# The research of burst hazard of the rocks massif of Rasvumchorr mineral deposit according to seismoacoustic monitoring

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**Abstract.** Results of geomechanical research of burst hazard of the rock mass of Rasvumchorr mineral deposit with application of measuring complex are presented in the paper. Measuring complex includes the automated seismoacoustic system of rock pressure control "Prognoz-ADS" and the local geoacoustic device "Prognoz L". The measuring complex was developed in Mining Institute of the Far Eastern branch of Russian Academy of Sciences. Measurements and the analysis of parameters of the seismoacoustic events reflecting geomechanical processes in the developed massif is the basis for estimation of rock massif burst hazard.

**Keywords:** burst hazard, stressed state, seismoacoustic activity, tectonic disturbance, monitoring system, prognostic assessment.

#### 1 Introduction

The problem of rock pressure control is one of most difficult and important tasks in underground mining of mineral deposits. The most hazard forms of rock pressure are rock burst and mining-induced earthquakes. Rock pressure creates serious hazard for miners, breaks the normal mining operations and reduces the effectiveness of mining in the conditions of the deep horizons and big tectonic strength of the rock massif [1-4].

In Russia most the burst hazard of fields apatite-nepheline fields of the Kola Peninsula on which all range of dynamic manifestations of rock pressure is registered, up to destructive rock bursts with serious consequences are among, and the problem of their prevention is particularly acute very. Despite rather small depths of conducting mining operations on the "Integrated Kirovsky" Mine of the Kola Branch JSC "Apatit" (stocks the of the upper horizons are generally fulfilled now) all range of dynamic manifestations of rock pressure in the form of slabbing, a dynamic distribution of cases of intensive formation of rock blocks on the contour of working and rock bursts is already noted here. Due to the further decrease in mining operations body height of quantity and intensity of these dangerous phenomena is predicted. When drilling unloading wells, high pressure in the pillars (fig. 1) is confirmed.

The rock bursts are brittle failure of pillars or edge parts of the rock massif. The rock bursts happen at a particular combination of geological and mining conditions. One of the reasons of rock bursts is sudden destruction of edge parts of the rock massif in combination with the energy input from surrounding rocks. The changes in rock massif as a result of mining operations provoke activation of the hidden center of the seismic event created mainly due to energy of the deformations generated by natural nonuniformity of the tension field [5-6].

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**Fig. 1.** Destruction of crosswell interspace of unloading wells in the 5th bottom gangway (block 7/10, the "Integrated Kirovsky" Mine)

It is known that the most effective solution of this problem is reached at stages of design and constructions of the mining enterprises. In these stages there is an opportunity to provide a complex of the regional and local preventive measures beforehand. It sharply reduces hazard of dynamic manifestations of rock pressure.

Reliable on-line information about properties and conditions of the developed massif is required for this purpose. This information can be received with application of special methods and technical means. The most popular are geophysical, including microseismic and seismoacoustic measuring complexes

# 2 Mining-and-geological conditions and technology of development of mineral deposit

The apatite-nepheline mineral deposit Kukisvumchorrsky and Yuksporsky developed by "Integrated Kirovsky" Mine are located 8 kilometers to the northeast from the Kirovsk town, Murmansk region. The Rasvumchorrsky Mine has reserves of apatite-nepheline ores and performs mining preliminary works within mining lease of "Apatite Circus" and "Plateau Rasvumchorr" mineral deposits which are a part of the southwest ore field of the Khibiny massif [7].

These mineral deposits are 5.7 kilometers course, course of "Plateau Rasvumchorr" is 3.2 km and "Apatite Circus" is 2.5 km. Borders of "Apatite Circus" in the West with Yuksporsky deposit and in the east with the "Plateau Rasvumchorr" deposit are relative and pass across lines of exploratory wells.

Apatite-nepheline ores are located in the top of the intrusion of ijolite-urtite structure, and blocked by nepheline syenite-rischorrite. The top contact of a deposit with the covering minerals is sharp and visually established. The bottom contact is gradual and fixed by results of testing. Bedrock is porphyraceous urtite and ijolite-urtite (fig. 2).

Two sites are allocated on the "Apatite Circus" mineral deposit according the position, textural and structural features and quality characteristic:

1) The southeast site of a mineral deposit is complicated by bulges and narrowing. Thickness of a deposit changes from 70 to 160 m and average one is 117 m. All types of apatite-nepheline ores with grothite-apatite mineral on the top with 5-10 m thickness are presented here.

2) The northwest part of the mineral deposit is made up of brecciated and apatitenepheline ores with sharp variability of  $P_2O_5$  content and 10-50 m thickness. Veins of lujavrite up to 5 m cross the ore body. Principal angle of incidence increases in the top contact up to 40-50°. The extension of an ore deposit smoothly changes from width ("Plateau Rasvumchorr") to northern-west 290-300° ("Apatite Circus"). Structure of a deposit is non-uniform, symmetric and zonal.



1 - Quaternary deposits; 2 matte zones; 3 - rischorrite; 4 – luyavrite; 5 - malinyite: 6: a - urtite coarse and middle-grained, b - urtite fine-grained; 7: а melteygite, b - ijolite gneisslike; 8 - apatite-nepheline ores; 9 - spotty ores; 10 lens-lamellar ores; 11 titanite-apatite ores; 12 massive ores; 13 - block ores; 14: a - urtite apatite, b urtite with apatite; 15 - mesh ores; 16 spotty and lamellar ores; 17 - pit contours

Fig. 2 Schematic geological map of Rasvumchorr mineral deposit

The system of development with break of subfloor drifts with the subsequent collapse of pillar is applied on "Integrated Kirovsky" Mine. Height between subfloor developments is 24-30 m. Distance between drilling rooms is 25-30 m. Ventilating and assembly drift is on each block (or several blocks). Drift ends with the block fan for the organization of an outgoing stream during the clearing works.

At a subfloor system with face production of ore height between subfloors is 20-26 m, the distance between ore transportation developments is 16-24 m depending on conditions. The upraise ore-pass of an ore body are located perpendicularly in 95-100 m distance from each other; along an extension are located in 50-100 m. Drawing drift are developed for the connection of all the ore-pass rising to the uniform system of ore transportation. Their location depends on a block design.

The beginning of mining works on each subfloor begins with cutoff for the sublevel caving system. First of all, cutoff is a beginning for cutoff upraise.

During the level caving collapse with ore transportation under protection of a temporary over-drift (ort) pillar parameters of subfloor developments are the same, as at basic option of level caving. Difference is in preparation of the floor of the block. The size of an over-drift pillar is 12-20 m. Distance between ore transportation developments is14-16 m for break and transportation of ore under the caved ore massif and up to 24 m under a hanging wall for the assessment of a stability of mine caves at manifestation of rock pressure.

### 3 Methods and measuring control devices for burst hazard

Various methods and tools are applied for monitoring of a condition of testing block 7/10 and for the forecast of hazard manifestations of rock pressure during mining process on the "Integrated Kirovsky" Mine. Tools include the seismoacoustic control system of rock

pressure "Prognoz-ADS" developed at Mining Institute FEB RAS and the local "Prognoz-L" device [8-15].

Assessment of a geomechanical condition of the rock massif according to seismoacoustic monitoring with application of the automated control system of rock pressure (ACSRP) "Prognoz-ADS" is one of the most perspective directions of the forecast and prevention of sudden destructions of pillar and mine excavations [8-10]. ACSRP "Prognoz-ADS" is intended for the continuous registration of impulses of a seismoacoustic emission in 0.5...12 kHz frequency range in the massif of rocks, determination of their parameters (energy, coordinates, spectral and other characteristics of acoustic events) and representations of results of monitoring in the form of catalogs, maps, schedules, etc. with application of the modern software of 3D visualization. The measuring computer system allows to allocate and control parameters of the acoustic and active and potentially hazard zones, to carry out the assessment of a geomechanical condition of the massif of rocks.

The "Prognoz-ADS" system is developed on the basis of the modern microprocessor, software and geoinformation technologies, including high-performance computers with the special software.

The system of monitoring consists of underground and surface parts. The highperformance personal computer of the operator with the productive system of management of database which will provide data collection, processing and remote management of a system by local network is installed in the surface complex of "Integrated Kirovskii" Mine in department of geotechnical monitoring. The program complexes "GeoControl" and "GeoAcoustics-ADS" are a part of the software.

The following tasks are carried out in the automated workplace (personal computer) of the operator:

1. Processing of monitoring data in the GeoAcoustics-ADS application;

2. Work in AutoCad, CorelDraw, MineFrame, 2D and 3D graphics;

3. Work in local network and on a remote desktop of the underground computer.

Underground part of the Prognoz-ADS system includes switching and distributive knot (fig. 3) which is placed in an underground equipment room on -170 m horizon and the RADCi40 network. This network consists of piezoelectric digital transducers installed in different points of mine. Transducers are connected to with the switch node by the symmetric copper cable lines.



Fig. 3 Switching and distributive node of the automated system "Prognoz-ADS"

Highly sensitive piezoelectric transducers record impulses of an acoustic emission in 0.5-12 kHz frequency range. The digital transducers RADCi40 integrated with piezoelectric transducers (fig. 4), record an elastic impulse, keep in the memory buffer, process a signal and divide it from technological interferences, reveal the signal nature, transform an analog signal to a digital form and transfer to the database according RS-485 protocol. Database is stored on the personal computer in one box with switch node. The database in underground and surface computers of a system are synchronized each 10 min in the automatic mode. Reliability of data storage is provided. Piezoelectric transducers and RADCi40 digitizers are established in 2 m depth wells; they have 90-110 mm diameter, drilled horizontally in a mine working board. Converters are connected to distributive lines sequentially no more than 4 pieces on one channel.



**Fig. 4** Elements of the automated "Prognoz-ADS" system: a) RADCi40 digitizer; b) piezoelectric transducer in assembly with an embedded part

Thus, at the moment 13 piezoelectric transducers are established in a monitoring zone. They include 10 sensors on the -170 m horizon, (upraising drawing drift, the 5th drawing drift, the 4th drawing drift, the 7th drawing ort, the 10th drawing ort). Three sensors are located on -236 m horizon (31 ore transportation ort, 36 upraising ort, 31 upraising drawing drift).

The portable "Prognoz-L" device is intended for local express assessment of a geomechanical condition of regional parts of the massif and the peripheral sites of underground excavations. "Prognoz-L" is applied both independently and is collateral with the stationary automated multichannel control systems of rock pressure for verification of results of the regional forecast of rock bursts and technogenic seismicity [11-13].

The "Prognoz-L" device carries out the registration of impulses of the elastic vibrations radiated in the course of irreversible rocks deformation (process of a natural acoustic emission), determination of the acoustic emission parameters and calculation of indexes and criteria of burst hazard with delivery of projections about a condition of the rock massif (fig. 5).

For carrying out measurements by the "Prognoz-L" in mine conditions it is necessary to perform preparatory work which include:

1) setup of the device and modes of measurement;

- 2) choice of the points of measurement;
- 3) fastening of primary converter to the massif.



Fig. 5 Local "Prognoz-L" device

## 4 Results of seismoacoustic monitoring of the rock massif

The database of parameters of geoacoustic activity in a controlled zone is formed by results of seismoacoustic monitoring. The information contained in the database is constantly supplemented; it is a basis for the current and perspective forecast of the mine field and its certain sites. Maps of seismoacoustic activity, mining-and-geological models reflecting process of redistribution of tension in the massif under the influence of natural and technogenic factors, definition of seismoacoustic active regions are designed according obtained data (fig. 6).

Calculation of complex indicator of burst hazard is carried out for each allocated acoustically active regions by results of monitoring in the GeoAcoustics-ADS program.



**Fig. 6** The map of acoustic activity in the rock massif (block 7/10 "Integrated Kirovsky" Mine KB JSC "Apatite"; Jan.-Oct., 2018; level 236 m)

Parameters of acoustic activity in hazard zones in block 7/10 (external signs of burst hazard were periodically observed: spalling of mine working walls and a roof, and the crash in the massif) were confirmed by readings of device of local monitoring of rock pressure "Prognoz L". High amplitude of the recorded impulses of AE reflects the beginning of processes of join (clustering) of shallow cracks in larger ones that indicates the formation of burst hazard situation on this site of the rock massif (fig. 7).



Fig. 7 Signalogram reflecting emergence of important acoustic events

#### **5** Conclusions

1. The seismoacoustic method with use of the automated multichannel control system of rock pressure "Prognoz ADS" and portable devices "Prognoz L" is applied for the forecast of rock bursts on "Integrated Kirovskii" Mine.

2. The complex indicator of burst hazard considering a number of burst hazard signs (concentration of the centers of seismic-acoustic emission events, their energy, etc.) is applied for regional assessment of burst hazard. The following criteria are used for local monitoring of a condition of the massif with use of the geoacoustic device "Prognoz L": 1) quantitative criterion; 2) index of amplitude distribution.

3. Important advantage of "Prognoz-ADS" is an opportunity of preliminary, early stage, identifications of the centers of preparation of hazard geodynamic events that allows to take necessary measures for their prevention. Reliability of the forecast is provided by use of portable devices "Prognoz L". It is possible to introduce local control of burst hazard of regional parts of the massif by means of this devise.

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