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Structure of Dallackau Landslide on the Refraction Data with Interpretation by Homogeneous Function Method

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SUMMARY

Inner structure of Dallackau landslide has become the focus of investigations for evaluation of possible damage. Geoscientists have to cope with different types of faults and breaks when looking at seismic sections. We showed the potential of the homogeneous function method for use in interpretation of refraction data of engineering seismic line running across the Dallackau Landslide located in Northern Caucasus (Russia). The resulting seismic section is much more detailed than that provided by the traditional method (previous models for these lines). New sections involve different faults and thrusts, even though the new section and the previous model are identical on the average. The purpose of this paper is to summarize how the faults can be identified from 2D seismic images by demonstrating some of the sections through the Dallackau Landslide.

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Introduction

The landslides in a mountain part of Republic Northern Osetiya-Allaniya (Russia) (Fig.1) are widely spread and create danger of damage or destruction of the buildings. The instability of landslides is aggravated by the increased seismic activity. Large the Dallackau landslide is located at the right shore of the Mamikhdon river and nearby of future tank. The landslide has arisen during earthquake 1905 year by force about 7 which have resulted in destruction Dallakau village located at its foot. The landslide is well investigated: geological, geophysical and the drilling works are executed. Thickness of the landslide varies from 40 up to 80 m. Total length of the landslide is 1130 m, width is 600m. It is a sliding landslide in loose deposits. Bedrock is aleurolites and clay slates of Lower Jurassic. The weak activization showing of displacement of landslide rocks is marked periodically - occurrence of open cracks of breaks and displacements of separate blocks is observed. After filling of tank the front of the landslide which is taking place on marks about 1690 m, will be flooded. The activity of development of processes, first of all in a frontal part, certainly, will grow.

Figure 1 *Red square shows location of Dallackau Landslide on the map of Russia.*

Seismic investigations

During the 2002 year at the surface of Dallakau landslide the seismic works were carried out along four lines (fig. 2) by ZSGNEO (Moscow). The seismic works were carried out by a method of refracted waves with 24-channel seismic station. The generation of waves was produced by blows on a metal support and explosions. The registration of waves was made in a mode of accumulation of a signal. The reception of seismic waves was carried out by vertical receivers. The receiver interval was 2m, the system of observations (traveltime curves along line 2) is shown in fig. 3, and maximal shot-receiver offset was 138 m.

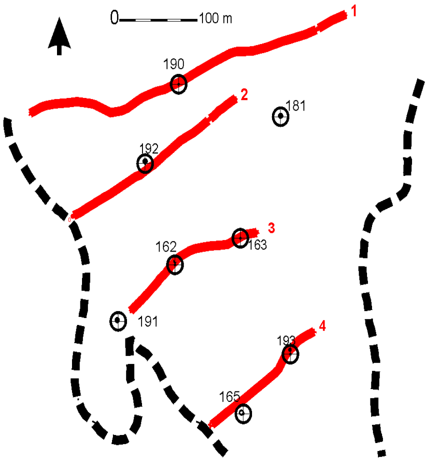

Figure2 *Location of seismic lines (red lines) at the surface of Dallackau Landslide. Black dash lines are borders of the landslide. Location of wells is shown by circles.*

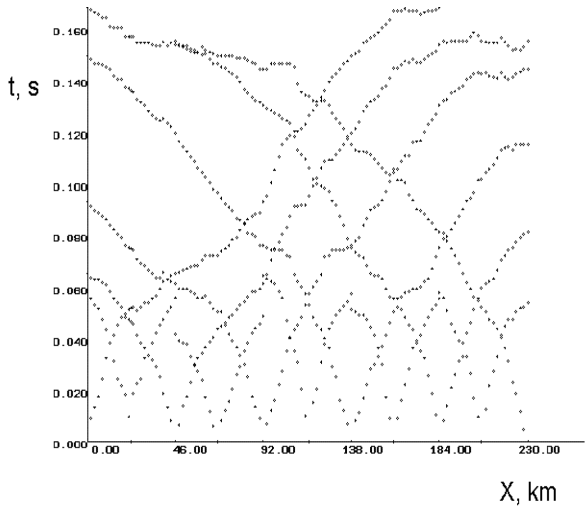

Figure 3 Observed *refraction traveltime curves along line 2.*

As a result of the interpretation by plus-minus method the seismic sections were constructed along four lines. In Figure 4 a section along line 2 is shown. The conclusions were made that the sub horizontal layering is traced in a body of a landslide. The bedrock (layer 5) are characterized by velocity of Vp = 3.6 – 4.2 km /s. We note that any faults were not received in the section.

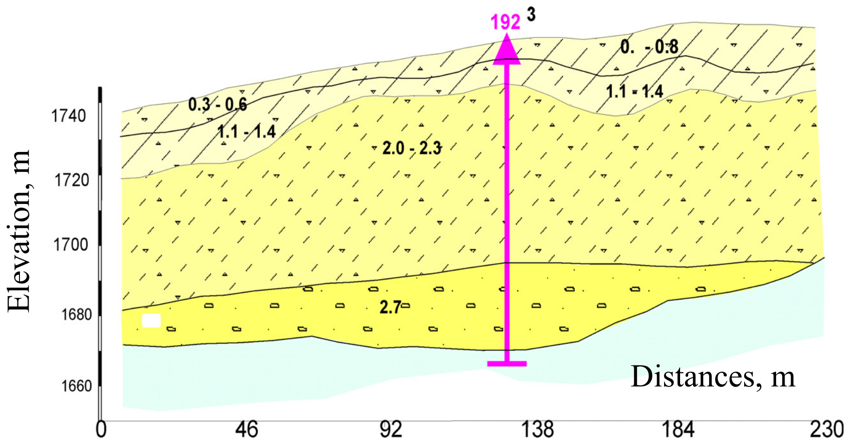

Figure 4 *Seismic section along profile 2, calculated by traditional methods. Digits are values of seismic velocities. Location of well 192 is shown.*

Method of reinterpretation

The seismic observations at the surface of Dallackau landslide along the four lines were reprocessed with homogeneous function method and software package "Godograf".

Main property of velocity function, appropriate to geological sections is the similarity of the contours. Let's recollect a syncline or anticline folds, inside which borders of the layers are similar to each other. Geological sediments usually collect in water environment, and originally have horizontal bedding. The subsequent deformations break such bedding; however, similarity of surfaces of the layers is kept. Homogeneous functions of two coordinates are wide class of 2D functions and they have properties necessary for the description of geological media. Their contours are arbitrary curves but they are similar to each other. The important property of homogeneous velocity functions is the following. The unique homogeneous velocity function can be steadily calculated from two reverse traveltime curves of first arrivals. Interpretation by the homogeneous function method is done automatically, no initial model being required. The identification of waves related to different layers is also carried out automatically (Piip 2001).

The interpretation involves two main phases: a rigorous solution of the inverse problem, which is to determine an increasing homogeneous function from two reversed traveltime curves of the first arrivals (local velocity field), and superposition of the local velocity fields calculated for different pairs of traveltime curves using the priority principle. The final velocity section is given by velocity values computed at points of a rectangular grid. These values of the detailed velocity field define the locations of the discontinuities and faults in the section. They can be detected automatically using representing sections as surfaces with shadow relief. A seismic section can also be represented in the form of velocity contours at equal intervals of (usually) 100-200 m/s. The distance between velocity contours is inversely proportional to the value of velocity gradient, and for this reason allows visual determination of the velocity gradient as well. Discontinuities in 2D media can be of two kinds: a discontinuity of the first order is a velocity contrast, while one of the second order is a contrast in velocity gradient. The sections constructed by a method of homogeneous functions, completely satisfy to the modern requirements to accuracy of constructions accepted by the international community. It is confirmed by accounts of theoretical traveltime curves, which always coincide with observed ones in allowable limits.

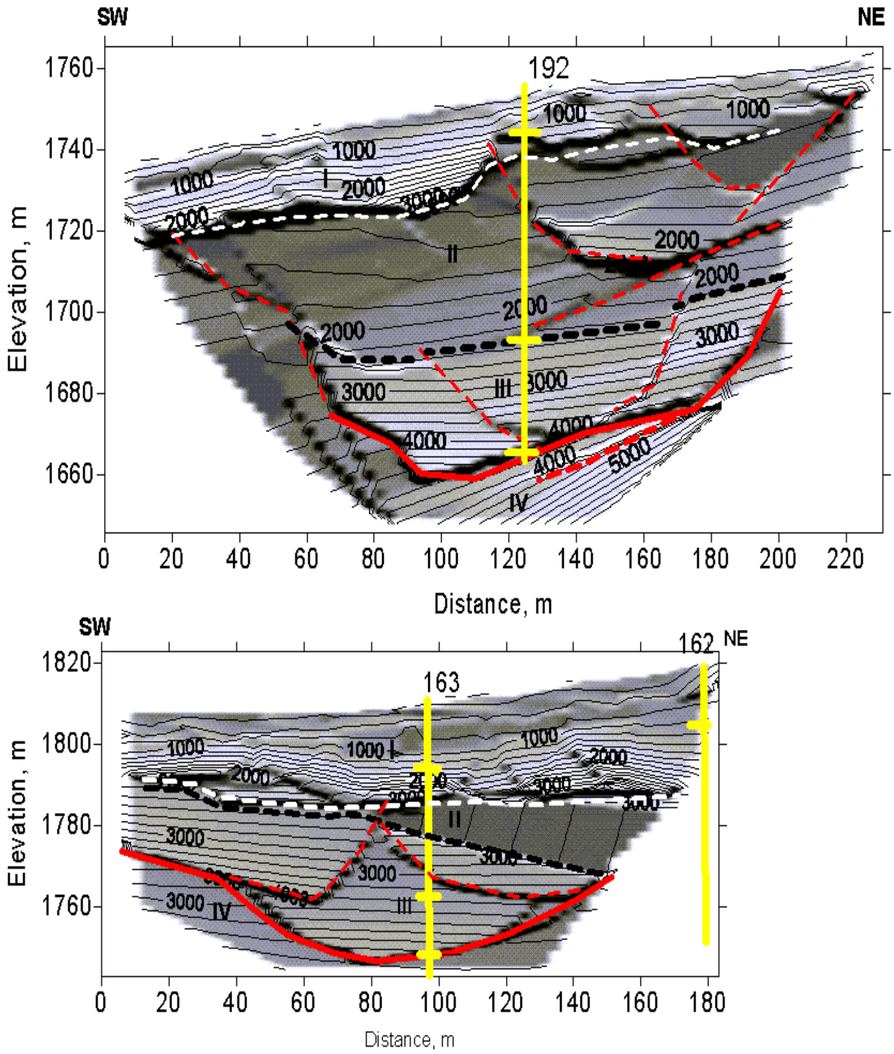

Figure 5 *Seismic cross sections along profiles - 2 (above) and 3. Inversion boundaries are shown by white dash line. Other boundaries are indicated by black dash line. Red dash lines are faults. Solid red lines denote the landslide sole. Yellow vertical lines are wells with marks of layers. Contour interval is 200 m/s. The sections are represented as surfaces with shadow relief.*

Results of interpretation

The grid-model was designed on each from four profiles, when the velocity of waves was computed in nodes of a rectangular grid by the size 78 x101 with a step 3m x 1.2 m. Data of relief were taken into account in process of calculation of the seismic sections. The sections represented as surface with illuminated relief are submitted in Figure 5. Simultaneously the velocity contours are shown in the sections. Such kind of sections allows seeing complex layered structure of a landslide and allocation of boundaries and faults. Generalizing results of interpretation by method of homogeneous functions along all profiles, we can make the following conclusion.

All sections have a similar structure. In the basis of a landslide the large blocks of bedrock, divided by faults lay. Velocity interval for this layer is 2500-4500 m/s; values of velocity gradient are practically constant (50-70 s^{-1}). The landslide sole is inversion boundary for which velocity in sole of landslide is higher than velocity in the bedrock. Two layers divided by inversion boundary are located in upper parts of these sections. In each of the layers the velocity toward sole of layer sharply grows. In the top part of the layers the rock with relatively low velocity (the loose sediments) are located. The location of a sole of the landslide and sole of loose sediments in new sections everywhere has coincided with the data of wells. The faults - listric and rectilinear- are clearly visible in the sections. It is very important for an estimation of a condition of a landslide because faults define an opportunity of future movements of a landslide. The boards of the landslide are complicated by subvertical faults, with fall to the centre of the landslide.

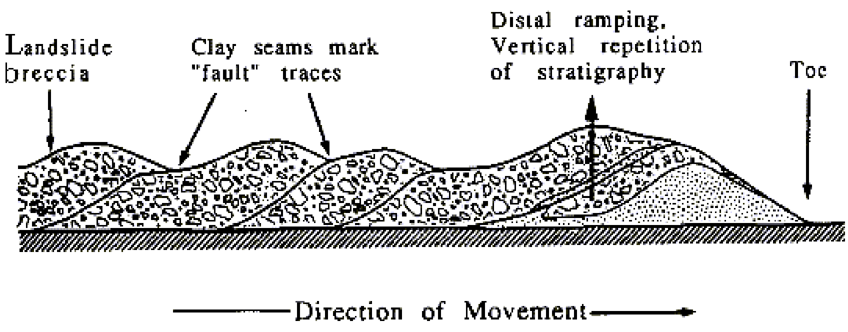

Figure 6 *Structure of Blackhawk landslide southern California. Movement direction was from left to right. Hatched pattern indicates substrate material. The distal apparently came to rest first, forcing the trailing limestone breccia show ramp up behind it and causing imbrications of the distal reaches of landslide. (Shalle, 1999)*

It is possible that the inversion boundaries are thrusts in direction of movement of the landslide. It is well explained by example of geological longitudinal section of the Blackhank landslide in southern California (Fig. 6), which contains layers divided by thrusts.

Conclusion

We represented method homogeneous function to generate detailed 2D seismic sections from refraction first arrivals. The qualitatively new and quantitatively exact information on an internal structure of Dallackau Landslide, having real geological character is received. Using these detailed sections, we can evaluate risk of activation of landslide significantly more precisely.

References

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