Drilling and blasting parameters in sublevel caving in Sheregesh mine

AA Eremenko[1*], VN Filippov[1], AI Konurin[1], AP Khmelinin[1], DV Baryshnikov[1] and EA Khristolyubov[2]

[1]Chinakal Institute of Mining, Siberian Branch, Russian Academy of Sciences, Novosibirsk, Russia
[2]Gornaya Shoria Division, EVRAZRUDA, Russia

E-mail: *eremenko@ngs.ru

Abstract. The factors that influence geomechanical state of rock mass in Sheregesh Mine are determined. The authors discuss a variant of geotechnology with fan drilling. The drill-hole patterns and drilling-and-blasting parameters are presented. The revealed causes of low-quality fragmentation of rocks include the presence of closed and open fractures at different distances from drill-hole mouths, both in case of rings and fans, as well as the blocking of drill-holes with rocks.

Sheregesh iron ore deposit occurs in Gornaya Shoria within the Altai–Sayan folded zone featuring active tectonics and seismicity to Richter magnitude 7 and higher [1, 2]. The current mining depth is 800 m, the deposits is ranked in the rockburst-hazardous category [3].

Sheregesh Mine widely applies blasting technologies with changes 89 and 160 mm in diameter in mining with caving by blocks and levels with levels to 70–80 m high and blocks from 27 to 30 m wide. Ore levels are blasted in the direction of compensation space or are subjected to confined blasting. Blocks are undercut. Ore drawing involves vibration machines VDPU-4TM and scrapers.

Blasting is a process that has a highest influence on rock mass. After large-scale production and process blasts, aside from ore fragmentation, dynamic events due to rock pressure are observed, including spalling, bumps, microshocks etc of any intensity [4–6]. In connection with this, Podruslovy site was subjected to mining with sublevel caving at sublevel +255 ÷ +185 m.

Stoping starts with making a cut along the length of a block at the ore and rock interface. Slot raises in the extraction blocks are made by blasting in parallel holes drill from level +255 m. Then, ore is blasted from the cut towards the slot raise. Widening of the cut is made from drifts at level +220 m. The cut has the width not les than 3 m, its length is equal to the length of the block, the height equals the height of the sublevel +255/+220 m (35 m). While the cut is made, rocks from the caving zone above level +255 m is bypassed to level +220 m and fills the cut.

Confined blasting is performed toward the broken rocks in the cut (at the first stage) and then towards mined-out void filled by rocks. Fan of upward holes are drilled from drilling blind drifts at level +220 m. Ore is stopes is blasted by a layer per a fan. As mined-out stope is enlarged, ore blasting is made by 2–4 fans of blastholes.

Ore is discharged from stopes using load–haul–dumpers via entries of drilling blind drifts and in diagonal loading accesses driven from the haulage drifts at the level. For the safety of the haulage drifts, ore pillars are left above them. Complete ore extraction after total ore breakage in two adjacent

drilling drifts, the ore pillars left above the haulage drifts are drilled and broken in the backward direction towards the interblock ore pillars. As ore pillars are broken above the haulage drifts, broken ore is discharged from the haulage drift ends. An average block has a height of 45 m, length of 40 m and a width of 20 m.

Ore in stopes is broken by sections. At first, when blasting is performed toward the cut, a section is made by 1–2 fans of blastholes. After a few explosions in the stope, the confining space becomes wider to 12–15 m, and a blasting section can be 2–4 fans. In blasting, explosive Grammonit M21 is arranged in holes with a diameter of 89 mm. In the confined blasting by fans at the fragmentation standard of 500 mm, the powder factor ranged from 0.73 to 64 kg/m^3.

The burden in the confined blasting was 1.8 m, the spacing of ends of holes in fans was 2.3 m. The drilling-and-blasting design in a fan is described in Tables 1 and 2.

From the evidence of the analysis, specific consumption of explosive for secondary fragmentation remains high and is 0.3 t/m^3. Therefore, the studies were initiated to understand the causes of off-standard fragmentation by means of georadar surveys and visual observation in fans of blastholes.

Table 1. Drilling-and-blasting design.

Hole no.	Hole length, m	Charge length, m	Uncharged length, m	Explosive weight, kg
1	8.9	3.2	5.7	23
2	10.9	6.8	4.1	48
3	13.7	7.9	5.8	56
4	17.7	14.7	3.0	104
5	16.7	9.4	7.3	67
6	16.0	13.5	2.5	96
7	15.6	8.8	6.8	62
8	15.5	13.1	2.4	93
9	15.6	8.8	6.8	63
10	16.0	13.5	2.5	96
11	16.7	9.4	7.3	67
12	17.7	14.7	3.0	104
13	13.7	7.9	5.8	56
14	10.9	6.8	4.1	48
15	8.9	3.2	5.7	23
Total:	214.5	141.7		1006

Table 2. Blasting parameters.

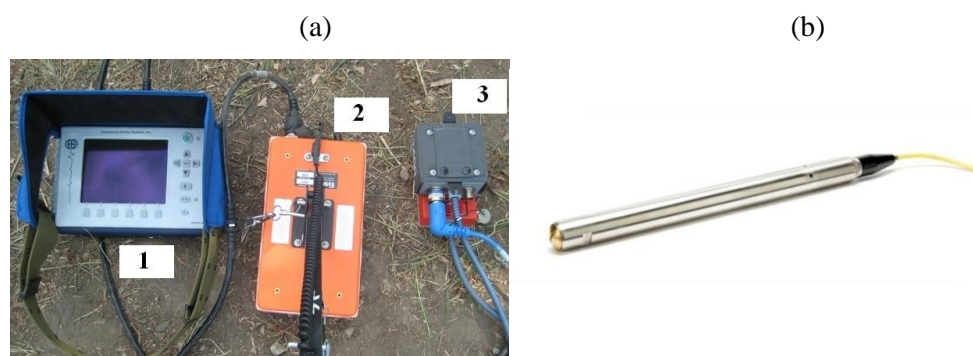| No.	Description	Unit of measurement	Total
1	Broken ore volume	m^3	604
2	Hole length	m	14.3
3	Total hole drilling length	m	214.5
4	Number of holes	holes	15
5	Quantity of: Explosives	kg	1006
	Electric detonators	detonators	24
6	Specific consumption of explosives for secondary fragmentation	t/m^3	0.2–0.3

Figure 1. (a) Georadar SIR-3000 with antenna assemblies: 1—georadar; 2—antenna assembly with the central frequency of 900 MHz; 3—antenna assembly with the central frequency of 2600 MHz; (b) down-the-hole probe with the central frequency of 1000 MHz.
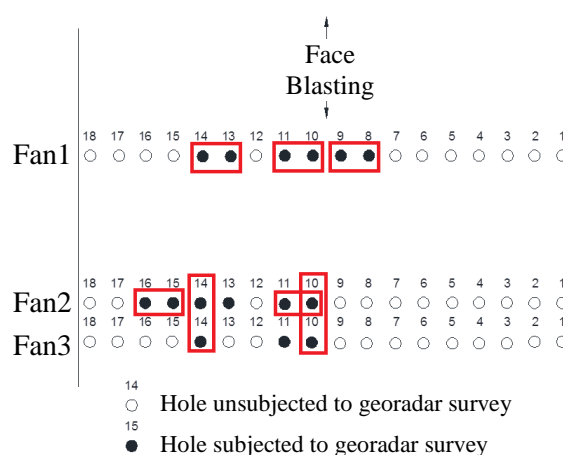

Figure 2. Drilling patterns in fans 1–3.

Georadar survey was carried out using georadar SIR-3000 with an antenna assembly having a center frequency of 2600 MH for calibration tests and using hole probes with center frequencies of 500 MHz and 1000 MHz (Figure 1). The patterns of drilling and arrangement of fans are shown in Figure 2.

The measurement probe was installed in a hole, and a metal rod was placed in the neighbor hole. The probe and the rod were simultaneously put deeper in the holes, and georadar made marks in the hole each 50 cm with a view to match the georadar survey data and the hole length together. In the radargrams, these marks are shown as white dashed lines. Upon reaching the hole bottom, the data recording stopped and the test was performed in the backward direction. After the in situ tests, the detailed analysis of the obtained radargrams was undertaken with RADAN.
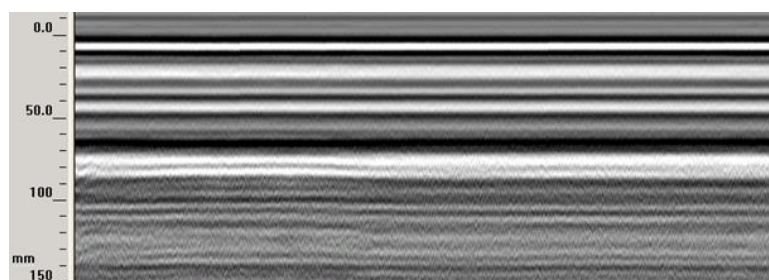

Figure 3. Radargram after calibration tests of georadar on a specimen.

After the georadar calibration test on a specimen of ore, it was found that the probing signal attenuated greatly and the radargram contained numerous multiple frequencies. The presence of such frequencies can be explained by conduction currents that are the sources of secondary waves inconsistent with the reflections from the ore–air interface (Figure 3).

After calibration and adjustment of the value of capacitivity, holes 8–9, 10–11 and 13–14 in the first fan were surveyed (refer to Figure 2).

The analysis of the radargrams in the listed holes yields that the useful signal is heavily depressed. At a depth of 70–80 mm, the clear line of correlation corresponds to the reflection from the inward surface of the hole. At a depth of 280–300 mm, the line of correlation is conditioned by spurious multiple frequencies that are noise and useless. So, in the tested segment 2 m long, the hole spacing is 40–50 mm, the useful signal corresponding to the reflection from the metal rod attenuate with depth and is barely distinguishable in the radargrams.

In the second stage, the tests were carried out in the second fan after the first fan blasting was completed.

At a depth of 80–85 mm, the clear line of correlation conforms with the reflection from the inward surface of the hole as in the radargrams in the first fan. At a depth from 280 to 340 mm, the line of correlation is conditioned by spurious multiple frequencies that are noise and have no useful information.

In the segment of the first 2 m in the hole, there are correlation lines corresponding to the reflections from the metal rod. The spacing of the hole at this depth is from 45 to 60 mm. The useful signal attenuates with depth in the hole and is untraceable against noise.

In the third stage, the holes in the neighbor fans were examined, namely, in the second and the third fans.

The radargrams from the neighbor fans contain correlation lines corresponding to the reflection from the inner surface of the holes (at a depth from 80 to 85 mm) and spurious signals that are noise. The line of correlation to fit the reflection from the metal rod is undistinguishable in the radargrams, which is explained by heavy attenuation of the signal in ore by the numerous multiple re-reflections induced by spurious conduction currents.

The visual inspection exhibited locations of closed and open cracks in the hole and hole bottoms (Figure 4 and Table 3).

It has been found that after explosion, the coverage is observed at the depth from 11.1 to 14 m in fan 1, from 12.1 to 12.4 m in fan 2 and at 12.4 m in fan 3. The length of the holes is 9.4 to 20.2 m. Cracks grow in-between the holes at a depth of 5.2 and 10.4 m (holes 3 and 5), 13.4, 15.8, 16.9 and 18.7 m (holes 5 and 8) etc. Between fans 2 and 3, cracks merge at a depth of 2.8, 4.1, 8.0 and 13 m and deeper. Cracks from fan 1 seldom reach fan 2: at a depth of 10.8, 15.8, 17 and 19.9 m.

Figure 4. Images of holes and cracks in fan 1.

Table 3. Summary data on depths of holes in fans 1–3.

Fan 1	3	5	8	9	10	11	12	13	14	15	16	17	18
Depth, m	13.0	>20.2 (nd)	>19.3 (nd)	>19.4 (nd)	>13.8 (c)	11.7 (c)	11.1 (c)	10.4 (c)	11.0 (c)	11.1 (c)	15.0 (c)	124	9.4
Fan 2	3	6	–	9	–	11	–	13	–	15	–	–	–
Depth, m	13.1	>20.0 (nd)	–	>12.2 (c)	–	>12.1 (c)	–	>12.4 (c)	–	>13.6 (c)	–	–	–
Fan 3	4	6	8	–	–	11	–	–	–	15	–	–	–
Depth, m	>18.6 (nd)	>19.4 (nd	>18.4 (nd)	–	–	12.4 (c)	–	–	–	>13.2	–	–	–

Comment: nd—depth not determined; c—coverage

Conclusion

The drilling-and-blasting patterns have been design for fan drilling and blasting in the conditions of Sheregesh deposit.

The research has revealed factors of influence on the blasting quality, including drilling patterns and the presence of crack at different distances from the hole mouth.

The research proves that the georadar survey aimed to estimate expansion of hole spacing in magnetite ore is impossible. The further research will use the method of ultrasonic sounding.

Acknowledgments

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