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Assessment of structurally-controlled slope failure mechanisms and remedial design considerations at a feldspar open pit mine, Western Turkey

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ABSTRACT

A variety of structural discontinuities crossing the slopes of Alipasa feldspar open pit mine, in western Turkey, caused different types of slope failures which led to interruptions in ore production. Thereupon, extensive geotechnical investigations, including geological characterization, in-situ and laboratory geotechnical testing, long-term movement monitoring, back-analyses and possible remedial measures, were conducted. Field observations and subsequent analyses suggested that the failures were limited to benches and the movement developed down-slope along discontinuities due to the following reasons: (i) unfavorable orientations of the foliation planes and joints, (ii) low shear strength along discontinuities and (iii) exceptionally heavy rains filling the tension cracks prior to failure. Comparisons between movement vectors and orientation of discontinuities showed a good agreement that indicates two types of instability, namely, planar and wedge failures. A back analysis procedure for the assessment of failures along the rough discontinuities, with non-linear failure envelopes, was successfully applied to the unstable slopes in the pit. The results of the 2-D limit equilibrium back-analyses and movement monitoring data suggested that the wedges and/or planar blocks formed at the uppermost benches tended to move down to fill the gap which resulted from the previous movement of the blocks in the benches. Remedial measures such as dewatering and reduction of height of the benches were suggested. Results of stability analyses conducted for possible remedial measures were presented and discussed.

1. Introduction

Rapidly increasing population in the World has resulted in an increasing demand for mineral deposits. Consequently, mining depths in open pits have been increasing steadily and recently there are open pits where mining depths are exceeding 800 m. A major problem with increasing open pit depths is the increasing risk of large scale slope stability problems which may threat the entire height of the final pit slopes. In order to achieve both safe and economical production in open pit mines, the major goal of the slope design is to prevent instabilities which may threat the safety of people and may cause an interruption in ore production. Thus, design of the final pit slope limit is determined not only by the ore grade distribution and production costs, but also by the stability considerations through geotechnical properties of the materials forming pit slopes and discontinuities.

There is a number of feldspar mines operating in the western part of Turkey, called Aegean Region. Two of the largest adjacent mines, where sodium feldspar (albite) is being produced for industry by a private company, are the Sarikisik and Alipasa open pits (Figure 1a, b). In both pits, the overburden mainly consists of ortho-gneiss. It is loosened by blasting, excavated by shovels, and transported to the outside dumping area by trucks (Figure 1a). The reserve in the Alpasa pit is 14,727,131 metric tonnes of sodium feldspar. Present bottom elevation of the pit is +395 m and it has been planned to produce the ore to an elevation of +340 m. The highest elevation of the eastern pit slope, which consists of nine benches, is at +530 m (Figure 1c). Based on the initial pit design, height, width and face angle of the benches, in both overburden and ore body, were planned to be 15 m, 15 m and 65° respectively, and the final overall slope angle of 35°. However, benches have been constructed with face angles varying between 45° and 60°, and the overall slope angles of the eastern and western pit slopes are 28°–30° and 26°, respectively.

The problem in general is that very distinct, continuous, undulating and rough foliation planes in the overburden rock and ore body are oriented with strikes approximately parallel to the pit walls and dips towards the bottom of the pit. The foliation systems, joints and their intersections create a possibility for planar and wedge failures.

The instabilities were experienced in the eastern slope of the pit in August 2008 after a rainy spring season. A number of highly persistent tension cracks propagated and planar and wedge failures occurred in some benches (Figure 1d). Preliminary observations performed by Ulusay (2009) called for a detailed geo-engineering investigation.

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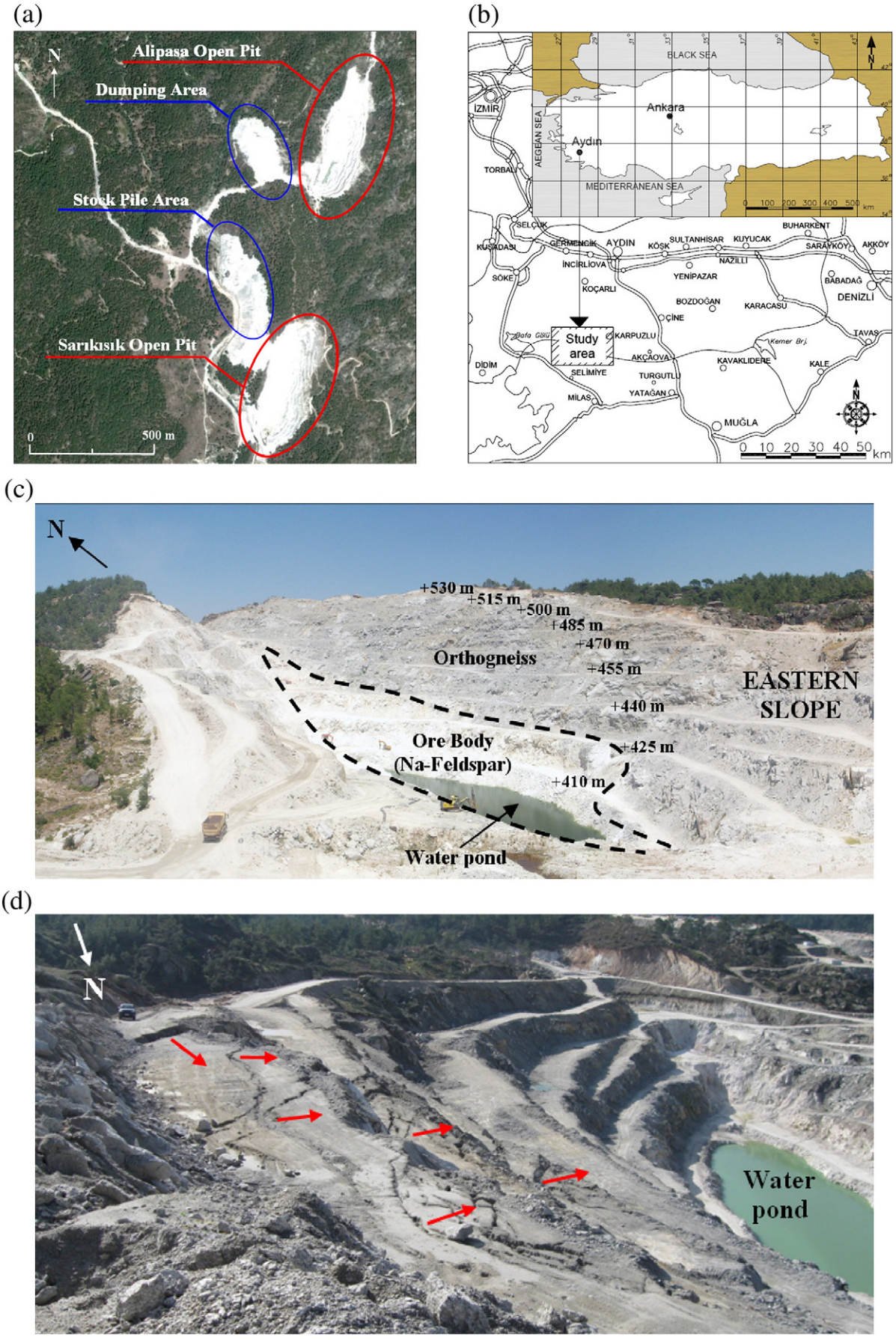

Fig. 1. (a) Satellite view of the Alipaşa feldspar open pit and its surroundings (www.maps.google.ca), (b) location map of the study site, (c) a view from the Alipasa pit, (d) view from some structurally-controlled bench instabilities occurred at the eastern slope.