D and E (Fig. 6c and d).

An example of pebbly mudstone from locality D is illustrated in Fig. 6c. It is composed of a matrix of black silt or coarse mudstone in which are enclosed in random distribution well-rounded pebbles and cobbles of exotic material, which are apparently identical in composition to the pebbles forming the conglomerate beds exposed immediately to the east (Fig. 6a and b). These conglomerates were originally at a higher level in the trough near the shelf edge and the outer unstable part underwent mass re-mobilization and flowage, which was possibly triggered by seismic shocks, becoming mixed with interbedded muds during flow. In the bulk of this deposit the pebbles are widely scattered but in parts of its exposure where a concordant basal contact can be seen this pebbly mudstone grades downwards into a conglomeratic layer 2 m.



a b c d

Fig. 6. a. Regular-bedded conglomerates, sandstones and mudstones at locality B. The two conglomerate beds have a total thickness of 3·5 m.
b. Chaotic bedding morphology at locality C due to limited, irregular gravity flowage near the edge of the shelf. The width of the outcrop in the photograph is approximately 20m.
c. The intrusive contact between a pebbly mudstone and a striped siltstone at locality D. The hammer shaft is 0·35 m. long.
d. Mass-flow breccia at locality E. The sequence shown in the photograph is 10 m. thick.

thick resulting from the sinking of the pebbles through the fluid mud. The strongly discordant steep contact between the pebbly mudstone and the striped siltstone at locality D, and the deformation of the stripes near the contact, indicate that this is not a normal sedimentary junction but that it resulted from the intrusive flow of the pebbly mud into the plastic banded sediment. Similar pebbly mudstones have been recorded by the author from locality F and by Taylor (1966) from locality H. These outcrops lie in a zone parallel to the axis of the trough, marking the trace of the shelf edge.

The second type of mass-flow deposit is exposed at locality E in the same palaeogeographic position as the pebbly mudstones; it is a sedimentary breccia composed of angular, commonly platy blocks of black mudstone randomly embedded in a coarse, poorly sorted grey sandstone (Fig. 6d). Certain of the slabs of mudstone show dilation or floating apart of the flaggy layers by the interjection of the mobile sand. This deposit is extremely variable in thickness and it is thought to have originated from the disruption of an earlier lithified mudstone bed or series of beds in a re-mobilized hydrous sand which underwent down-slope flow to a more limited extent than the pebbly mudstones, because the latter are much more constant in thickness than this breccia.

Mass-slide Deposits on the Shelf

In the inshore rocks of this trough deltaic and inter-deltaic facies sequences are developed. At locality A, the contact between an underlying argillaceous inter-deltaic sequence and an overlying arenaceous, fluvio-deltaic sequence is well exposed. Marking the contact is a thin interval of sediments which underwent disruption and sliding probably as a result of tectonism in the hinterland and basement which is reflected in the vertical facies change.

The most striking of these deposits is a 3 m. horizon composed of large isolated blocks of white sandstone embedded in a re-mobilized sandy matrix (Fig. 7). The sandstone blocks

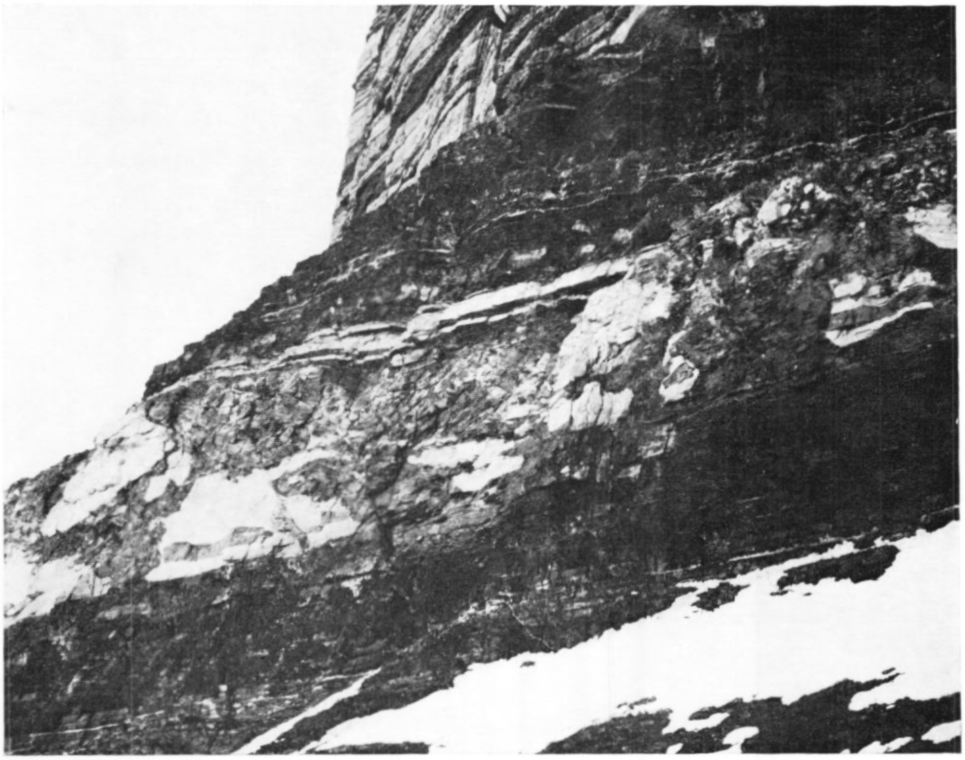


Fig. 7. A disrupted horizon, about 4 m. thick, at locality A.

contain darker weathering, elongate calcareous concretions. Where they are developed in undisturbed sandstones in the same succession, the long axes of these concretionary layers are horizontal, and hence the blocks in this deposit have not been rotated but merely disrupted upon mobilization of their enclosing beds.

Beneath this horizon is a thick, massive, texturally isotropic hybrid argillite which is a product of slurrying of sediment. Randomly dispersed in a matrix composed of equal parts of material of silt and mud grade are small distorted patches of coarser sand, small angular rock and mineral fragments and fossil material. The convolute structures described above are the product of shearing of incompetent horizons by the sliding of the overlying beds, and the pebbly mudstones and breccias are the product of surface mass flow. Here, however, there is no evidence to indicate whether these deposits have an essentially intraformational origin or whether they are the product of superficial meta-depositional slumping (Nagtegaal, 1965).

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