# Stress state of rock mass under open pit mining in the influence zone of tectonic disturbances (in terms of the Oktorkoi Fault, North Tien Shan)

**KCh Kozhogulov[1], OV Nikolskaya[1], AK Rybin[1,2] and SI Kuzikov[2]**

[1]Institute of Geomechanics and Development of Subsoil,
National Academy of Sciences of the Kyrgyz Republic, Kyrgyzstan
[2]Research Station, Russian Academy of Sciences, Bishkek-49, Kyrgyzstan

E-mail: krsu@krsu.edu.kg

**Abstract**. The qualitative connection between the crack growth direction and the orientation of the main axes of horizontal deformations in rocks mass in the area of the Boordin gold ore province is revealed. The effect of the rock mass quality (RQD) and contact conditions of crack surfaces on the stability index of pit wall rock mass is evaluated, and the influence of the rock mass quality index on the pit wall stability is determined.

One of the key tasks of open pit mining is stability of pit walls. Open pit mining in mountainous regions is faced with complicated geology, tectonics and hydrology. Enclosing rock mass is a rule composed of intrusive and effusive rocks susceptible to hydrothermal and metasomatic alteration. Rock mass is heavily fractured, and density of fractures grows at the contacts of rocks and faults.

It is highly important to ensure stability of pit walls in upland regions in the influence zones of faulting. Prior to starting mining, it is required to determine directions of the ground surface deformation inside the mine field and in adjacent areas.

In Kazakhstan gold deposits mostly occur at different regional faults, dip-slips and thrust faults.

At the present time, underground mining has been started at Taldy-Bulak Levoberezhny deposit, and surveying is implemented with a view to open pit mining at Kurandjailyau deposit. These deposits and mined-out fields such as Aktyuz and Kutesay belong in the Boordin gold ore province (BGOP). Spatially and structurally, they adjoin the Oktorkoi Fault (Figure 1).

The main faults in the ground in this region strength north-eastward and rupture comparatively young Palaeogene–Quaternary formations. The Oktorkoi Fault together with lower-scale faults of Chuyskaya Depression (Issyk-Atinsky, Shamsinsky) are active faults. Out of Central Asia GPS network points within the distance of 10–20 km from BGOP, only 3 discrete survey points are situated to the west and east of the gold ore province. In Figure 1 velocity vectors are plotted in the framework of EURA-2008 system for 1995–2015. The northern and southern GPS points are more than 30 km away from the province and are beyond the geographic limits in Figure 1. The absolute values of the velocity vectors are 2.3–3.8 mm/yr horizontally and –0.5–1.1 mm/yr vertically. The velocity vectors have narrow orientation window of 34–36°. It is noticeable that the northern and eastern components of the vectors gradually lower in the line from the south to the north, and on a regional scale.

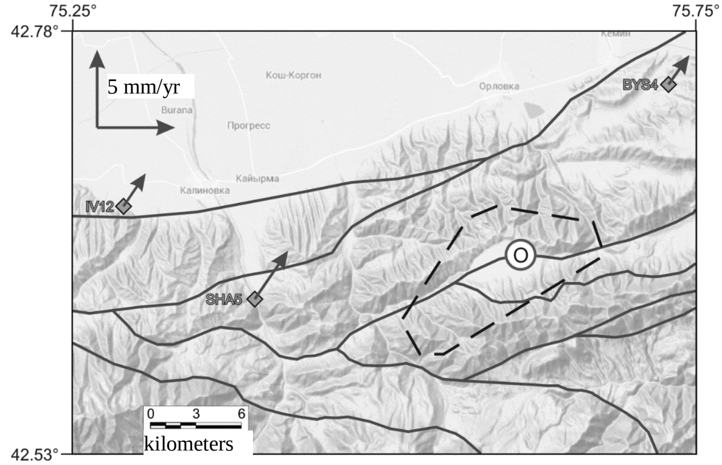


**Figure 1.** Boordin gold ore province—dashed polygon. Lines show active faults. O—Oktorkoi Fault; rhombs and signs—GPS points and their coded names; arrows—velocity vectors (mm/yr, EURA-2008, 1995–2015).

Moduli of difference (north to south) of the shown velocity vectors in three-dimensional space are IV12-BYS4 = 0.7, SHA5-BYS4 = 1.6, SHA5-IV12 = 1.2 mm/yr. The greater difference falls at the horizontal components (– 0.2, 1.2, 1.5 mm/yr, respectively) oriented at 20 to 36° (average ~30°). The vector difference moduli of the mentioned GPS points relative to the farther points are not higher than 3–4 mm/yr.

The averaged deformation picture in the area of BGOP based on the GPS data is shown in Figure 2. Here, based on the information from [1], the orientations and values of horizontal deformation velocity are given in the major axes with the averaging of data from GPS points within a radius of 25 km. The axes of contraction velocity are within a narrow range of azimuths 7–10° at the values of –31÷–66 (average –53)$\times 10^{-9}\times yr^{-1}$, respectively; in the axes of elongation velocity, the values vary as 9–23 (averageв 17)$\times 10^{-9}\times yr^{-1}$. The maximum velocities of deformation in the region of the Kirgiz Ridge are observed westwards this territory (~75°East longitude) and slightly exceed the presented values. The horizontal deformation velocity decreases from the west to the east and from the north to the south.

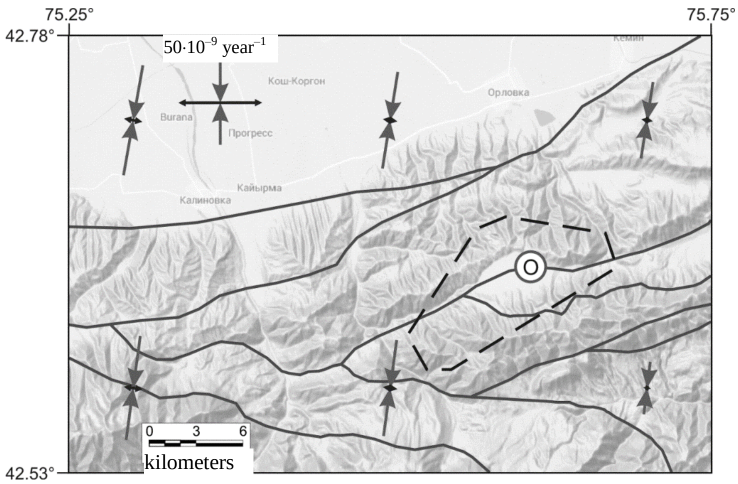


**Figure 2.** Arrangement of major axes of horizontal deformation in BGOP area (dashed polygon). Counter arrows—contraction; differently directed areas—elongation; the length of the arrows is proportional to the value of deformation relative to the reference of $50\times 10^{-9}\times yr^{-1}$.

Regarding the data on seismology in the given area, the orientation of major deformation axes is similar, the azimuths of the contraction axes are 350÷0°, and deformation is $-0.2\times10^{-9}$. The ratio of deformations in the axes of contraction and elongation is somewhat different. For instance, in the depth interval from 0 to 10 km, they are approximately equal; with depth the values grow along the contraction axes and reduce along the elongation axis to a ratio of 3 : 1, respectively [2].

With respect to the stress state in the discussed area, using the seismic data, it is possible to perform zoning of faults [3] by the value of normalized Coulomb's stresses $\tau_C / \tau_f$ . It appears that BGOP occurs in the zone of faults subjected to the increased stresses.

Considering the direction of the earth crust movement, values of deformation and the increased stresses of active faults, the detailed analysis of jointing of geological medium within Kurandjaylyau was carried out.

With this end in view, it was chosen to examine a section of the future pit wall the exposed surface of which clearly shows orientations of joints, and it was possible to count the systems of joints for the statistical data collection. Three basic systems of joints were distinguished within the test section. The average spacing of joints, estimated based on there measurements in different points of the pit wall, ranged between 0.02 and 0.1 cm. the main direction of growth of joints coincided with the revealed direction of tensile deformations of the earth crust (Figure 3).

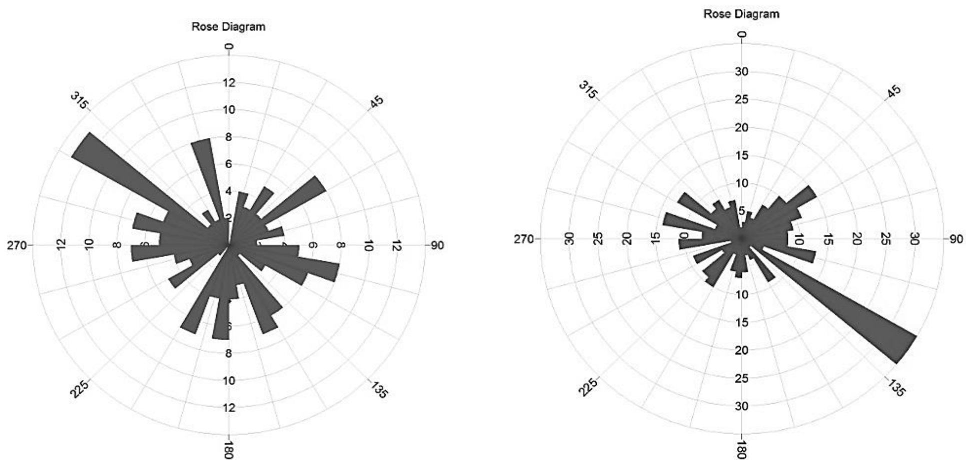


**Figure 3.** Illustrations of the principal orientation of jointing in the area under study.

The basic characteristics of rock mass jointing are the degree of jointing, average spacing of joints and a structural parameter.

In order to design safe pit wall in jointy rock mass, it is necessary to define the rock mass quality index *RQD*, rock mass rating and geological strength index *GSI* [4].

The international practice of rock mass quality estimation widely uses MRMR classification by Laubscher (Mining Rock Mass Rating) [5–7].

According to this classification, the rock mass rating is based not only on stress characteristics of rocks and their geomechanical behavior but also on the description of its jointing.

The index *MRMR* is given by:

$$MRMR = RMR \times K;$$

$$RMR = RRBS + JS + JC,$$

where *RRBS*—rock block strength; *JS*–index of joint number; *JC*—index of joint condition; *K*–persistence to account for weathering, joint orientation, rock mass stresses, blasting, groundwater.

Using the data on location of the major axes of horizontal deformation in the area of BGOP and directions of joints within the open pit mine under planning at Kurandjaylyau, it was assessed how tectonic faulting and jointing affected stability of enclosing rock mass around an open pit pit mine.

All values of strength characteristics determined from testing of drill core samples were recalculated for rock mass and corrected with regard to the degree of jointing in order to determine stability and slope of open pit wall.

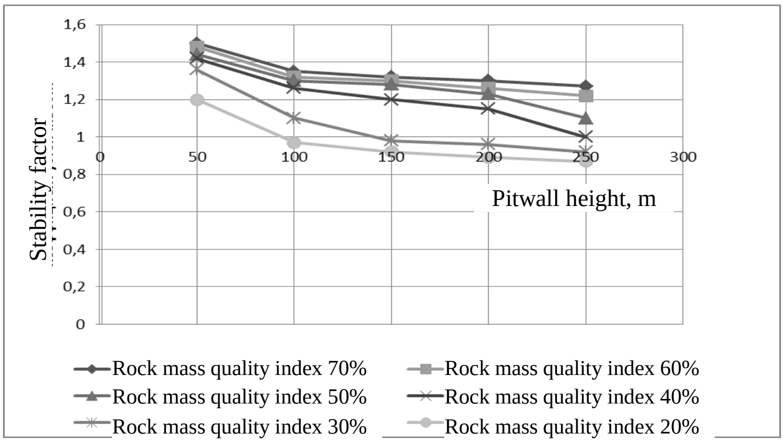


**Figure 4.** Stability factor versus depth of pit wall and rock mass quality index ($\sigma_{com}$ = 210 MPa, pit wall slope of 45 deg).

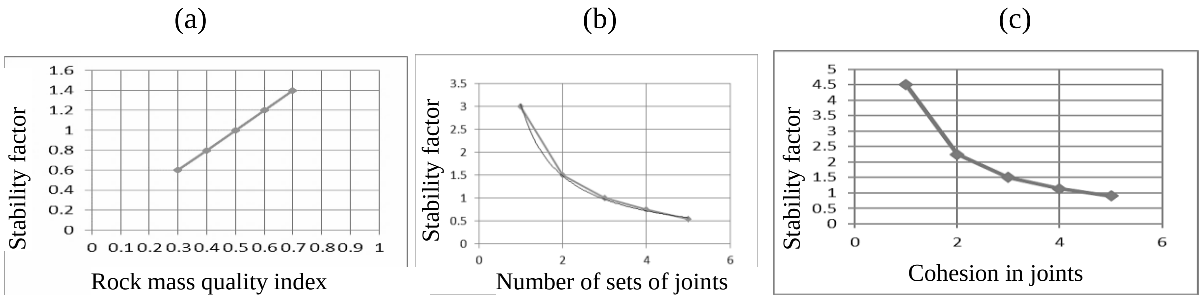


**Figure 5.** Stability factor of pit wall rock mass versus conditions of jointing: (a) rock mass quality index; (b) number of sets of joints; (c) cohesion in joints.

The average spacing of joints from the three measurements at different points of the slope is from 0.02 to 0.1 cm. the density of jointing is $w$ = 2.5. The structural weakening coefficient $\lambda$ = 0.03. By the rating *RQD*, the quality index of this rock mass is not higher than 0.2 [7].

The resultant characterization of stability of open pit wall rock mass is depicted in Figs. 4 and 5.

## Conclusion

The direction of the ground surface deformation is the governing factor of growth and orientation of joints in rock mass.

Jointing and the conditions of jointing exert a determining influence on rock mass quality and pit wall stability by the geological index of rock mass quality.

## References

[1] Mansurov AN 2016 The velocity field of the modern deformation of the Earth's crust of the Northern and Central Tien Shan according to the observations of the Central Asian GPS network *Vestnik KRSU* Vol 16 No 1 pp 157–160

[2] Rebetzkiy YuL 2016 Tectonic-physical zoning of active faults of the Northern Tien Shan *Geolog. Geofiz.* Vol 57 No 6 pp 1225–1250

[3] Sycheva NA 2016 Comparison of the estimates of the crustal deformation of the Northern and Central Tien Shan obtained on the basis of seismic and GPS data *Vestnik KRSU* Vol 16 No 1 pp 178–182

[4] Hoek E 2002 *Practical Rock Engineering* London: Institution of Mining and Metallurgy

[5] Laubscher DH 1990 A geomechanics classification system for rating of rock mass in mine design *J. South African Inst. Mining and Metallurgy* Vol 90 No 10 pp 257–273

[6] Laubscher DH and Jacubec J 2000 *The MRMR Rock Mass Classification for Jointed Rock Masses. Foundations for Design Brisbane* pp. 475–481.

[7] Bieniawski ZT 1989 *Engineering Rock Mass Classifications* New York: John Wiley & Sons