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Investigation of deep seated gravitational slope deformation in the Sartal and Kuh-e-Sefid anticlines, Northwest of Dehdasht

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Abstract

The area of Charousa and Lendeh in the Kohgiluyeh and Boyer-Ahmad province in southwestern Iran is geologically part of the folded Zagros. In this area, the core of the Kuh-e-Sefid and Sartal anticline of the Ilam-Sarvak limestone are the main high altitudes of the region. At these altitudes the scar of large landslides and evidence of deep seated gravitational slope deformation are visible. The largest of these are the Almor landslide in the Sartal anticline with an approximate volume of over 600 million cubic meters. In this study, the evidence of deep seated gravitational slope deformation of these anticlines has been investigated and the causing factors for Almor landslide have been determined. To investigate of this issue, a combination of geological field survey, image processing studies, and laboratory studies of rock mechanics and soil mechanics were used to prepare preliminary data. This data are processed and analyzed by a combination of kinematic analysis, limit equilibrium sensitivity analysis, and finite element numerical modeling. Finally, a three-dimensional geological model is proposed to illustrate the proposed mechanism for this landslide. According to this study, a combination of deep seated gravitational slope deformation, along with wedge failure and three hinge buckling, was the causes of this avalanche.

Keywords: *Ilam- Sarvak Formation, landslide, deep seated gravitational slope deformation*

Extended Abstract:

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1. Introduction

The area of Charousa and Lendeh in the Kohgiluyeh and Boyer-Ahmad province in southwestern Iran is geologically part of the folded Zagros. In this area, the core of the Kuh-e-Sefid and Sartal anticline of the Ilam-Sarvak limestone are the main high altitudes of the region. At these altitudes Giant and numerous historical landslides have occurred in the Kuh-e-Sefid and Sartal anticlines and evidence of deep seated gravitational slope deformation are visible. The largest of these are the Almor landslide in the Sartal anticline with an approximate volume of over 600 million cubic meters.

Paleolandslides are pre-historic mass movements documented using geological and geomorphological evidence. Deep-seated gravitational slope deformation (DSGSD) is diagnosed as slope “sagging” or gradual adjustment under gravitational (Zischinsky, 1966; Beck, 1968). Geomorphic features that can demonstrate past or present DSGSD include grabens, trenches, uphill-and/or downhill-facing scarps, split ridges, and toe bulging (Varnes et al., 1989). This process over the long term, can lead to large catastrophic landslides (Apuani et al., 2007; Hradecky and Panek, 2008; Pedrazzini et al., 2013). This study investigates the geological, structural, and evidence of deep seated gravitational slope deformation of the slopes in the study area and the causing factors of this landslide.

2. Materials specifications and methods of analysis

To investigate the subject of this research, a combination of conventional surveying methods and image processing studies has been used to obtain orientation of rock discontinuities. The characteristics of discontinuities (roughness, spacing, aperture and etc.) have been obtained from field geological observations. To determine the engineering properties of the rock mass, we used the results of the field and lab studies. Intact rock specifications have been determined from laboratory studies of rock mechanics and soil mechanics, and rock mass engineering parameters have been obtained, using appropriate failure criteria and rock mass classification methods (RMR, Q, GSI and RMi). Materials hydraulic properties were obtained using oil exploration wells data and groundwater flow analysis was performed by numerical simulation. This data are processed and analyzed by a combination of kinematic analysis, limit equilibrium sensitivity analysis, and finite element numerical modeling. To simulate the gravitational deformation mechanism of the slope and calculating the slope’s stability and safety factor, we used Phase2 v06 2D software (Rocscience, 2007). Mohr-Coulomb and tensile failure criterions used for rock mass and Barton and Bandis (1990) failure criterion used for discontinuities.

3. Discussion: Landslide mechanism

Based on field and laboratory studies on the Almor landslide, slope instability in this area can be divided into several Phases.

1-8. The gravitational deformation phase of the slope

The field observations such as the general settlement in the limbs of the region’s anticlines, split ridges, circulare scarps and grabens, suggested the slopes’ gravitational creep before the failure stage in the studied area. Studies show that the weak bed of disconformity boundary between Ilam and Sarvak formations and numerous interbeds in Ilam formation causes gravitational deformation of these slopes (Figs. 1, 2). The regional joints and the very extensive bedding, the convex slopes and the tectonic joints resulted from the folding stage have played a role in the development of the situation. But their role is facilitating.

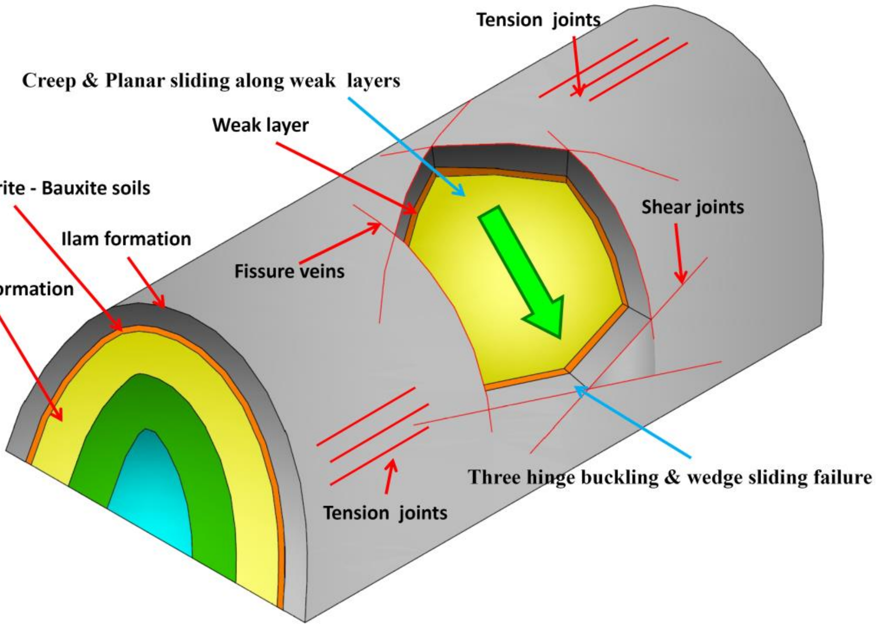

Fig. 1. Three-dimensional view of the mechanism of large landslides in the study area

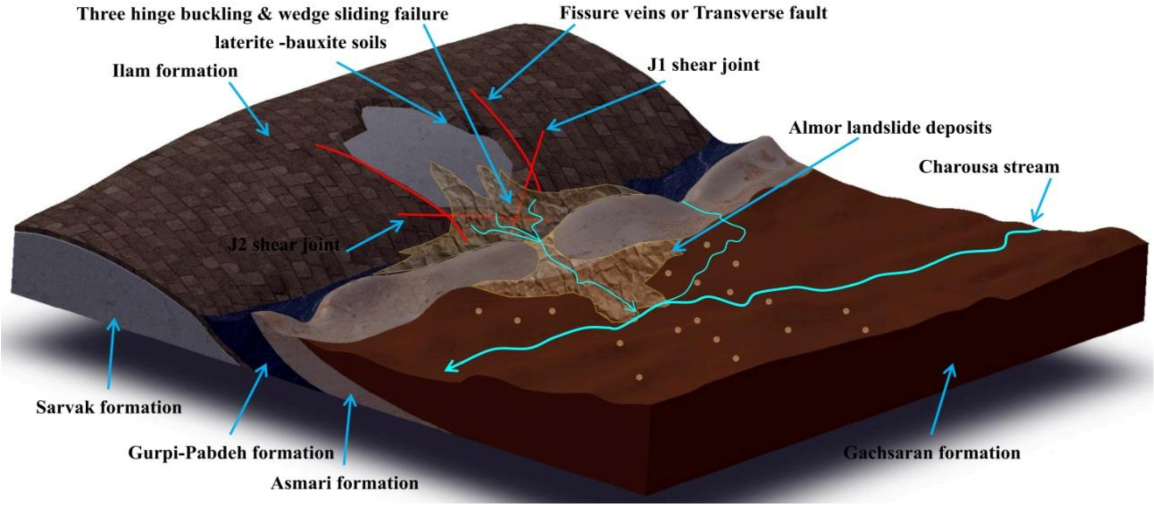

Fig. 2. Geological 3D model that illustrates the mechanism of Almor avalanches event.

2-8. Slope failure phase

The field studies on several landslides of the studied area showed that fissure veins and transverse faults played an important role in the definition of the lateral geometric dimensions of the region's large landslides by separation of the rock mass down to the slide plane (Fig. 1). The separation of the rock mass in the slope's toe has taken place by either the thrust faults or along the large wedges developed due to the combination of two shear joint sets resulted from the folding (Fig. 1). Taking the region's conditions into account, two possible mechanisms might be considered for triggering large landslides: 1) Variations of groundwater level and rising pore pressure, 2) Earthquake.

4. Conclusion

The research indicated that the causes of large landslides in the studied area were not simple and there were a combination of various factors affecting it. Hence, the various combinations of the factors each influenced the deformation development and the slope instability. The weak bed of the rock mass made a suitable ground for the slope's creep deformation and the development of a shear plane within the slope. The convexity of the slope and the bedding being parallel to the topographic surface was effective in making it susceptible for buckling development. The combination of the large shear joints resulted from folding provided the appropriate ground for the development of large wedge slides in the slope's toe which in turn triggered large translational landslides. The role of fissure veins and transverse faults, the lateral release of the rock mass and their spacing defined the geometric dimensions of the landslide. Finally, the concentration of tensile and shear stresses at the point of dip increase in the slide's toe and the tensile joints resulted from folding caused the triple hinges buckling. None of these factors triggered the landslide, though they brought it to the verge of instability.

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