UNDERHAND CUT AND FILL STOPING WITH ARTIFICIAL ROOF
1. Outline

Underhand cut and fill stoping with artificial roof was developed in the 1960s at Kosaka Mine, in Akita Prefecture, the Kuroko mine. Kuroko, a relatively young deposit in Japan, was formed by sedimentation from activities of subterranean volcanos about 15 million years ago. While the Kuroko deposit boasts a very high economic value because it contains gold, silver, copper, zinc and other rate metals, the ore in accompanied with clay and mud, because it is a sedimentation deposit of submarine origin, and contains many cracks. This phenomena brings with it strong roof pressures that must be effectively controlled during stoping.

This superior stoping method has a number of advantages and since its development, it has thus been the fundamental technology for exploiting the Kuroko deposits in Japan:

1. It provides unparralleled stoping performance, nearly 100% of ore bodies of even the most complicated shape can be extracted without dilution by waste.

2. It is a safe method with no fear of roof fall, because work is done under an artificial roof of reinforced mortar.

3. It hardly influences the ground surface because it fills quickly and perfectly backs the mined stopes, enabling control of strong roof pressures.

In the text, using Hanaoka Mine as an example, underhand cut and fill stoping with artificial roof
in a trackless system is explained in the order of processes.

2. Exploration and Development

At Hanaoka Mine, excavation of galleries for exploration and development has been streamlined and standardized by taking future ventilation and haulage systems into consideration:

(1) On the basis of information obtained from surface core drillings, lower levels are excavated 20 to 30 meters below the ore horizon.

(2) Taking the lower level as a base, core drillings are driven upward in a fan shape to confirm the ore body form. At Hanaoka Mine, a high efficiency has been achieved by reverse circulation method, which feeds pressurized drilling mud into the outside of the boring rod, i.e. the gap between the rod and the rock bed surface or the casing. The core, together with the drilling mud that is returned to the inside of the rod, is continuously taken up along with the progress of the core drilling.

(3) Upper levels and then inclined drifts are excavated onto the ore horizon.

(4) An ore pass is excavated between the upper and lower levels with a shield raise machine. A raise of up to 1.8 meters across can be driven very safely and very efficiently with this machine which can prepare supporting with shielding segments of iron while excavating with a large caliber bit.

After completion of ore passes, lower levels are used as haulage levels for trucks and, in the future, also as air-return ways by connecting them to upper levels with air way thirling.

3. Stoping

Stoping is conducted successively from upper to lower slices by horizontally dividing the ore body into 3-meter thick portions and excavating these levels with headings 5-meters wide by 3-meters high.

(1) A gate drift is driven horizontally and straightforward into the uppermost slice of the ore body.

(2) A cross-cut stoping is begun at right angles to the gate drift when no ore is obtainable from the gate drift.

(3) The cross-cut drift is subjected to the hydraulic backfill with tailing mortar immediately after the completion of stoping, and an adjacent cross-cut stoping is driven.

(4) Stoping is driven from the far end to the front side of the gate drift and ore is replaced with mortar by repeating cross-cut stoping and the backfilling.

(5) Stoping is shifted to the next slice just under the uppermost one when the latter slice has been completely backfilled. The second slice is stoped using procedures (2) through (4), and thus stoping is extended to the lower slices.

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Fig.2 Typical Configuration of Underhand Cut and Fill Stoping with Artificial Roof
As mentioned above, this method is used to stope an ore body while driving a drift; one drift driving-cycle consists of blasting, mucking and timbering. Accordingly, stoping work is a simple repetition of this cycle, which makes standardization of the work easy. A key element to ensuring profitable throughput of ore is to efficiently repeat the operation. Hanaoka Mine has obtained good results by introducing turntable, small-double drilling jumbos that can drill rock at right angles to vehicle movement direction even in a narrow drift, by using timbering vehicles (Timbos), and communication system provided with continuous 2-way communications, as well as by adopting a group-working system in which a four-worker group takes charge of three stopes.

![Fig.3 Timbering Vehicle (Timbo)](image)

Attention should be paid to following items during stoping.

1. For each slice, excavation of upper levels and inclined drifts is planned and performed after sufficient consideration of approached to the corresponding level.

2. Depending on the shape of the target ore body, stoping of each slice is so designed that as far as possible the gate drift is shorter and cross-out drifts are longer and less in number.

   - The gate drift, which must be maintained over a long term, is made short.

   - The time and labor for opening a cross-cut drift worked from the gate is minimized.

   - Most of the preparation work for backfilling is spent on fabrication of bulkheads for backfilling. Therefore, reducing the number of cross-cut drifts and making them longer results in a reduction of the number of bulkheads.

3. The specifications of the drift heading must be followed, the floor level must be horizontal, and the gate and cross-cut drifts must be prepared at the same level. The size of the heading directly influences the stress concentration, and an uneven floor brings about an uneven roof when spotting the level just below the level under existing spotting. (However, with a drift that hits the end of an ore body, the heading and level of the drift is adjusted to prevent mixing-in of waste.)

4. For blasting under artificial rooves, back holes must be limited to a very small number and be drilled at low positions at low angles. When drilling and explosive charging are appropriate, ore will spontaneously come off from, or can be readily peeled off in the way of scaling from, the artificial roof mortar. No lagging is needed under artificial rooves.

4. Backfilling and Its Preparation

The stoping method is so distinctive that the drift is excavated by blasting just below previous backfills, and its peculiarity is to place reinforced artificial rooves some 60-centimeter thick in hydraulic backfilling. The procedures are explained as follows:

4-1. Preparation for Backfilling

1. Positions of bulkheads must be decided. Basically any mined stope (i.e. any unnecessary drift) must be immediately backfilled. To provide compact backfilling and to prevent leakage of backfilling material, bulkheads must be located at a site where the artificial roof is as high as possible (because the backfilling material can be hydraulically transported only up to the top of a bulkhead, as transported water is squeezed out), there must be no cracks in the sidewall, and the fabricating bulkheads must not prevent work being performed in the vicinity.

2. The floor of the drift to be backfilled must be leveled out with a bulldozer.
(3) Iron bars are laid on the leveled floor. First, 6-cm square wooden spacers are spaced on the floor, 13-mm diameter iron bars are nailed on these spacers. In principle, iron bars are arranged with a 30-cm pitch in the lengthwise direction and with a 2-m pitch in the transverse direction.

(4) Bulkheads are fabricated. Bulkheads are used to partition the drift to be backfilled, to receive cement mortar transported hydraulically, and to squeeze out transported water. A bulkhead must be provided with a large window where a worker can enter and exit to confirm conditions of the hydraulic transport system immediately before backfilling up.

(5) Piping must be provided for backfill transportation and drainage. To compact the backfill up against the roof, the discharge opening of the backfill transportation line should be fixed as high as possible. The preparations for backfilling have been completed when an underwater pump in front of the bulkhead is in place to drain off the transported water squeezed out from the bulkhead.

4-2. Backfill Transport

(1) The artificial roof is fabricated. A 13% mixture of cement with tailings and volcanic ash is hydraulically transported to form a 60-cm thick backfill layer on the floor of the backfill drift, whereby:

. A complex and compact mixture consisting of a number of useful components, Kuroko is ground down to a 70 % minus-200-mesh at a mill, and is then subjected to flotation. Such fine tailings cannot ensure adequate backfilling strength, so that the tailings are sized with a cyclon at the mill, and only relatively rough under-flow is used for backfilling.

. Volcanic ash is added to enhance dehydration and to increase backfill strength.

(2) After one night to allow dehydration and curing, the artificial roof is checked for fabrication, and a 3 % -wt mixture of cement and tailings is hydraulically transported onto the artificial roof.

. Here again, only under-flow of tailings from the cyclon is used.

. The bulkhead must always be kept under observation during hydraulic transport, so that the bulkhead is not destroyed by the transport pressure. If necessary, the backfilling work should be divided into 2 or 3 portions with one night intervals for dehydration and curing.

5. Conclusion

During the quarter century since the stoping was devised, various improvements and technological developments have allowed underhand cut and fill stoping with artificial roof to greatly contribute to the development of mining technology in Japan, and assisted the exploitation of the Kuroko deposits. The stoping method is expected to undergo further development, and in future be applied as a safe and efficient mining method for not only the Kuroko deposit, but also for many other kinds of economically valuable ores. It will also be effective for excavating large cavities in soft rock beds in the civil engineering field.