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IMPACT-INDUCED DENDRITIC RIDGES IN SOFT SEDIMENTS

Pl. XXXIII—XXXIV and 1 Fig.

Struktury deformacyjne na powierzchniach hieroglifów uderzeniowych

Tabl. XXXIII—XXXIV i 1 fig.

Abstract: Laboratory experiments and field evidence indicate that deformational structures consisting of dendritic ridges may occasionally develop in response to tool impacts. The ridges result from instantaneous loading and horizontal shear forces at the interface within layered sediments showing a normal density gradient.

Soft-sediment deformational structures consisting of regular polygonal and longitudinal ridge patterns may form either at the interface between a moving suspension and soft bottom sediment (Dżułyński and Walton, 1963; Dżułyński and Simpson, 1966), or within layered soft sediments which have experienced a reversed density gradient. The systems with reversed density gradients have been indicated as (*b*, *a*) systems (Anketell, et al., 1970), where *b* refers to a higher density layer at the top, and *a* refers to a lower density layer at the bottom of a system. Systems of this type were contrasted with (*a*, *b*) systems, which exhibit a normal density gradient. The (*b*, *a*) systems were also divided into horizontally mobile and non-mobile systems, depending on the respective presence or absence of unidirectional horizontal shear between the *a* and *b* members. Deforming mobile systems characteristically give rise to longitudinal ridge patterns, while non-mobile systems generally produce polygonal ridge patterns. Although the regular convective patterns of deformations generally arise from reversed density gradients, it is realized that they are essentially due to the interpenetration of viscous fluid media differing in kinematic viscosities. Therefore, they may also develop in normal (*a*, *b*) systems, if the top layer *a* is vertically compressed into underlying layer *b*. Such compression could result from a superimposed load.

In the laboratory syntheses of deformational structures in (*b*, *a*) systems (Anketell et al., 1970), one experiment was also conducted on an (*a*, *b*) system. This experiment resulted in the development of both polygonal and longitudinal ridge patterns by purely mechanical means. For the sake of clarity, the essentials of this experiment are here briefly dis-

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cussed. A clay suspension was allowed to settle through a standing body of water to form a layer with a positive density gradient i. e. (*a*, *b*) systems. The water was then removed, exposing the upper part of the system to air. Since the uppermost part of the sediments was highly water-saturated and consisted of a metastable framework of fine clay particles, its viscosity was lower than that of the underlying denser material. The top surface of *a* was then uniformly loaded by using a metal plate, thus pressing down layer *a* into the underlying layer *b*, in a manner similar to that caused by a reversed density gradient. The resulting deformational pattern at the layer interface consisted of a polygonal ridge pattern. A similar experiment was also conducted using a rolling cylinder instead of a plate. The rolling inflicted a unidirectional horizontal shear component at the interface between layers *a* and *b*, resulting in the temporary development of a horizontally mobile system, and the consequent production of longitudinal dendritic ridges (A n k e t e l l, et al., 1970, fig. 14). Identical ridges may develop from any external force capable of generating a unidirectional horizontal shear, and rolling may well be substituted by a slight semi-tangential, impact, such as might be produced by a current-transported tool (Fig. 1).

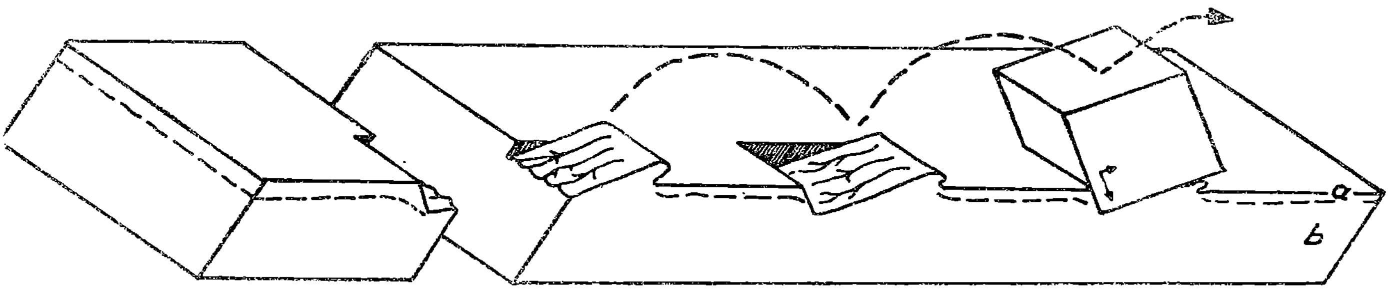

Fig. 1. Powstawanie grzebietów dendrytycznych pod wpływem nacisku przedmiotu uderzającego o dno. Według doświadczenia

Fig. 1. Proposed mechanism by which tool impacts may produce longitudinal dendritic ridges in a system exhibiting a normal density stratification. Based upon experiments.

Similar structures to those discussed might be expected to occur within natural (*a*, *b*) systems on the sea floor, as a result of tool impacts upon the top of a low density layer underlain by one of higher density. An example of such natural structures is provided by a peculiar set of prod and brush-marks, which occur on a sandstone slab derived from the Oligocene Krosno Beds within the Polish Carpathian Flysch (Pl. XXXIII, Pl. XXXIV, Fig. 1). These brush and prod-marks were produced by a fish vertebra, which was proding the bottom while being transported by a turbidity current. The surface of the prod and brush marks is sculptured by a delicate pattern of longitudinal dendritic ridges. Similar ridges have also been produced experimentally, using fish vertebrae in an artificial turbidity current flowing upon a soft substratum. Such ridges superimposed on brush and prod marks were previously interpreted as the result of an increase in flow turbulence behind moving tools (D ż u ł y ń s k i, 1965). However, the experiments by A n k e t e l l and others (1970) allow a new interpretation of both the natural and experimental structures here described. The ridge mould on the surfaces of the prod and brush marks shown in Fig. 1 and Pl. XXXIV are here interpreted as having been formed in temporarily unstable (*a*, *b*) systems resulting from tool impact. The impact results in the forcible penetration of a low-density top layer of bottom mud into a slightly denser and more viscous substratum. Simultaneous with the induced instability, the momentum of the impacting tool produces a horizontal shear between the two layers, resulting in the mobilization of the lower layer, and the consequent development of longitudinal dendritic ridges.

In conclusion, it may by noted that longitudinally dendritic ridge patterns characteristic of mobile (*b*, *a*) systems may also occasionally develop in normal (*a*, *b*) systems. This could occur in response to the tangential impacts of tools, which produce both simultaneous loading, and horizontal shear forces acting upon the layer interface.

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STRESZCZENIE

Podłużne grzbiety konwekcyjne powstają najczęściej w ruchomych układach (*b*, *a*), czyli w układach o niestatecznym uwarstwieniu gęstościowym (por. Anketell et al. 1970). Bezpośrednią przyczyną ich powstawania jest jednak wzajemne przenikanie się dwu nie mieszających się ze sobą ośrodków o różnej lepkości kinematycznej. Grzbiety konwekcyjne mogą zatem tworzyć się również w układach (*a*, *b*), jeśli np. warstwa *a* zostanie przyciśnięta do podścielającej ją warstwy *b* pod wpływem dodatkowego obciążenia. Deformacje tego rodzaju, powstałe wyłącznie w drodze mechanicznej, zostały uzyskane doświadczalnie (Anketell et al. 1970, p. 18). Naturalnym odpowiednikiem tych deformacji są struktury widoczne na powierzchniach hieroglifów uderzeniowych (Tabl. XXXIII—XXXIV, fig. 1). Przyczyną powstania grzbietów konwekcyjnych było, w tym przypadku, wciśnięcie warstewki *a* w podścielającą ją warstewkę *b* przez uderzający o dno krąg rybi. Wciśnięciu towarzyszyło nieznaczne przesunięcie poziome (fig. 1), co spowodowało chwilowe utworzenie się układu ruchomego.

EXPLANATION OF PLATES

OBJAŚNIENIA TABLIC

Tablica — Plate XXXIII

Prod marks produced by a fish vertebra exhibiting moulds of dendritic ridges. Krosno Beds, Oligocene Wetlina locality, Polish Carpathians 1/3 natural size
Ślady rybiego kręgu z odlewami grzbietów dendrytycznych. Warstwy krośnieńskie, Wetlina 1/3 naturalnej wielkości

Tablica — Plate XXXIV

Close-up view of one of the prod marks illustrated in Pl. XXXIII
Szczegół struktury uwidocznionej na tabl. XXXIII
×1,5

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