Engineering geological investigation of Akha landslide, Iran

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Abstract: Landslide site investigation costs may be very high since landslides may be extremely large, structurally complex, and topographically severe. Engineering geological investigation of landslides can reduce subsurface investigation and result in savings of time and budget.

In this research an engineering geological investigation of the Akha landslide, Central Alborz, is presented. The work includes aerial photographic interpretation, field investigation and geophysical measurements.

With an approximate understanding of the overall topographic extent of the slide, a detailed field investigation was conducted to delineate the aerial extent and a general direction of movement of the landslide zone, assess the geology and geologic structure, estimate the causes of the sliding, and predict future movement. All surface deformations, was recorded to define the boundaries of the landslide, size, direction of the movements, and optimal locations for geophysical investigations.

A combination of electrical sounding and seismic refraction measurements were conducted with the principal aim being to provide additional information about the geological framework and mechanism of the active slide.

The results indicate that Akha area includes several small unstable blocks inside a main block. The landslide is mostly composed of the eroded sediment of Shemshak formation and river sediment as well. The active block is a rotational slide with intermediate depth. The results of field investigations are presented as several engineering geological maps and cross-sections which clarify the geometry and subsurface characteristics of the slide.

Résumé: L'investigation in situe des glissements de terrain dépendamment à leurs dimensions, topographies et structures peut être très coûteux. Dans ces cas, les études géologiques de l'ingénieur vas jouer un rôle importent pour diminuer le coût d'exploration sous terrain et aussi le temps.

Dans cet article, les résultats des études géologiques de l'ingénieur de site de glissement de terrain Akha, placé au centre de la chaîne d'Alborz, est présenté. Ces études comprends trois parties : l'interprétation de photographie aérienne, l'investigation in situe et les études géophysiques.

Après avoir estimé l'extension globale de glissement de terrain, on a effectué une étude détaillée sur le chantier à fin de préciser la dimension, la direction générale de glissement, la géologie, la structure géologique, le cause de glissement et aussi la prédiction de future déplacement de la pente. Cette investigation, qui comprend un programme d'observation précise de déplacement superficielle, nous a permise à optimiser le programme d'étude géophysique.

Une combinaison des sondages électrique et séismique a été effectuée pour fin de préciser la structure géologique et le mécanisme de glissement.

Les résultats détectent que la région Akha comprend plusieurs petits blocks instables placés dans un block principal. La pente est, en fait, composée des matériaux alluviaux et de sédiments érodés venant de déformation Shamshak. Le block actif est un glissement rotatoire ayant une profondeur intermédiaire. Les résultats sont présentés sous forme de différentes cartes géologiques de l'ingénieur et sections transversales.

Keywords: engineering geology, geophysics, maps, shale

INTRODUCTION

The available methods for analyzing slope systems have been classified by Hutchinson (1983) into two principle groups: The first group combines surface movement observations, direct measurements of sub-surface displacements, and geoacoustic sensing. The second group utilizes methods such as in-situ observations in holes and characteristics of geologic materials obtained from drill cores. However, even when drilled, when the maximum core recovery is recorded and geotechnical borehole logging has been successful, drill holes represent only single-point information in a lateral dimension. In contrast, geophysical methods are generally non-invasive and give highly resolved two-dimensionally distributed data (Mauritsch et al 2000).

On the other hand, conventional methods of stability assessment however are often restricted by the difficulty and expense of drilling in broken and possibly waterlogged ground. Drilling into the broken ground of a landslide is impeded by water loss, the movement of blocks causing bits and drill rods to jam, the difficulty of recovering core in disturbed materials, and the possibility of slip reactivation due to the injection of drilling fluid into a shear zone.

The feasibility of geophysical methods to resolve details of sliding masses, such as groundwater regime, the internal composition of sliding mass, geometry of the slide, and depth to bedrock, has been studied by Bogoslovsky et al. (1977), Muller (1977), Campagnoli and Santarato (1995), Mauritsch et al. (2000), and Lapenna et al. (2003).

Geophysical methods do not replace borings and sampling of test pits and trenches. Rather, they supplement these procedures and greatly reduce time and cost and environmental problems that often result from large-scale drilling operations. On the other hand, detailed engineering geological investigation can clarify many unknown aspects of a slide that helps to interpret the results of geophysical surveys.

In this research a combined engineering geological investigation and geophysical sounding has been used to investigate the Akha landslide.

STUDY AREA

The study area lies between the 52° 13″ to 52° 20″ E and the 35° 54″ to 35° 59″ N. The landslide area is located in northeast of Tehran city and is 90 km from Tehran. It is along the main Tehran to Amol (Haraz) road to the southeast of the Damavand Mountains. Most of the area is covered with high mountains. Several villages are distributed in the area. The lowest point in the area is 1300 meters above average sea level located in the northeast of Shangladeh and the highest elevation, 3280 meters above average sea level is located at Amiry Mountain.

GEOLOGICAL SETTING

The study area is located on the southern slopes of the eastern part of central Alborz. The Alborz mountain system in northern Iran, extending in a sinuous manner for about 2000 km from Lesser Caucasus of Armenia and Azarbaijan Republics of the former Soviet Union in the northwest to the Paropamisus mountains of northern Afghanistan to the east, forms a composite polyorogenic belt, (Alavi, 1995). Among the geological formations in the central Alborz, the following strata outcrop in the study area:

Jurassic	Shemshak (shale and sandstone, and coal bedding), Dalichai (bedded limestone, marly limestone), and Lar (massive to bedded limestone) Formations outcrop in the area.
Cretaceous	Gypsum and Melaphyre units and the Tizkuh Formation (Orbitolina limestone) are the main lithological units in the Lower Cretaceous. Biogenic and cherty limestones form the main units in the Upper Cretaceous.
Palaeogene	The Palaeogene units are made of polygenetic conglomerates (Fajan Formation, Nummulitic limestone, Ziarat Formation), and green tuffs and lava flows (Karaj Formation).
Quaternary	Alluvial terraces and scree form the Quaternary deposits in the area.

Figure 1 illustrates the geological map of the study area. Many active faults are observed in this region. These faults change the natural formation of the folding resulting in the present shape. Average annual precipitation varies from 347.1 mm to 720.9 mm.

ENGINEERING GEOLOGICAL INVESTIGATION

Aerial photographic interpretation of the area was performed using 1:20000 aerial photos of the site and its vicinity. Detailed on-site mapping and geophysical measurements were undertaken to define major features of the slide such as composition, extent, and slide surface characteristics. During this stage, optimal locations for the geophysical investigations were determined.

Investigation of Surface Deformation

The investigation of surface deformation was conducted to clarify the geological characteristics of the landslide area and define major slide features, such as scarps, cracks, bulges, areas of disturbed topography, the boundaries of the landslide, size, and direction of movement, and to determine individual moving blocks of the main slide. All of the landslide features were recorded on the topography map (scale 1:500) of the landslide area.

Geoelectrical Resistivity

The electrical resistivity method is described in considerable detail in the literature (Keller and Frischleneeht, 1966, Telford et al., 1976, and Parasnis, 1980). The geophysical methods commonly used in site investigations are equally applicable for the study of landslides. These methods can provide valuable information regarding slip surface depth, groundwater regime, types of materials, and depth to bedrock.

A geoelectrical resistivity sounding survey was conducted, with the principle aim to provide information about the geometry of the slide. In this study the Schlumberger and dipole-dipole configurations were utilized. The location of the geo-electrical profiles for the Schlumberger configuration is presented in Figure 5. The survey was undertaken on a 50×50 m network (survey length 400 m and width 300 m) and AB/2=150 m. A total of 40 geoelectrical soundings were performed, with 3 dipole-dipole configurations utilized.

RESULTS AND DISCUSSION

The Akha landslide is located in the Amiri landslide zone. In this landslide zone several villages are located on the colluvial materials formed from erosion of the Shemshak Formation. The Akha landslide is characterised by many cracks, subsidence, and uplifting of the ground. Evidence of the slide can be observed in the area as cracks on the garden walls and residential buildings, displacement in the road, and inclination of power transmitting lines, (Figures 2, 3, and 4).

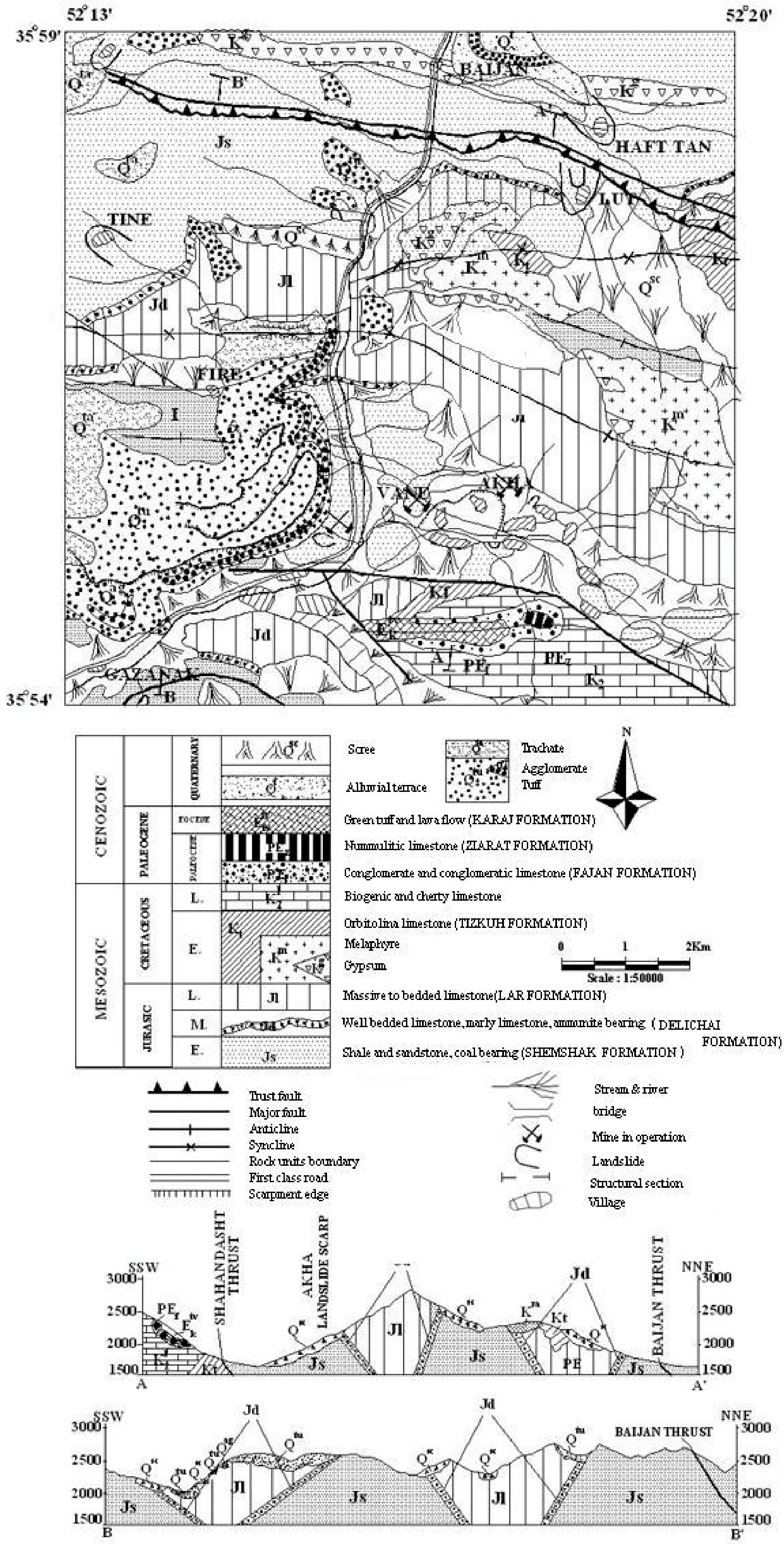

Figure 1. Geological and geomorphological maps of the study area

The result of on-site survey is presented in Figure 6 to 10. According to the proposed characterization of landslides by Varnes (1978) four individual blocks can be distinguished. The main block is about 935 m in width and 800 m in length covers an area of about 1 km^2. From a geological point of view the landslide area is composed of Shemshak Formation and colluvial materials resulted from erosion of this formation. The Akha landslide is also composed of colluvial materials, which build a heterogeneous body with rocks of different size, while its sliding surface (zone) develops along the contact plane of colluvium and bedrock. In several locations of the slope, due to the morphological conditions, the Shemshak Formation outcrops at the surface. The investigations show that lithological features of the Shemshak Formation control the stability of the slide. Rapid weathering of shaley layers exposed on the slopes, and consequent development of a colluvium layer, is the most important factor that controls the stability of slopes in the area. Due to the slow movement of the slide, it can be concluded that the slide encounters the weathered part of the Shemshak Formation. Site investigation also indicates that the slide can be considered as a shallow slide.

Figure 2. Surface displacement in access road

Figure 3. Bulging at the toe of the Akha landslide

Figure 4. Inclination in power transmitting line at the toe of the slide

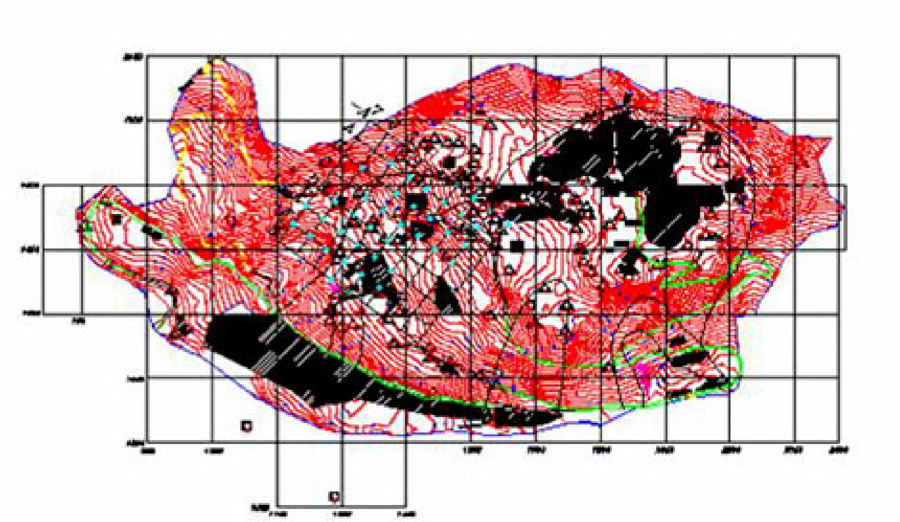

Figure 5. Location of geoelectrical prospecting network in the Akha landslide

The location of the geoelectrical network on the landslide body is presented in Figure 5. To find out about the characteristics of the slide several transverse and longitudinal cross sections were prepared. Figure 6 illustrates the results of these geoelectrical soundings as fence diagrams.

While there is some local inhomogeneity, in general, all of the soundings show three resistivity extents. Figures 7 and 8 present two transverse sections. In both cases three different resistivity states can be observed. In the surface part of the profiles a local change in resistivity is observed. This resistivity implies surface dry soils and colluvial materials. These materials in a dry state presents high resistivity values and in local cases due to water bearing strata lower resistivity values in the surface part is observed. The second resistivity layer belongs to more shale rich layers of the Shemshak Formation that are due to a high clay mineral content showing low resistivity values. The third layer indicates the sandstone layers of the Shemshak Formation with high resistivity values.

Longitudinal changes of the resistivity are shown given in Figures 9 and 10. In these profiles also shaley layer of Shemshak Formation is observed in all soundings of the profiles. In a number of soundings a low resistivity layer belonging to a shale unit is observed at the surface. This phenomenon is in a good agreement with the on-site investigation.

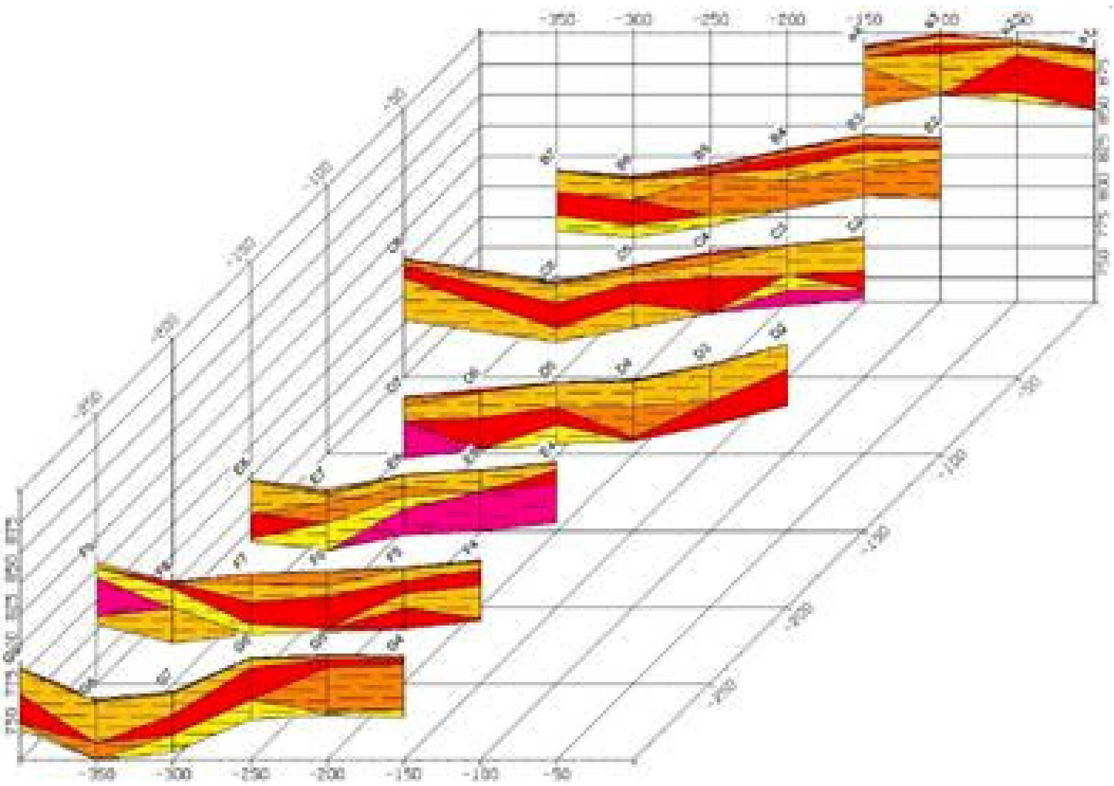

Figure 6. Transverse geoelectric cross-sections

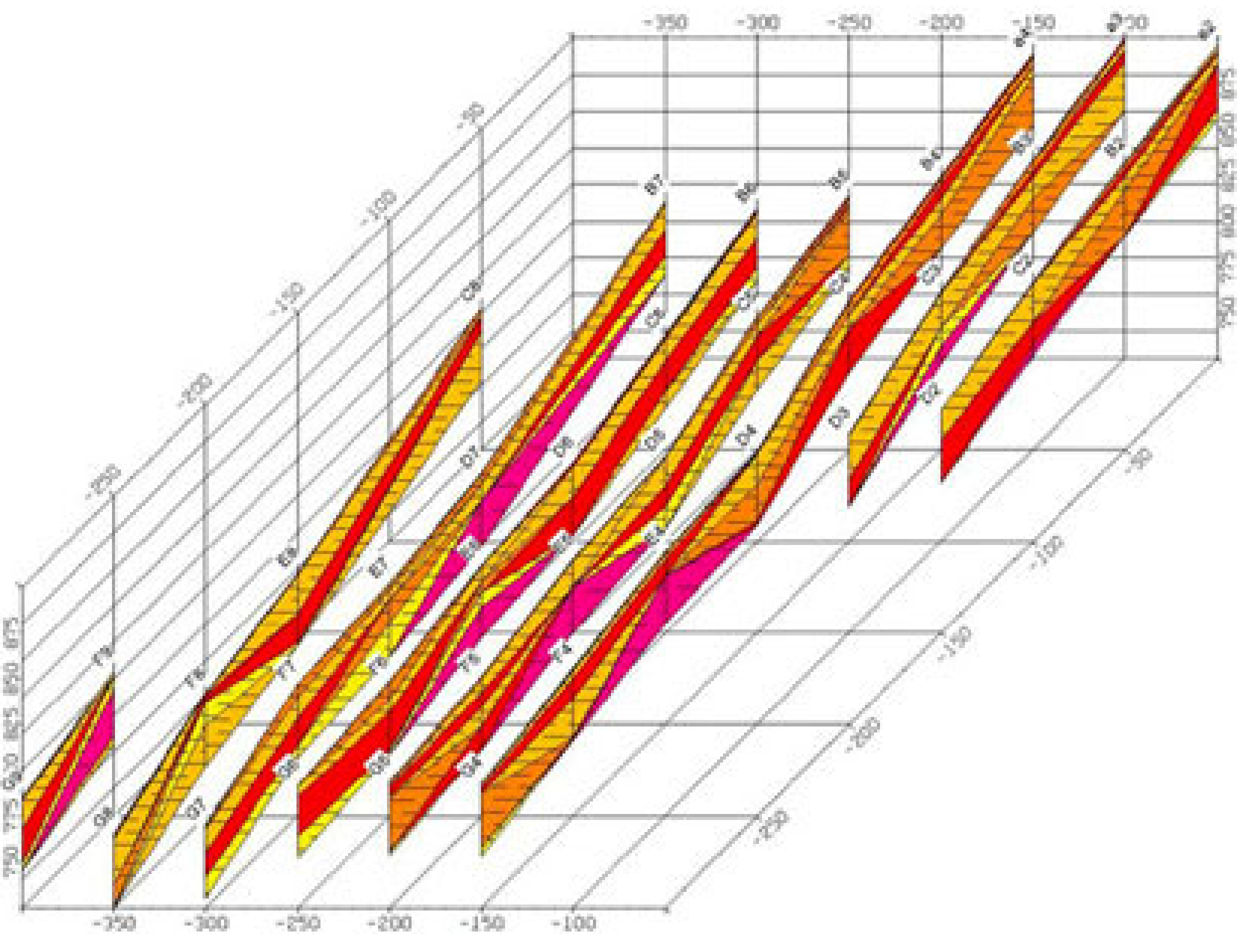

Figure 7. Longitudinal geo-electric cross-sections

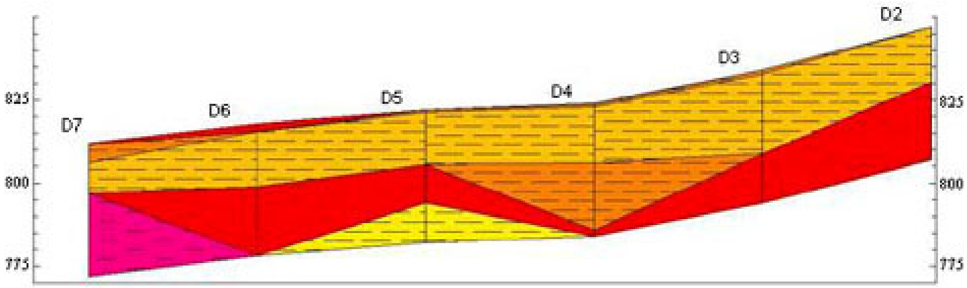

Figure 8. Transverse geoelectrical profile (D2-D7)

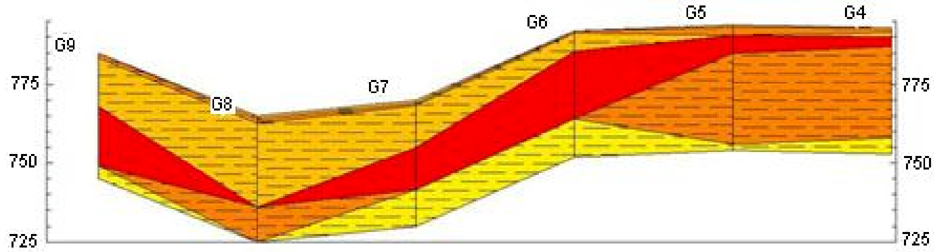

Figure 9. Transverse geoelectrical profile (G4-G9)

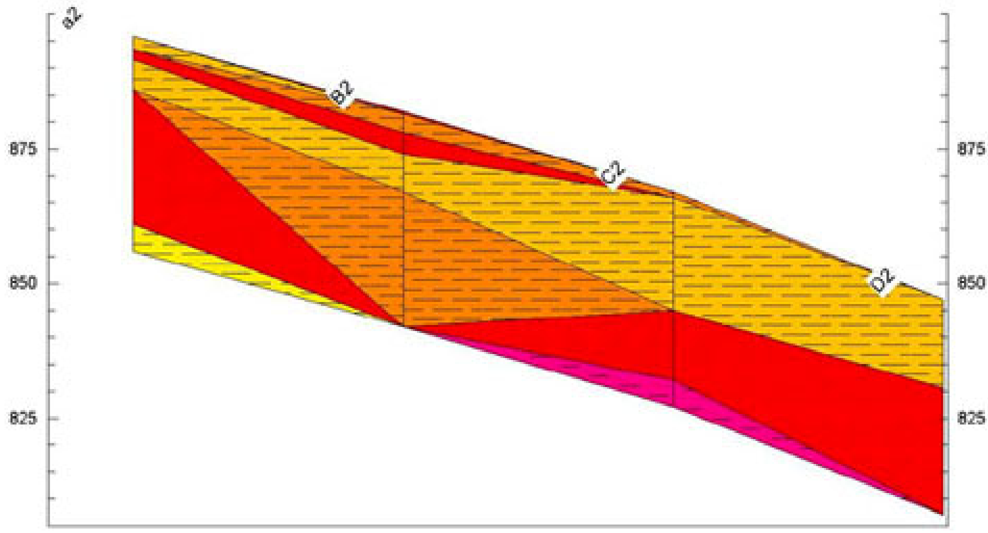

Figure 10. Transverse geoelectrical profile (A2-D2)

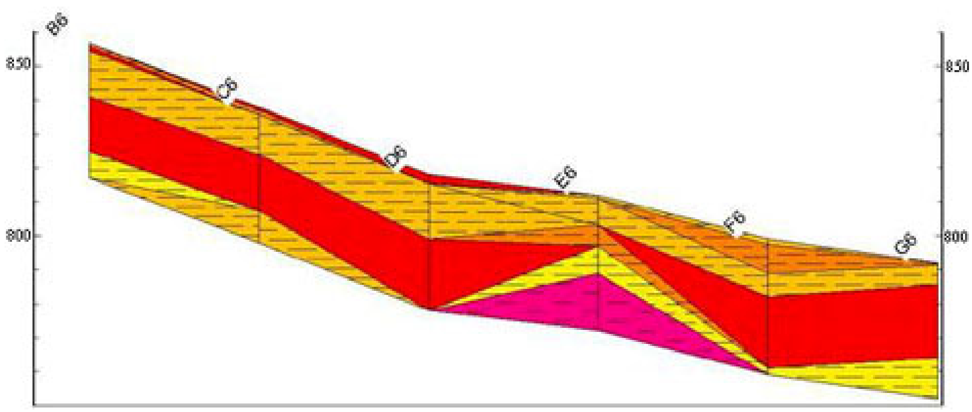

Figure 11. T transverse geoelectrical profile (B6-G6)

Two dipole-dipole configurations also confirmed the previous results.

CONCLUDING REMARKS

In this research an engineering geological investigation of the Akha landslide, Central Alborz, is presented. The work includes aerial photographic interpretation, field investigation and geophysical measurements. The results indicated that:

- The Akha landslide is composed of colluvial materials, which build a heterogeneous body with rocks of different size, while its sliding surface (zone) develops along the contact plane between the colluvium and bedrock.
- The Akha landslide sliding surface (zone) develops along the contact plane of colluvium and bed rock.
- The investigations show that the stability of the slide is controlled largely by the lithological features of the Shemshak Formation. Rapid weathering of shaley layers exposed on the slopes, and consequent development of colluvium layer, is the most important factor that control the stability of slopes in the area.
- Due to the slow movement of the slide, it can be concluded that the slide encounters the weathered part of the Shemshak Formation. Site investigation also indicates that the slide can be considered as a shallow slide.
- Geoelectrical sounding indicates that high resistivity state for surface dry soils and colluvial materials. Relatively low resistivity conditions belong to the shaley layers of the Shemshak Formation, which is as a result of high clay mineral content within this formation.

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