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ORIGINAL PAPER

''Noah's Ark'': its relationship to the Telçeker earthflow, Mount Ararat, Eastern Turkey

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Abstract The southern slopes of Mount Ararat are formed of an interbedded sequence of limestones and mudrocks in which a 1,000 m deep valley has been eroded. During the glacial/periglacial climates of the past, mass movements took place in this mountainous area, resulting in a debris mantle on the slopes and a blocky colluvium in the valley floor. The 150 m × 50 m × 4 m high ship-like feature, sometimes referred to as ''Noah's Ark'', is considered to be a large discontinuity-bounded block of Miocene limestone which has slumped and crept downslope on the weak Eocene clays. The shape of the feature has been modified by abrasion caused by passing earthflow material as well as ice melt and limestone dissolution processes.

Keywords Noah's Ark · Mount Ararat · Earthflow · Slump · Creep · Axial displacement

Résumé Les pentes sud du Mont Ararat sont constituées d'une série de calcaires et d'argilites au sein de laquelle une vallée de 1,000 m de profondeur a été creusée. Sous les climats glaciaires et périglaciaires, des mouvements de versant ont affecté cette région montagneuse. Ils ont eu pour conséquence la formation de nappes d'éboulis sur les versants et l'accumulation de colluvions caillouteuses en fond de vallée. La forme à l'allure de bateau, de dimension 150 m × 50 m × 4 m, parfois nommée « Arche de Noé », est identifiée comme étant une masse de calcaire miocène, délimitée par des fractures, ayant glissé sur des argiles molles éocènes. Par la suite, cette masse glissée a été façonnée par le passage de coulées boueuses ainsi que par les eaux de fonte de glaciers et les processus de dissolution affectant les calcaires.

Mots clés Arche de Noé · Coulée boueuse · Glissement · Fluage · Déplacement axial

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Introduction

A study has been made of an area near the Turkey–Iran border, some 3 km south west of the Turco-Iranian highway (Fig. 1) as this area contains the remnants of some very large earthflows and an unusual geomorphological feature resembling a ship. It has recently been suggested that this is the Noah's Ark referred to in biblical stories.

The first significant research around Mount Ararat was carried out by Blumental (1959) and interest was further aroused after the publication of an aerial photograph in Life Magazine in (1959). Yılmaz Güner (1986) reported a detailed study concentrating specifically on the ship-like feature. He concluded that it was a residual hill of ophiolitic bedrock in the floor of the valley, which had been carved into its present shape by the slope-disturbed deposits. There are two main difficulties with Güner's hypothesis. Firstly, the feature is formed in a valley more than 1,000 m deep with no topographic anomalies, hence it would be surprising if such a hill survived despite the deep down-cutting in a well-stratified rock formation. Secondly, a close examination of the field and aerial photograph evidence indicates that the ship-like feature is on top of the very extensive disturbed material which forms the Telçeker earthflow.

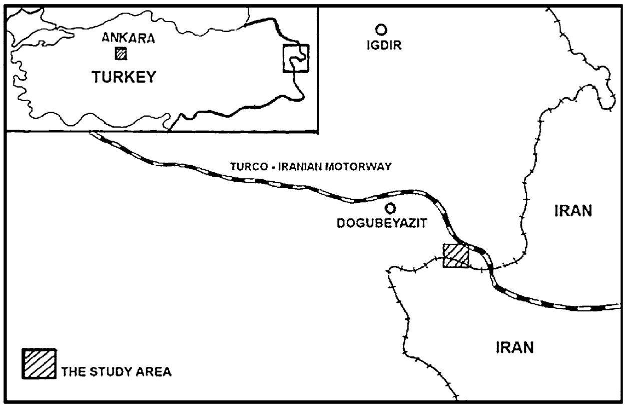

Fig. 1 Location map of the study area

Geological setting

There are three main stratigraphic formations in the area of the Telçeker earthflow. The oldest unit is the Upper Cretaceous ophiolite, which outcrops in and around the valley floor. The ophiolites are highly altered serpentinite, purplish reddish limestones and conglomeratic sandstones. This unit, having a high clay content, creates an aquitard such that water flowing through the overlying valley colluvium is restricted in its downward percolation, resulting in the upper surface of the ophiolites being a saturated zone of low shear strength.

Above the ophiolites is an interbedded sequence of Eocene age, consisting of greenish grey marl, sandstone, claystone and impure limestones. The harder horizons within the sequence vary in thickness up to 0.5 m and are easily removed as they are heavily fractured.

The youngest rock unit is a 4–5 m thick fossiliferous Miocene limestone overlying the low shear strength, soft, Eocene deposits. These Miocene strata are almost horizontal and are typically separated into large joint-bounded blocks. As a consequence, when occasional storms occurred and/or water was released from ice in the past, it would percolate through the joints to the soft Eocene clay such that large limestone blocks were able to move downslope by slumping/sliding. Limestone is the main component within the 5–10 m of colluvial cover in the valley floor, with the ship-like feature forming the largest of the blocks.

In the Quaternary, much of the area was covered by snow and glaciers as evidenced by the presence of glacial lakes and moraines. In the lithologies present in this area, repeated freeze-thaw cycles as well as seasonal percolation of ground water would be likely to induce the joint-bounded rock masses to move downslope on the saturated Eocene sediments.

Erosional processes and formation of Noah's Ark feature

Material disturbed by natural wastage and by instability of the valley sides would be constricted in its movement down-valley by the topography of the ophiolitic formations. As a consequence, not only was the rate of incision reduced but also topographic features caused accumulation of the earthflow material such that there is now a colluvial spread, in places up to many meters thick.

There are many areas in the world where competent rock overlying weak rock results in joint-bounded blocks of competent rock becoming detached from the valley sides and moving over low shear strength sediments by a process of slump/creep. It is considered that such a mechanism accounts for the presence of many of the large blocks in the valley and in particular the large ship-like feature measuring some 150 m × 50 m × 4 m.

Although there is indirect evidence that the large block of which the ship-like feature is formed was detached from the limestone around the crest of the valley some 1,000 m above, it is difficult to determine the full lithology within the feature in the field without significant excavation. Enigün (1988) carried out some geophysical investigations, which unfortunately did not yield significant information. Whilst drilling at several strategic points would allow a closer examination of the interior structure, in this location it would be both difficult and expensive.

The vast area of disturbed material known as the Telçeker earthflow did not originate as a single mass movement but resulted from several tributary flows coalescing in the upper area of the valley. Such disturbances probably occurred at a similar time, related to either heavy rainfall or water released by melting snow, in both cases exacerbated by seismic events.

Close study of the aerial photographs shows the great Telçeker earthflow took place in two stages, one probably following the other quite quickly with the stress release created by the first movement triggering the second disturbance. Both flows followed a similar direction, turning 90° where the valley passed across the Dogu Beyazit fault line. Although the surface characteristics of the two flow stages are similar, they are distinguishable by a slight difference in earthflow direction and surface texture. The boundary between the two flows is at point S in Fig. 2; the ship-like feature being within the earlier of the two.

The above explanation of a large rock progressively slumping down-valley is consistent with other disturbances which can be seen in the area. For example, a block which has experienced incomplete slumping can be observed at point PS in Fig. 2. This clearly developed before and was

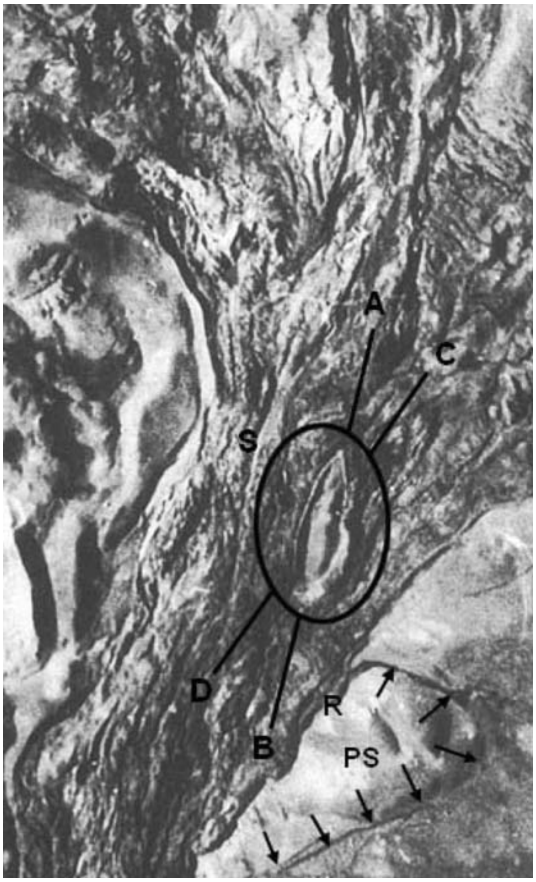

Fig. 2 Aerial photograph of the great earthflow (Noah's Ark highlighted)

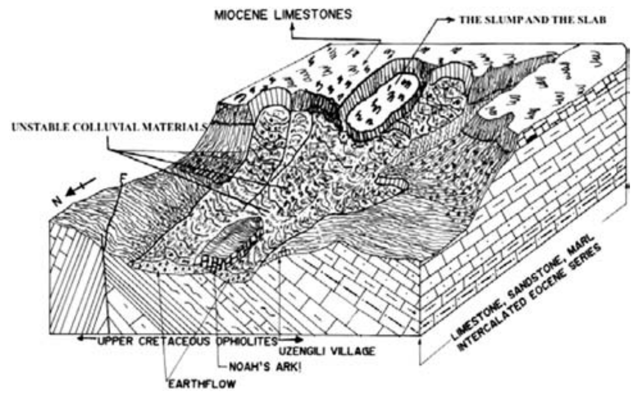

Fig. 3 Geology and geomorphological evolution of the site (not to scale)

Fig. 4 Ground photograph of part of the earthflow and the feature

independent of the Telçeker earthflow, which probably blocked the natural outward progression of the block into the valley. The block (PS) has little topographic expression today.

It is considered that the main ship-like feature was originally a large block which moved into the area by slumping/creeping, probably over a long period of time. This is shown schematically in Fig. 3 where an indication is given that a block moving from the limestone scarp at 2,500 m asl would need to move some 2.5 km in order to come to rest at an elevation of some 1,900 m asl. Scars at the front of the feature (Fig. 4) suggest it probably abutted other blocks as it moved downslope and it may well have rotated on its axes before finally coming to rest in its present position.

As can be seen in Fig. 2, there is an axial displacement of some 20° between the present axis of the ship-like feature (a, b) and the main direction of the earthflow within the valley floor (c, d). This displacement is likely to reflect the way the earthflow material moved out into the valley, pushing the lower part of the feature and causing the block to rotate. The present surface of the feature, with raised rim and higher central area, is anomalous. The hypothesis for this peculiar shape has been put forward on the basis of the likely duration and rate of ice melt and limestone dissolution in a frozen area, as shown schematically in Fig. 5. However, a full explanation awaits further study.

Conclusions

The aerial photographs and field evidence indicate there have been extensive mass movements in the area of the ship-like feature frequently referred to as Noah's Ark. At present the ''ark'' is at an elevation of 1,900 m asl while the in situ Miocene limestone of which it is formed occurs in the valley rim more than 500 m above.

Beneath the Miocene limestones are argillaceous sediments of Eocene age. These weak deposits may have experienced some interbed movement, exacerbated by water passing through the joints of the carbonate rocks, reducing the shear strength of the Eocene mudrocks/clays such that large discontinuity-bounded blocks moved from the scarp-like feature by slumping/creeping. At the time

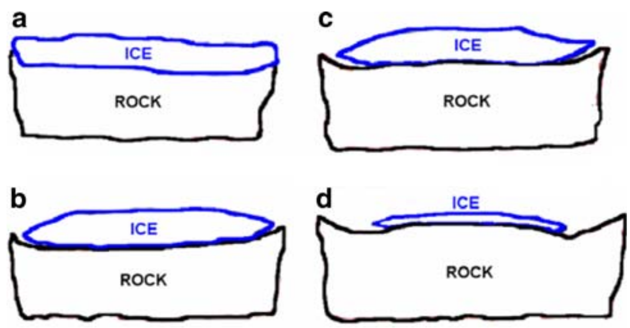

Fig. 5 The cross sections showing the final sculpturing stages of the feature

this process took place the area still had a periglacial climate.

Whilst many of the disturbed blocks broke up during transit from their original position, a particularly large mass remained intact. Having slumped downhill over many hundreds if not thousands of years, it is considered that this large block would have been progressively abraded at the front. A number of earthflows are likely to have occurred; the rock masses within these flows would have caused further abrasion, particularly along the sides of the feature, creating the shape it is today.

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