International Journal of Rock Mechanics & Mining Sciences 66 (2014) 136–150

Contents lists available at ScienceDirect

International Journal of Rock Mechanics & Mining Sciences

journal homepage: www.elsevier.com/locate/ijrmms

Application of two new stereographic projection techniques to slope stability problems

Cem Kıncal *

Geological Engineering Department, Engineering Faculty, Dokuz Eylül University, Tınaztepe Campus, 35160 Buca-Izmir, Turkey

ARTICLE INFO

Article history:
Received 18 July 2012
Received in revised form
5 December 2013
Accepted 3 January 2014
Available online 28 January 2014

Keywords:
Planar failure
Kinematic analysis
Overlay linear-element process
Foliation planes
Orthogneiss

ABSTRACT

Slope instabilities were observed in the benches of the Alipaşa open pit albite mine in the Menderes Massif forming one of the tectonic zones of the Anatolides in Turkey. Tension crack patterns observed in the berms were formed depending on the discontinuity planes cutting each other in the orthogneiss rock unit. Two new stereographic projection methods in the stability analyses were applied by considering two cases; the first one that used the overlay linear-element process based on the geometrical conditions relating to the ground movement directions on the survey monuments, dip direction-lines of the foliation planes and sloped bench faces, and the second one that based on the determination of relationships between tension cracks on the upper slope face and discontinuity sets into the slope forming release and lower surfaces of the sliding blocks. It is kinematicly investigated with the overlay linear-element process whether an agreement among these parameters is presence or not. If there is, this case is indicated that the planar sliding was occurred on the foliation plane beforehand, or in a critical balance in terms of the planar-sliding of a slope. The proposed method will be useful to determine quickly and efficiently whether the relationships between the discontinuity sets into the rock masses and tension cracks on the berms or upper slope faces in an open pit or not. In addition, whether the angular values from the kinematic analysis are in agreement with the ones directly measured from the field was also investigated. This study involved making stability assessment of the already failed and standing sloped bench faces in the open pit using the stereographic projection techniques and software.

1. Introduction

The study area is located in the Menderes Massif forming one of the tectonic zones of the Anatolides that outcrop in the Western Anatolia [1]. There are 18 albite open-pit mines with different sizes in this region (Fig. 1a). The most famous albite mines in the region are located in the Cevizdere, Alipaşa and Sarıkısık domains, from north to south, respectively (Fig. 1). From these mine deposits, slope instabilities are observed in the Alipaşa open-pit albite mine only. In addition, some sloped bench faces with the critical balance were also observed in some parts of the eastern side of the pit. Sloped bench faces that compose of the overall slope in eastern part of the pit were evaluated from the stability point of view by using the different stability analyses methods such as stereographic projection and software methods. This study involves not only the overlay linear-element process based on the comparison of the kinematic analysis and the observed slope movements but also the examination of the relationships between the discontinuities and tension cracks developed on the berms by employing the crack pattern analysis, and the exploration the effects of explicitly introducing the foliation planes in the stability analysis of the sloped bench faces.

The existing literature on the stereographic projection techniques is wide spread. Many authors have discussed procedures for defining failure mechanisms using the stereographic projection techniques [2–10].

The mean annual production of the Alipaşa open-pit albite mine is around 4×10^5 t. The albite mineralization runs in the N25E direction and is approximately 900 m long and 55 m wide in the N65W direction (Fig. 2). The pit was excavated as benches at slope angles of 45°–55°, 8–15 m in height, and with a 10–15 m berm width. The elevation of the base of the mine is 395 m at present.

Mining has been performed by removing the overburden and the ore without concern for the rock mass conditions in these pits. The slopes at the eastern side of the open pit showed signs of planar sliding in 2007. At present, some rock masses are instable and may fail at any time. Tension cracks on the berms range from 2 to 10 m in length and 1 to 5 cm in width and enlargement of the cracks have continued since 2007 (Fig. 2c). Some of benches failed along the foliation planes, but sliding movements towards the center of the mine have not yet occurred.

The area of potential slope slides is approximately 10^5 m^2 and sliding movements in this area have threatened mining operations. In 2007, it was thought that the overall slope could be affected from

* Tel.: +90 232 3017344; fax: +90 232 4531129.
E-mail addresses: cemkincal@gmail.com, cem.kincal@deu.edu.tr

1365-1609/$ - see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ijrmms.2014.01.006

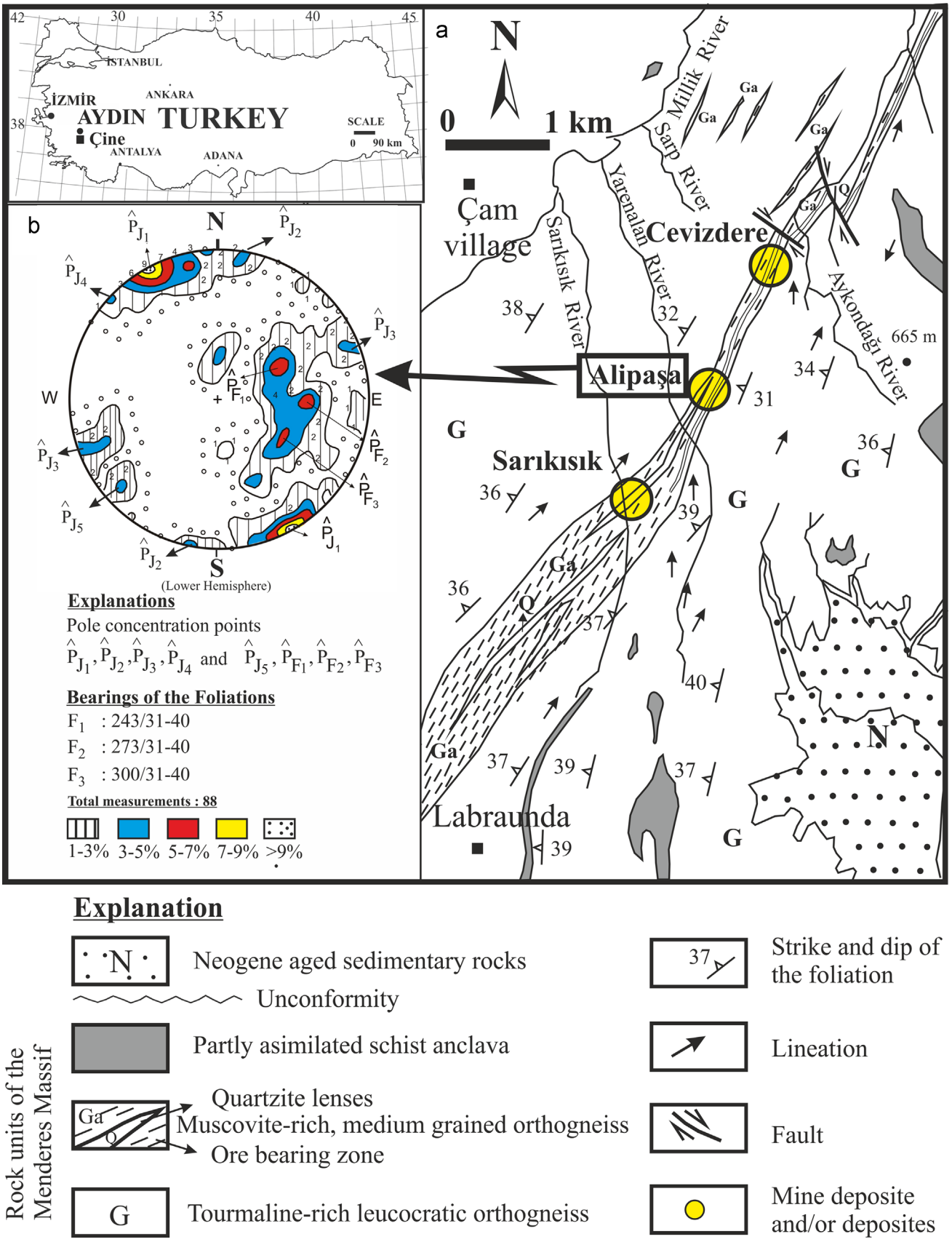

Fig. 1. (a): Location and geology map of the study area (modified from [1]), (b): Contour diagram prepared by utilizing from the attitudes of the discontinuities.

the mass movements observed in some benches. Accordingly, the idea which the overall slope could be affected from the slope slides in some of benches was dominated in mind of the concerned persons. Thus, all data was given by the authorities of the mine including the joint and foliation measurements, directions and amounts of the sliding movements in all sectors, attitudes of the