On Deformation of Lava During Formation of Salt Domes

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The authors have observed different types of deformation of lava caused by the flowage of salt into domes. The observations were made on a short stretch of the canyon of the Hrazdan River in Yerevan, Armenia.

GEOLOGIC DEVELOPMENT OF THE AREA

The geologic history of the area may briefly be outlined in the following manner: A series of big domal uplifts were formed in the region at the beginning of the Late Pliocene; they were separated by rim synclines. Several small asymmetric salt domes have grown on the periphery of one of the uplifts. The dips of strata overlying these secondary small domes are low towards the central uplift, whereas the strata dip steeply towards the rim synclines. The estimated height of one of these domes was 90 metres.

In Late Pliocene time intensive volcanic activity started in the Gegham Range to the northeast. It was accompanied by strong earthquakes and effusion of lava through fissures. The earthquakes have caused large scale rotational landslides on the steep external slopes of the domes; shortly after, these landslides were engulfed by lava flows. The lava through rapid burial of the slide bodies preserved the landslide forms (Ter-Stepanian and Arakelian, 1966).

Clay flowage took place underneath the liquid lava; clayey soil flowing from the rim synclines towards the domes. The result was the formation of depressions on the surface of Tertiary lava above the rim synclines.

Several subsequent effusions of Quaternary lava have alternated with long periods of rest, this occurring after the Hrazdan River had cut its canyon.

Further uprising of the strata covering the salt domes and sinking of rim synclines has occurred in Late Pliocene and Quaternary time due to continuous salt tectonics. The latter have caused the deformation of solidified lava described below.

The lava is of the andesite-basalt type. The rocks are very hard and dense; they are highly resistant to weathering and their original appearance remains nearly unchanged. Nevertheless, in the massif they behave as a very flexible and pliable material. This is well illustrated schematically by the geologic map (Fig. 1a), cross section (Fig. 1b) and longitudinal section (Fig. 2b).

Three secondary salt domes are shown on the geologic map as traces of the intersection of the top of the Middle Sarmatian gypsiferous clays with a plane constructed at river level.

EVIDENCE OF DEFORMATION

The cross section AB (Fig. 1b) shows the deformation of lava caused by salt flowage upward in the dome (left part of the drawing) and by the sinking of clayey soils over the rim synclines (right part of the drawing). The lava is fissured everywhere; however, above the dome the fissures are open whereas over the rim syncline they are partly closed. The appearance of the lava is very peculiar in the contact zone between the segments displaced in opposite directions, i.e., in the middle part of the cross section. Here the lava is crushed and cut by numerous fissures; many slickensides are observed. The change in degree of fissuring is also illustrated by the graph showing the relationship between the coefficient of permeability of the

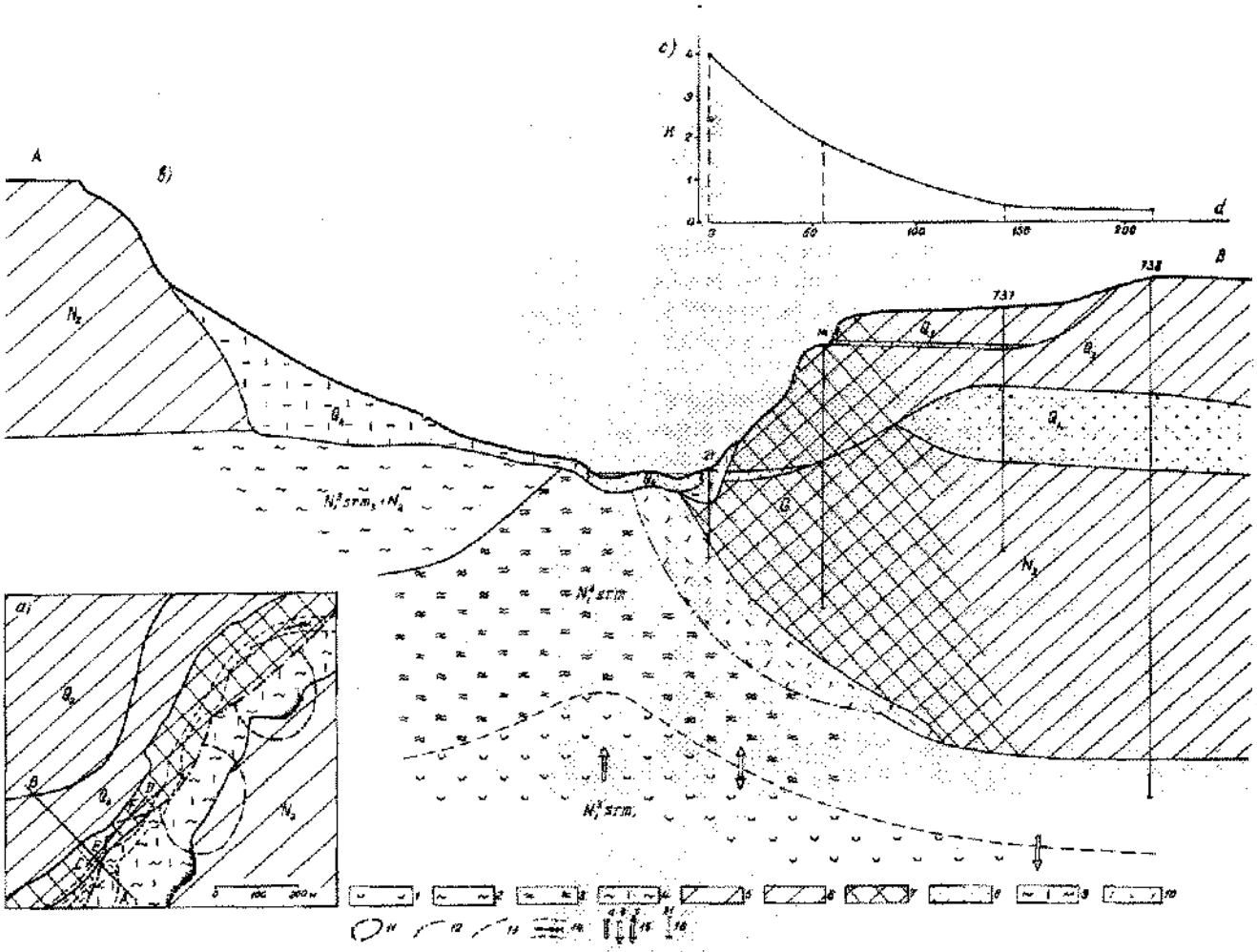

Figure 1. (a) Schematic geologic map of an area along the Hrazdan River. (b) Schematic geologic section AB across the canyon of the Hrazdan River. (c) Relationship between the coefficient of permeability (k) in metres per day and the distance (d) in metres from borehole No. 21 measured in a direction towards borehole No. 738.
1-Saltiferous clays (N_1^3 srm.). 2-Clayey-gypsiferous layer (N_1^3 srm_2). 3-Sandy-clayey stratified layer (N_1^3 srm_3+N_2). 4-Sedimentary rocks. 5-Andesitic-basaltic lava (N_2) over domes with open fissures. 6-Andesitic-basaltic lava (N_2, Q_2 and Q_3) in rim synclines with partly closed fissures. 7-Andesitic-basaltic lava (N_2 and Q_2) in the contact zone G; crushed, and with numerous fissures and slickensides. 8-Fluvio-lacustrine deposits (Q_1, Q_3 and Q_4). 9-Talus deposits (Q_4). 10-Body of the Late Pliocene fossil landslide. 11-Line of intersection of the top of Middle Sarmatian gypsiferous clays over the salt dome with a plane constructed at river level. 12-Line of intersection of the sliding surface of the Late Plioce landslide with a plane at the river level. 13-Upper limit of saltiferous layer. 14-The Hrazdan River. 15-Direction of displacement: (a) uprising, (b) sinking, (c) contact zone between lots of uprising and sinking. 16-Borehole and its number.

lava and the distance from the contact zone in a direction towards the rim syncline (Fig. 1c). Here the coefficient of permeability uniformly drops over a distance of 220 metres from 4.02 to 0.24 metres a day.

ENGINEERING CONSIDERATIONS

The relationship between the fissuring of lava and displacement may be seen on the longitudinal section CD (Fig. 2b). The profile cuts an inter-landslide ridge and the lateral parts of the adjoining landslides which are buried under the lava. The degree of fissuring controls the quantity (ordinate, Fig. 2a) of the dry cement used for the preparation of mortar for the construction of an impervious curtain. This quantity (q) reaches its maximum at points E and F at the junctions of the landslide blocks and the inter-landslide ridge.

Consideration of the extent of lava fissuring in areas affected by salt tectonics may be advantageous in the solution of such problems as prediction of seepage losses from reservoirs or layout of impervious curtains, tunnels, or large underground openings.

REFERENCES

Ter-Stepanian, G. and Arakelian, A., 1966, A case of deformation of lavas spread over Upper-Pliocene landslide, *in* Proceedings, First Congress, International Society for Rock Mechanics, Lisbon, 1966: v. 1, p. 647-649.

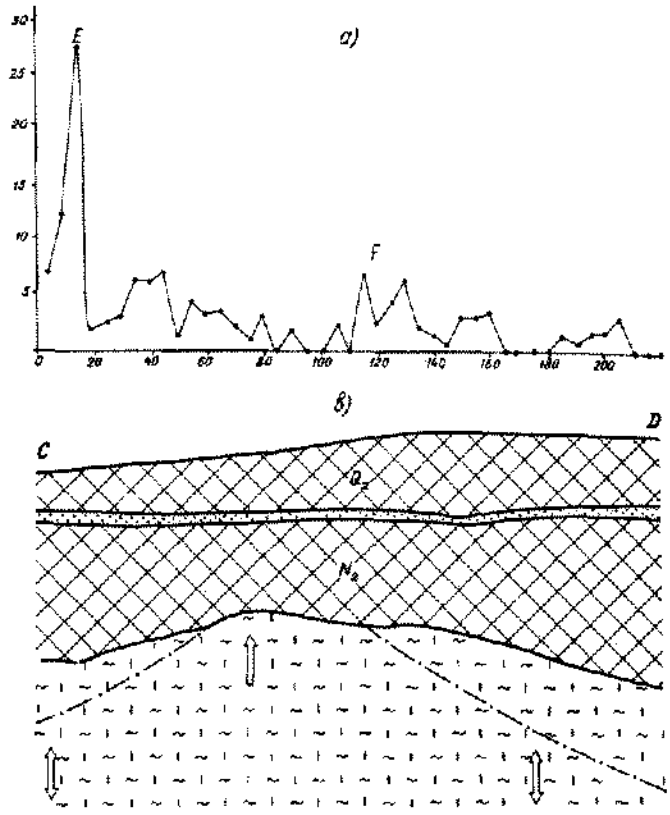

Figure 2. (a) Graph showing the quantity of injection (q) of dry cement (in kilograms per square metre) in the curtain. (b) Schematic longitudinal section CD along the canyon of the Hrazdan River. For symbols see Figure 1.