SIGNIFICANCE OF THE SHEAR PLANES FOR IDENTIFICATION OF THE SOLIFLUCTION PHENOMENA

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SUMMARY

The purpose of the submitted contribution is to outline the problems that are connected with mechanism of solifluidal movement of earths and with its manifestations. Regarding the present state of knowledge, these problems are not unambiguously solved and the suggested possibilities of solution would demand experimental or actuogeological verification. Questionable are also relationships of solifluction to relative slope-movements namely to planar slide and creep. The urgency to solve these problems and relations is evident from the fact that a great geomorphological importance is almost commonly attributed to displays of solifluction in spite of the unsufficiently known physical principle of this slope-movement.

The term "solifluction" is used in a broadly conceived and thereby not always clear sense of the word (see Krejčí, 1960, p.18-19).One of the reasons why this term has not been sufficiently defined is probably the fact that the mechanism of solifluction - as far I know - has not been exactly analysed, so that in geological, geotechnical and mainly geomorphological literature we can find only a description or a statement of manifestations of this slope movements (e.g. Roth, 1944, p. 12). The author of the term "solifluction" (Andersson, 1906) characterised the solifluidal action as ".. the slow flowing from higher to lower ground of masses of waste saturated with water this may come from snow-melting or rain...". In thus introducted characteristic one can see another objective cause of a very broad and unexact conceiving of this term. In Czech literature Sekyra (1960) limited the term "solifluction" in following sense "...the movement of ground over the inclined and freezed subbasement..." and thus the strict sense of the discussed term has mostly been interpreted also in world letters (e.g. Dylik, 1967; Jahn, 1969; Young, 1972; Carson, Kirkby, 1972; Washburn, 1979; Mosley, 1982). However practically by now one can find in literature a characteristic of solifluidal process as "... a displacement of the semifluidal or plastic ground mass over gentle slopes as a consequence of gravitation" (Činčura et al., 1983, p. 567). In this connection it is necessary to mention that all slope movements are energetically supplied by gravitation. In accordance with Pašek (in Svoboda et al., 1983, II, p. 541) are these movements divided into creep, sliding, flowing and earth fall, regarding the mechanism. In respect of priority of Andersson's definition ascribe the mechanism of flowing to the solifluction. That is why also Krejčí (1960, p. 18) characterised the solifluction as a liquid movement of earths acting by principles of hydrodynamic over the plane, which is not the plane of shear.

The important syndrom for identification of early solifluidal movement of earths should be then a plane in outcrops, along which the watered earth is shifted by flowing and which could also demonstrate the more or less sharp boundary between the top layer of freezed substrate and the lowest layer of watered earth (comp. Fig. 1). Krejčí

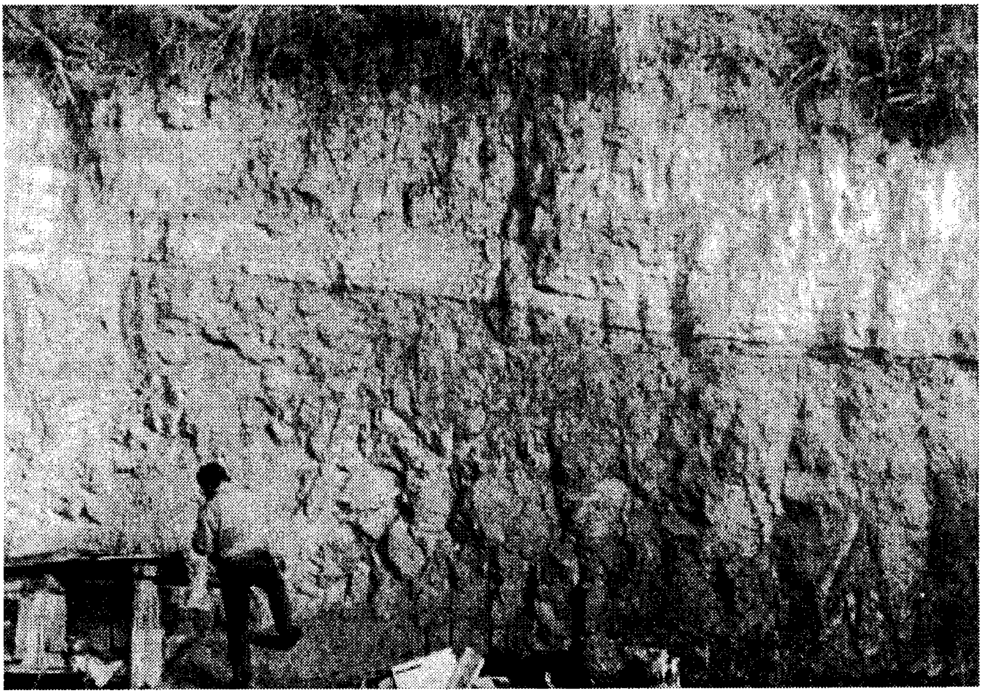

Fig. 1. Outcrop in solifluction-sediment and superposed loess in Rozdrojovice near Brno-town. In footwall of the solifluidal, distinctly laminated sediments (when the thickness of lamina increases downslope) the gently wheatered granodiorite of Brno-massif occurs, which is detached from solifluction sediments by expressive shear plane. In roof of solifluction sediments that are the mixture of granodiorite regolith with loess material, there lies a cover of the typical loess. Photo J. Karásek, February 1992

(1960) did not consider this plane as a shear one because he used the term "shear plane" in strict sense for a plane that is not predisposed by structural attitudes. He designate this plane as a "connection" or "contact" one. Because in run of solifluction there is, however, a shear movement over the contact plane, I will consider this plane as "shear" sensu lato in accordance with American structure-geological handbooks (e.g. Willis-Willis, 1934, p. 29 a.f.). As the deformations designated in Czech as "smyk" and "střih" cannot be terminologically distinguished, it is the only English term "shear" that is used in this connection.

The deformation-manifestation of the movement of watered earth over the shear plane should be in final effect the rise of the horizontal surface in the accumulation zone of solifluction, i.e. near the slope-foot. In Fig. 2, taken in the same site as Fig. 1, we can see that the boundary between solifluidal accumulation and the overlying loess builds a subhorizontally orientated relict of chernosem whose surface intersects with a projection of shear plane in the plane of outcrop at angle of about 6°. From morfological manifestation of deformation we can judge in this case about mechanism of solifluidal movement - flowing - according to rheological model of Newtonian body (liquid).

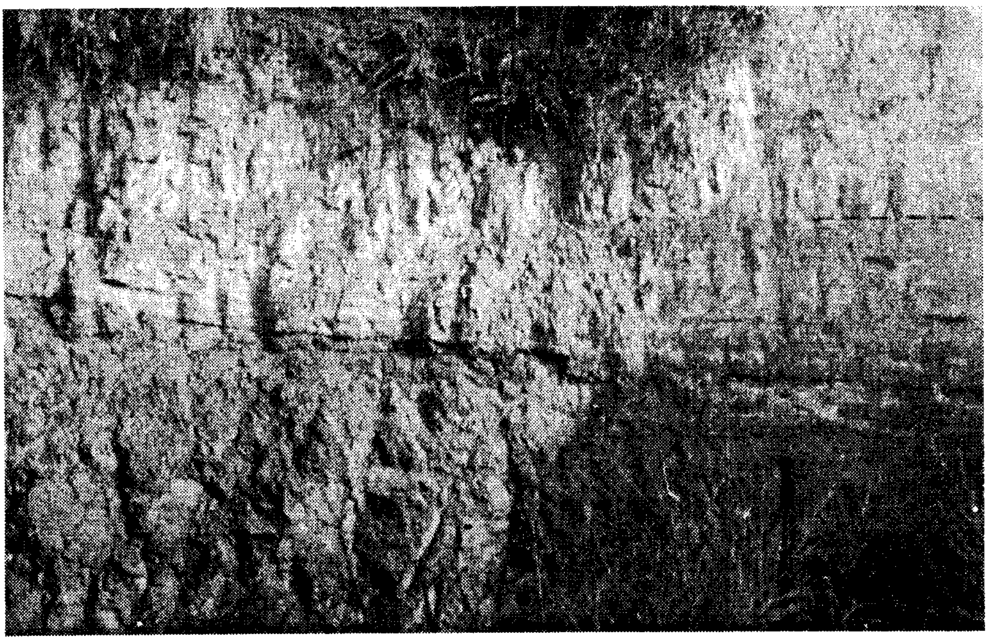

Fig. 2. See Fig. 1, topographically lower part of outcrop. The stratigraphical boundary between solifluction sedimets and loess cover form the relict chernosem, emphasized by dashing. Photo J. Karásek, February 1992

In literature, the so called "downslope bending of strata" (e.g. Záruba, Mencl, 1957, p. 194) is also often regarded as a consequence of solifluction. The considerations of this kind go even so far that exhumate downslope bending of strata in dells is considered as a proof of cryogenic origin of the dells (Demek in Demek, Novák et al., 1992, p. 194). By the term "downslope bending of strata" we understand an atectonic bending deformation of strata-edges intersected with plane of the slope (Fig. 3). Mechanically, it is mostly explained as a consequence of gravitational shift of waste downslope when intensity of shift gradually decreases with the increased depth in consequence of stronger friction. Regarding the present-day experience (Záruba, Mencl, 1987, p. 78) these shifts only reach to the depth where changes of temperature and moisture caused by changes of weather during the year can penetrate. It essentially means that the gravitational shift of waste is only possible to the depth where the earth can, in consequence of weather changes, at least occasionally, get over the moisture at the plasticity limit, but not necessarilly at the liquid limit that is a condition of solifluidal movement.

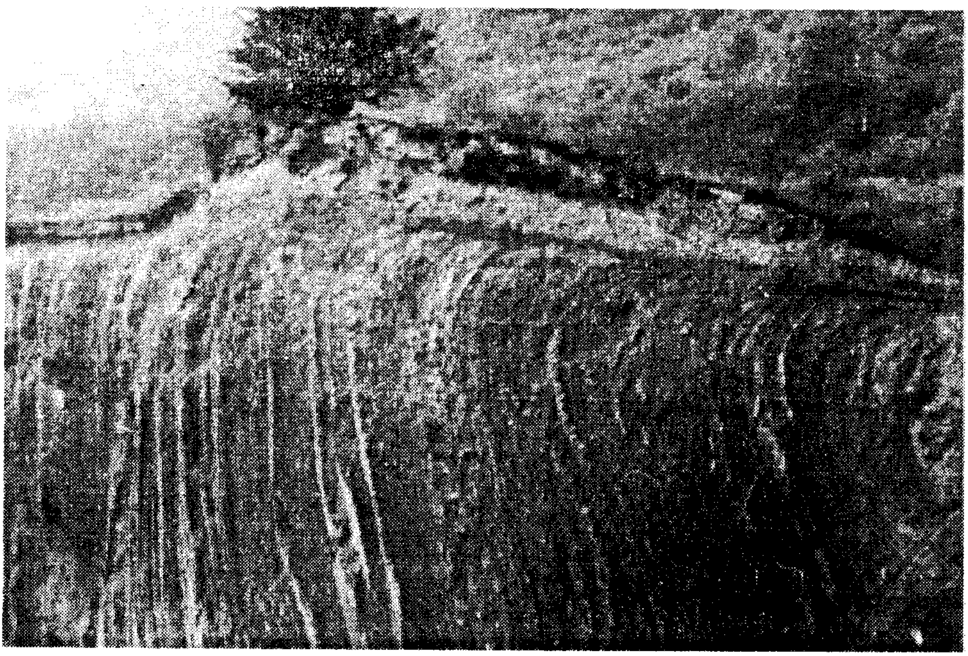

Fig. 3. Downslope bending of strata of Daleje-slates and Třebotov limestones in outcrop Praha-Hlubočepy (stratigraphy by Chlupáč, 1985, p. 138). Photo J. Karásek, July 1984

This could result in the fact for slope-movement causing the "downslope bending of strata" would be applied the rheological model of Maxwell body, at the deformation of which there occur largely the plastic strain and only partially the shift over shear planes. In the plastic strained part of strata formation there is no expressive change of strata thickness, which is evident from Fig. 3. The exception is only the upper layer of waste in which the primary thickness of strata is rather suddenly, but continuosly reduced, approximativelly to zero values. The reduction of strata thickness as a consequence of the tensile stress is called "drag" (e.g. Willis, Willis, 1934, p. 494). It is known that downslope bending of strata is often accompanied by drag phenomenon in the upper layer of waste. Possible explanation of this phenomenon is a follows: From unweathered beds toward topographical surface, i.e. to slope plane, the grain-size composition of waste changes in sense that there is a continuous increase of the portion of finer fractions and decrease of the portions of coarser ones. In the same direction the angle of internal friction brings down, however, and simultaneously the cohesion and potential capacity of water necessary to reach Atterberg limits (both plasticity and liquid limits) increased. As the source of moisture to reach Atterberg limits in weathered mass is both the seepage water from rainfall and the water capillarilly rising to the surface during the seasonal freezing of earth, then logically there be may at first the supersaturation of earth from water over the liquid limit in places immediately below the slope-plane, i.e. in vertical scope of drag-phenomena. In deeper layers then there occur only occasional supersaturation of earth over plasticity limit. In consequence this interpretation means that the zone of plastic strain of weathered rocks passes toward the slope surface without a sharp boundary in the zone of liquid strain. For the judgement of slope-stability one can conclude these facts that modelation of slope is in progress in condition of dynamical equilibrium and that occasional liquid movement in drag-zone can be hampered even by the roof-system of herbs of vegetation cover.

The downslope bending of strata (or of foliation) can be considered as strain consequence of solifluction only in the case when the bending is accompanied by drag and the solifluction has only appeared in vertical extent of drag phenomena. There are even some cases that the solifluidal conditioned drag came about without the plastical strain of "bending" at the gentle slopes (Fig. 4). This phenomenon act a rule in very fine and that means highly plastical wastes on slopes with very gentle dip. In this case then the rheological model of Bingham body can be applied to the mechanism of solifluction.

An unanswered question remains whether the existence of slip or shear plane (respectively) is the necessary condition of solifluidal movements of masses. Regarding Fig. 4 one could judge that the continuity of strata is not broken by shear even in the zone of drag. Despite of this, however, one can find the warnings in geotechnical letters that "...on the surface of draged, wheatered rocks, the shear planes have been formed on which manifests itself the tendency to landslide" (Záruba, Mencl, 1987, p. 80). The possible explanation of this contradiction can be seen in the conclusion of mechanical analysis of drag: "Masive, rigid rocks do not show effects of drag, since when stressed beyond elastic limit, they yield by shearing instead of by plastic distortion or bending" (Willis, Willis, 1934, p. 494).

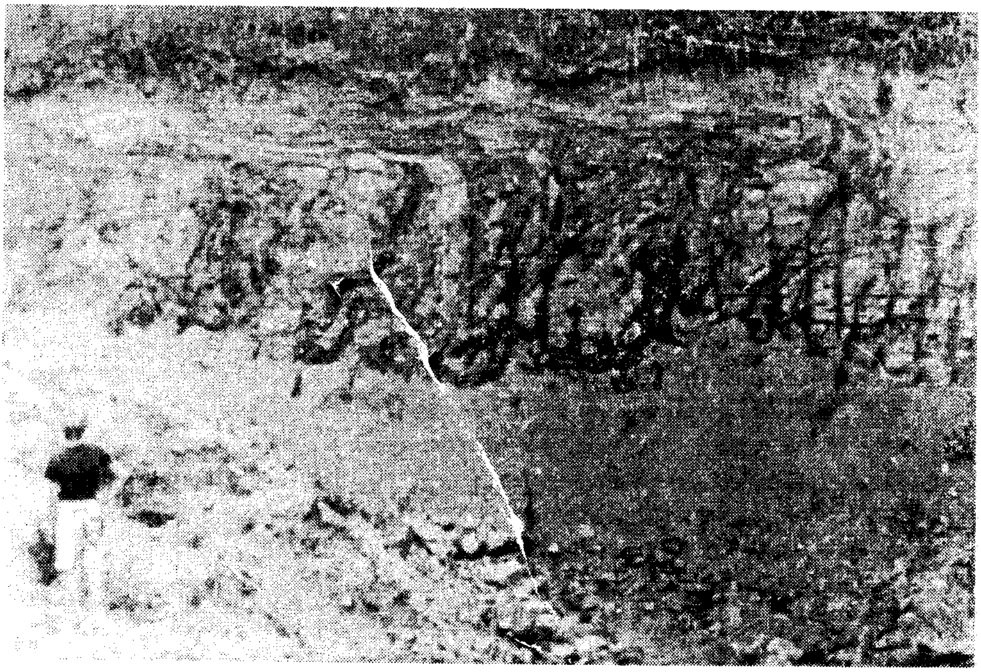

Fig. 4. By drag strained waste of migmatites in the Žďárské vrchy (hills). Blatiny near Mílovy. Photo A. Hynek, August 1990

If the shear planes rise during the drag, the strained earth can be designated as a plastic one with remnant elasticity to which the rheological model of Maxwell body could be applied. Regarding the solifluction and its rheological mechanism then the sequence of Figs. 1-2, 3 and 4 could ilustrate the ideal succesion from fluidal movement on distinctly developed shear plane (Figs. 1-2) over combination of drag with shear (Fig. 3) to fluidal movement by drag (Fig. 4), or in sense of rheological models from Newtonian over Maxwell to Bingham bodies.

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NOTE:

From great number of documented outcrops there are three most typical cases ilustrated, which features are near to the ideal rheological models.