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Study of a landslide using 1D and 2D resistivity surveys in northern Iran-Rudbar region

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Abstract

We use high-resolution electrical resistivity imaging to delineate the geometry of the landslide and discontinuity surface between slide mass and bedrock in Roudbar region, Ghazvin-Rasht-Anzali railway (the tunnel no. 2 at Km. 108+825). The Roudbar region characterized by high geological hazard and shows a complete panorama of mass movements. In this area, different landslide types predisposed and tightly controlled by the geostructural characteristics. Geoelectrical images are produced from dipole-dipole, schlumberger and combined resistivity profiling data along arrays spanning selected profiles positioned perpendicular and parallel to the tunnel route in landslide area. Regarding the surface geology, geomorphology, integration and comparison of dipole-dipole results with other geophysical data delineated the geometry and characteristics of the landslide and geological structures.

Key words: Geoelectric, Resistivity imaging, CRP, Dipole- dipole, Landslide.

بررسی یک زمین‌لغزش با استفاده از روش‌های بررسی یک‌بُعدی و دوبُعدی مقاومت الکتریکی در ناحیه رودبار – شمال ایران

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چکیده

در این تحقیق از تصویرنگاری مقاومت ویژه الکتریکی برای بررسی هندسه زمین‌لغزش و همچنین تشخیص سطح ناپیوستگی بین توده لغزشی و سنگ‌بستر متراکم در محدوده تونل شماره ۲ (کیلومتر ۸۲۵+۱۰۸) مسیر راه‌آهن قزوین- رشت- انزلی، استفاده شده است. منطقه مورد بررسی، از نظر زمین‌شناسی، منطقه‌ای با خطر زیاد همراه است و لغزش‌های قدیمی زیادی در آن دیده می‌شود. در این محدوده، انواع متفاوتی از لغزش رخ داده است و لغزش‌های موجود با ویژگی‌های زمین‌ساختاری کنترل می‌شوند. در گستره زمین‌لغزش، تصویرنگاری ژئوالکتریکی با استفاده از ۳ آرایه شلومبرژه، دایپل- دایپل و پیمایش‌های یک‌بُعدی ترسیم مختلط، در راستای نیم‌رُخ‌های عمود و موازی با مسیر تونل صورت گرفته و سعی شده است تا با مقایسه و تلفیق تحلیل‌های زمین‌شناسی سطحی، زمین‌ریخت‌شناسی و نتایج حاصل از روش‌های گوناگون ژئوالکتریکی با روش دایپل- دایپل، شکل توده لغزشی و ساختار زمین‌شناسی محدوده، مورد بررسی قرار گیرد.

واژه‌های کلیدی: ژئوالکتریک، تصویرنگاری مقاومت الکتریکی، نیم شلومبرژه، دوقطبی- دوقطبی، زمین‌لغزش

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1 INTRODUCTION

The studied landslide is located in Roudbar city, northern Iran (Figure 1 and 2), that is an area with great mass movements. This landslide is an ancient earth flow slide and is currently inactive.

Roudbar region is a part of the Alborz chain with more recent tectonic, is still suffers appreciable and differential neo-tectonic uplift. The geomorphologic evolution of the slopes is clearly influenced by mass movements of different types and sizes. Roudbar region exhibits the highest density of landslides. This high density of landslides is related to the presence of clayey materials, extreme rainfall events, deforestation, active tectonic, intense urbanization, and industrialization, which worsen the already inadequate drainage of surface and deep waters in the hills and mountains of the territory. Geomorphologic structures (the meander of Sefidroud toward west and presence of roughed topography etc), such as anticlines and synclines, destructive earthquakes in the past, are good evidences for active tectonic in the studied area.

Geophysical methods have been effective tools for studying geological problems and, in practicular, for defining the geometry of landslides (McCann and Forster, 1990; Bruno and Marillier, 2000; Gallipoli et al., 2000; Mauritsch et al., 2000; Lapenna et al., 2003; Perrone et al., 2004). Most recently, great attention has been devoted to the electrical resistivity imaging (ERI) method (Griffiths and Barker, 1993; Giano et al., 2000), which provides high spatial resolution with a relatively fast field acquisition time while being low in cost. Advanced instrumentation for data acquisition was combined with the data inversion method proposed by Loke and Barker (1996) using Res2dinv software. The challenge was to determine if electrical imaging has the potential to illuminate sliding surface that separate layers characterized by a relatively low resistivity contrast found in a complex geologic environment.

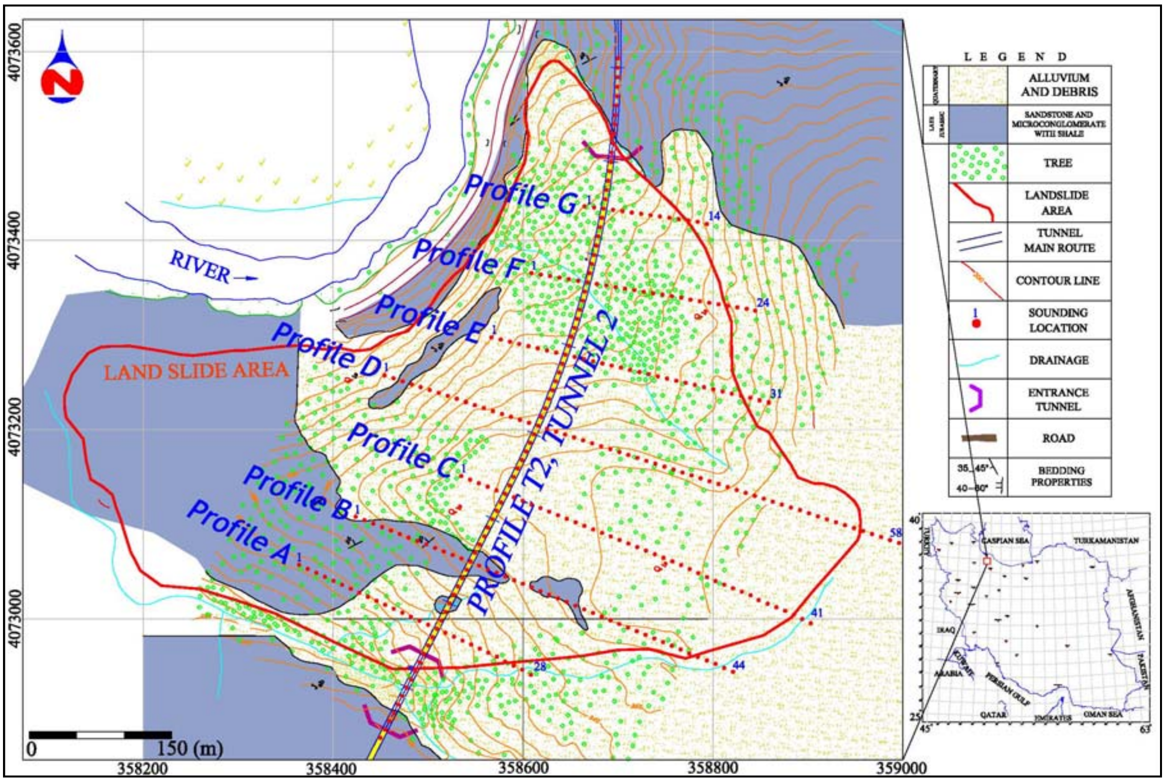

Figure 1. The geological map of the land slide area and sounding locations.

The geoelectrical results have been systematically integrated with the data obtained from geologic and geomorphologic surveys, satellite images and aerial photographs. These data are interpreted to identify the sliding surface, estimating the thickness of displaced materials and geological structures. We compared the result of the dipole-dipole array investigations with other arrays data. In particular, horizontal and vertical isogradient pseudo-sections and two-sided gradient transformation function (Candansayar and Peksen, 1999), allow us to reduce ambiguities related to estimating geoelectrical anomalies and thickness of the landslide material.

2 GEOLOGIC-GEOMORPHIC SETTING

The region is composed of alluvium terraces, sandstone and marly-shaly sandstone that are intensively tectonized and fissured, that disarranged blocks and debris are locally developed. Structurally complex clayey-marly sandstone belongs to the late Jurassic period. Geological structures mainly situated in NW-SE to W-E directions. The bed rock is folded and uplifted by tectonic forces and faults activities. According to the surface geology (figure 2), geomorphic survey and aerial photo analysis (figure 1), it is tried to reach a primary estimation of the detachment zone bottom and delineate the landslide boundaries.

3 ELECTRICAL RESISTIVITY IMAGING METHOD

In this study, it is tried to use different electrode arrays to provide more data for processing. Schlumberger and combined resistivity profiling (CRP) surveyed in the profile which is parallel to the tunnel route (profile T2). The dipole-dipole array applied for 7 profiles (A-G) which were perpendicular to the previous profile. Figure 3 shows the location of soundings and profiles on the topography map in studied area.

Figure 2. Oblique satellite image of studied region, landslide area has been shown in the picture.

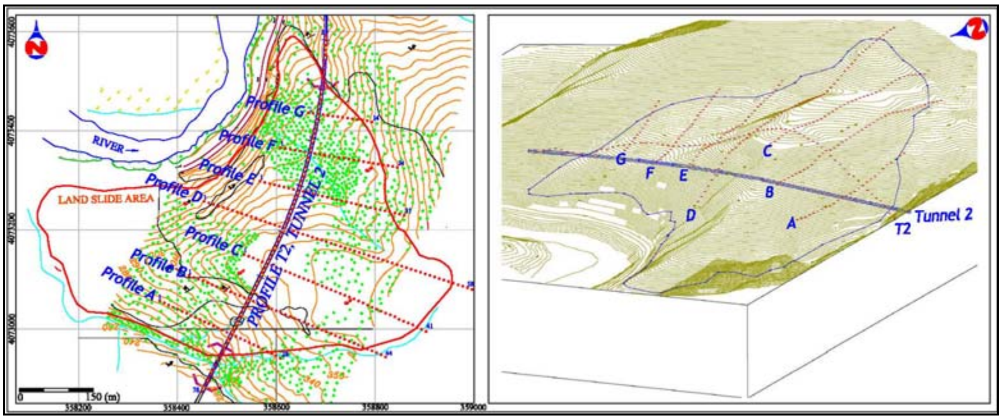

Figure 3. Location of soundings and profiles on the topography map.

In addition to different measurements, different processing methods applied to delineate the slide boundaries and detecting the geoelectrical discontinuities. In this part different methods and their advantages are explained.

In this study combined sounding-profiling measurements with the AMN, MNB arrays is used in T2 profile. The advantage of two-sided three-electrode configurations is that profiling and sounding is combined (Candansayar and Peksen, 1999). Karous and Pernu (1985) employed this electrode array and they claimed to get the maximum information about the buried object. The resistivity data from such measurements is presented as: a) Two Sided Gradient (TSG) transformation curves b) AMN, MNB resistivity profiling curves and c) apparent resistivity pseudo-sections. These methods give some information about the location and extension of discontinuities along the profile T2 (tunnel number 2 route).

Two Sided Gradient (TSG) transformations is more efficient in delineating the near surface discontinuities (Candansayar and Peksen, 1999). It can be used to determine the geo structural investigations (finding faults or dyke etc.). TSG method applied for T2 section in tunnel route path to detect the geophysical discontinuities. Most important anomalies that can be traced at different depths are marked with (Figure4).

AMN, MNB resistivity profiling curves are presented for profile T2 in figure 5. AMN, MNB resistivity profiling curves indicate anomalies that can be followed in different AB/2. Location of the most important conductive discontinuities detected in figure 5 in different AB/2.

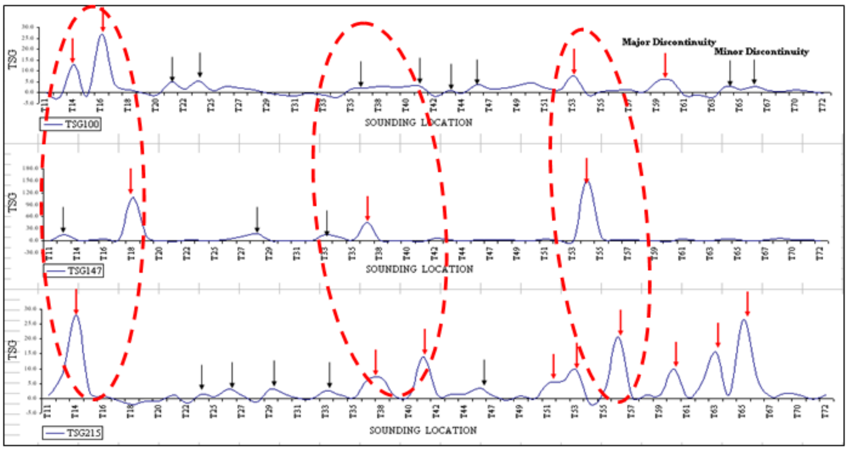

Figure 4. Two sided gradient transformation function along profile T2 in different AB/2.

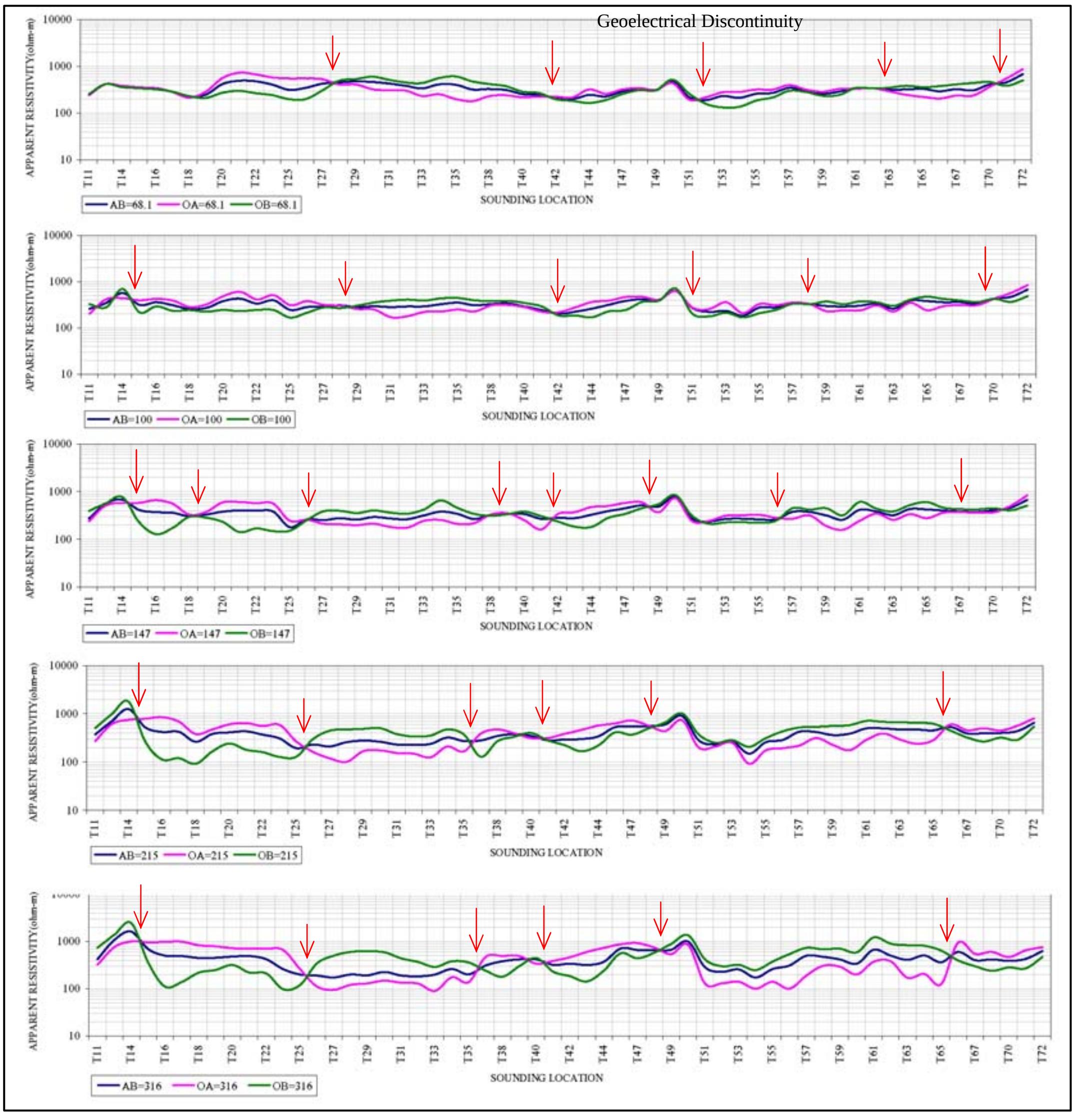

Figure 5. AMN, MNB resistivity profiling curves along profile T2 in different AB/2.

Combination of two asymmetrical AMN, MNB pseudo-sections is one of the most effective techniques to confirm and accurate the discontinuities. Figure 6 shows the AMN, MNB pseudo-sections along profile T2. In this figure changes of resistivity in both sections are detectable and compared with violet dash lines. These anomalies are in coincidence to previous data.

Bobatchev et al (1997) introduced TES (Total Electrical Sounding) technology for recognition of 2D anomalies. In this method, Horizontal gradient (G_h) transformation and Vertical gradient (G_v) transformation calculated using d Rhoa/dX and d Rhoa/dR. according to the results, the horizontal isogradient pseudo-section and the vertical one are drawn. Horizontal isogradient pseudo-section applied for detection of the vertical anomalies and vertical isogradient pseudo-section for detection of the horizontal anomalies along profile T2 (Figure 7). The most important vertical anomalies are marked in horizontal Iso-gradient pseudo-section and horizontal anomalies in vertical Iso-gradient pseudo-section.

The dipole-dipole array can detect both vertical and horizontal structures. Forward and inverse modeling applied for interpretation of dipole-dipole profiles (A, B, C, D, E, F and G) using RES2Dinv software. We used the method proposed by Loke and Barker (1996) to transform the apparent resistivity pseudo-section in to a model of the subsurface true resistivity distribution in dipole-dipole arrays. The inversion routine is based on the smoothness-constrained, least square inversion of Sasaki (1992) implement with quasi-Newton optimization technique.

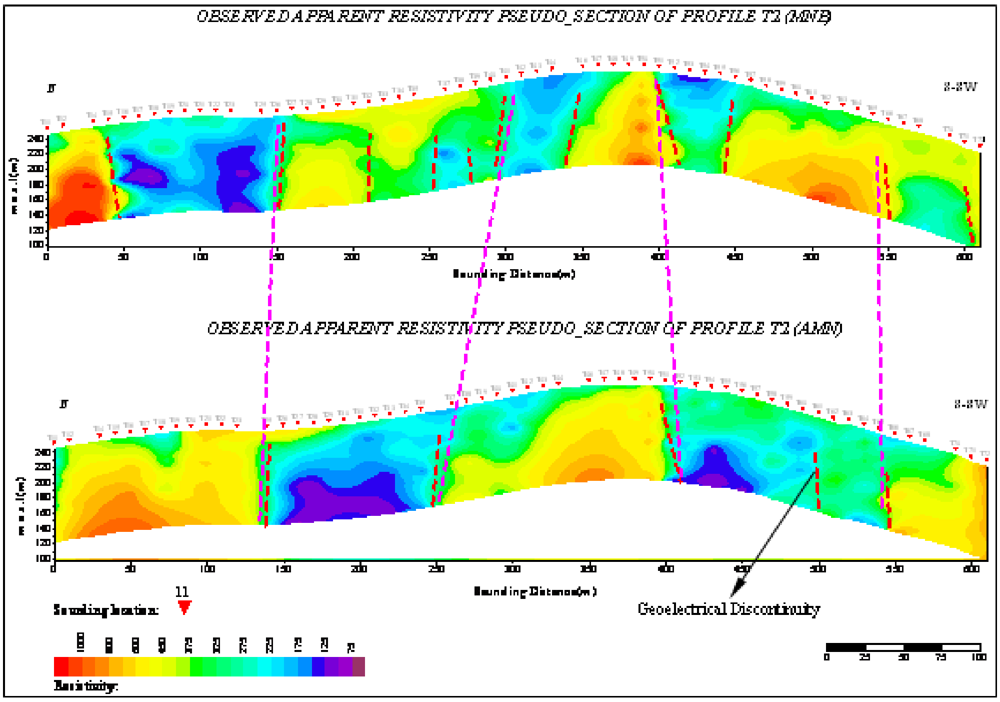

Figure 6. Observed apparent resistivity pseudo-section of profile T2 for MNB and AMN arrays.

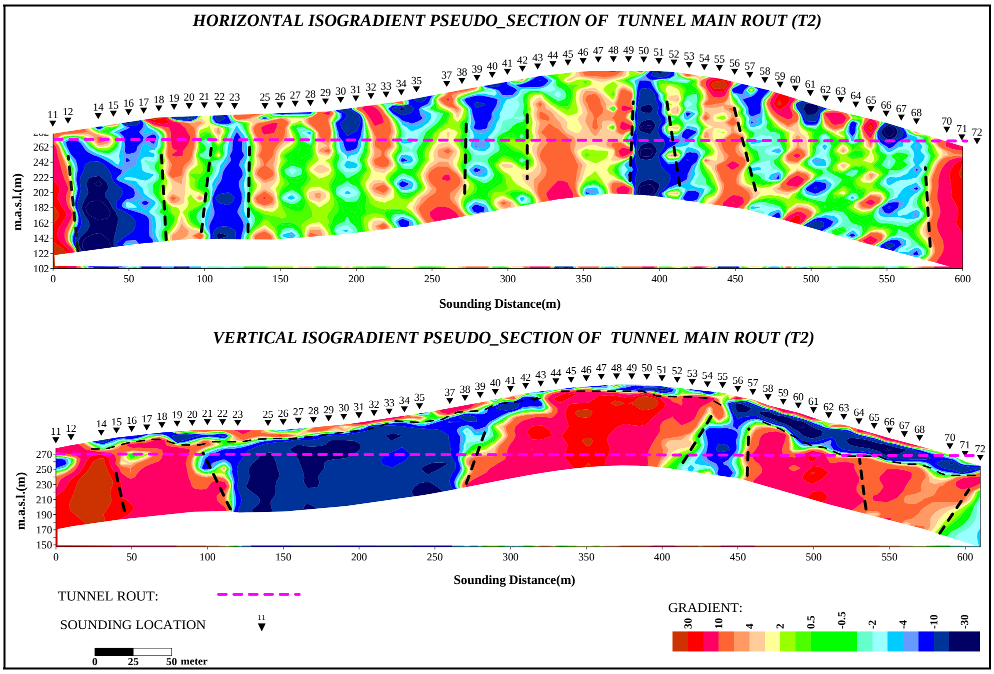

Figure 7. Iso-gradient pseudo-sections of profile T2 .

The optimization method iteratively adjusts the 2D resistivity model to minimize the difference between the calculated and measured apparent resistivity values. The subsurface is subdivided into rectangle blocks whose number is related to the measuring points. Figure 8 shows resistivity changes along profile A with geological interpretations (i.e sliding surface and different geological units) (Figure 8).

In section T2 the apparent resistivity pseudo-section transformed in to a model of the subsurface true resistivity distribution by winglink and surfer softwares.

Figure 9, shows interpreted true resistivity section of profile T2 along tunnel main route. The shallow wide range of resistivity located in the upper parts of the ERI profiles, is associated with the sliding mass.

Finally Geological model along the tunnel main route (Figure 10) drew and geological map of the area (Figure 12) completed based on the geoelectrical methods, surface Geology, geomorphology and other analysis. Dipole –dipole sections combined with section resulted from shlumberger measurements to create a 3D geoelectrical model (Figure11). In these models, deep discontinuities detected by different CRP interpretation methods and were in coincidence with low resistivity zones from true resistivity models, introduced as fault or crushed zones because of some surface evidences and following structural trends. According to the results of this study a drilling layout proposed for detail studies.

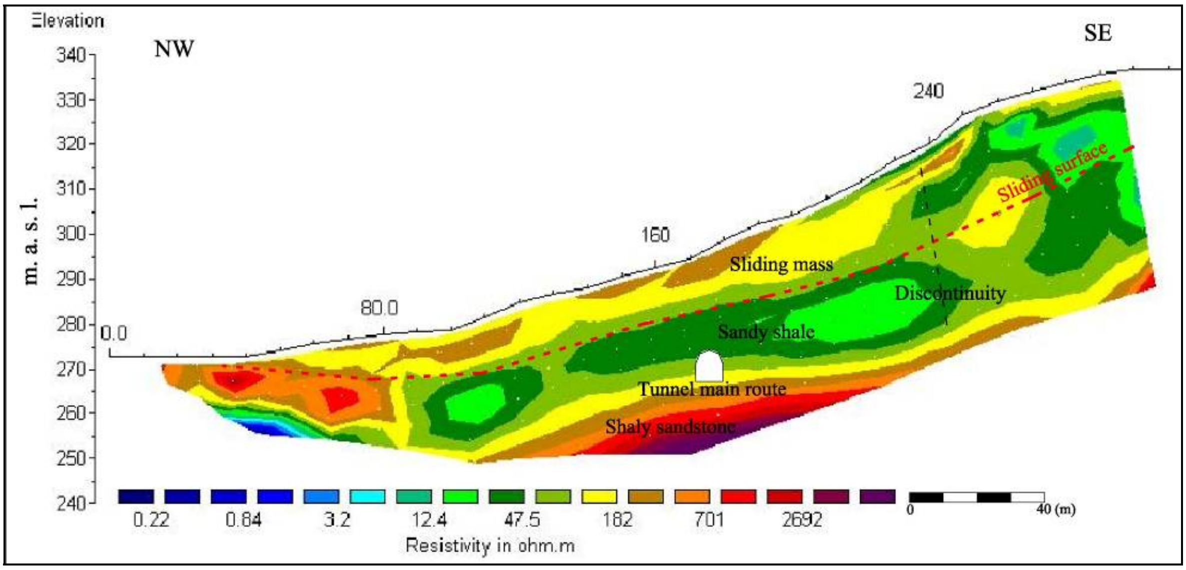

Figure 8. Geoelectrical section of dipole-dipole array in a perpendicular profile to the tunnel route.

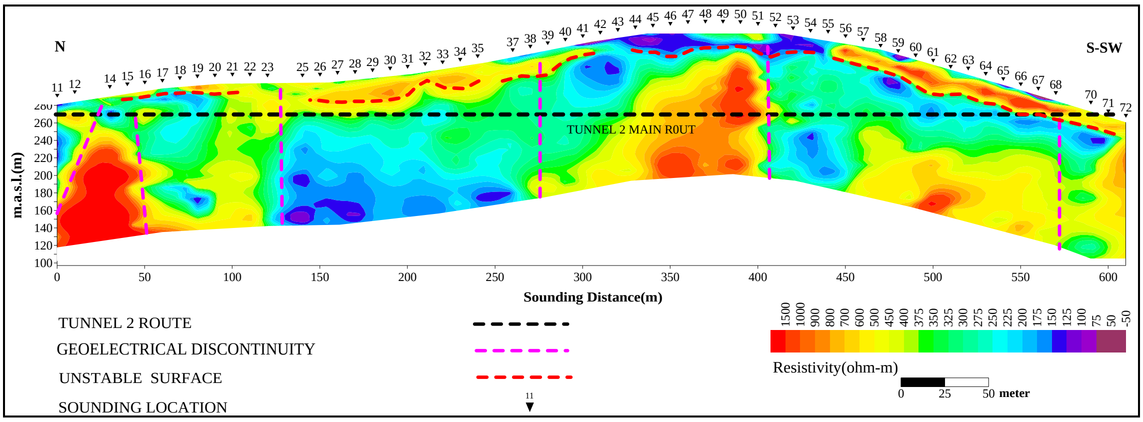

Figure 9. Interpreted true resistivity section of schlumberger array along profile T2.

Slide mass is approximately 700 m long and about 60 to 450 m wide. It developed along an area ranging from 420 m to 200 m above sea level (asl), and has a mean inclination of about 25° toward W to NW. Tunnel main route stand in 270 meter above sea level .The most thickness overburden is 90 meter and the least is 10.

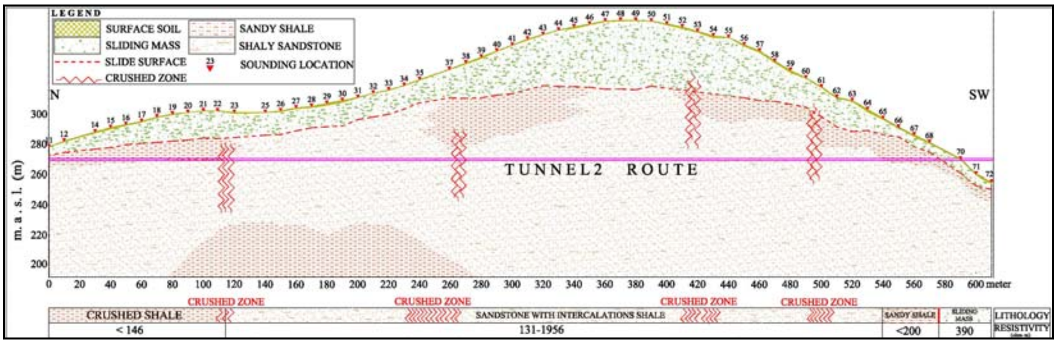

Figure 10. Geological model based on geoelectrical interpretation of profile T2.

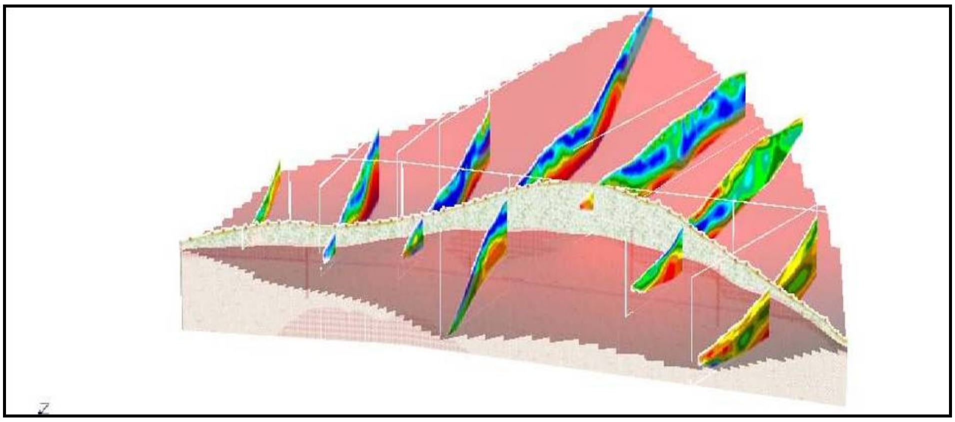

Figure 11. 3D view of geoelectrical sections in studied area.

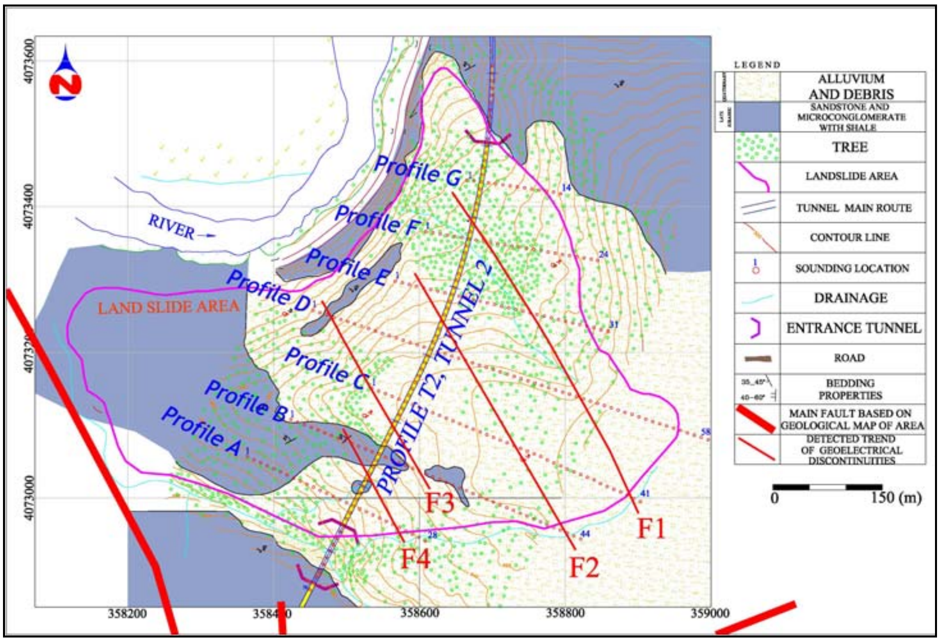

Figure 12. Completed geological model based on geoelectrical interpretation and other studies.

4 CONCLUSIONS

The geophysical data interpreted using geologic constraints from surface geology, geomorphic survey and satellite images. The 2D electrical images, notwithstanding the geologic complexity of the investigated areas and relatively low resistivity contrast between the slide materials and bedrock, outlined the geometry of the investigated landslide. Different measurements and analysing methods applied to outline the slide boundary and detect the discontinuities. Therefore, the ERI method appears to be a robust method for imaging the subsurface geology and dipole-dipole array in comparison with shlumberger measurements that interpretd by different methods, is a powerful tool for imaging the geometric boundaries of landslides. This can be helpful as a fast field data acquisition and low cost. Although the main route tunnel is mostly located on the rock masses but about several meter of its both ends is surrounded by collapsible crushed shaly materials (Figure 10) and needs additional engineering techniques in excavation and stability.

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