The awesome power of gravity

Sublevel stoping, in all its forms, is probably the most widely used method in modern underground mining, and the technique continues to be adapted and improved.

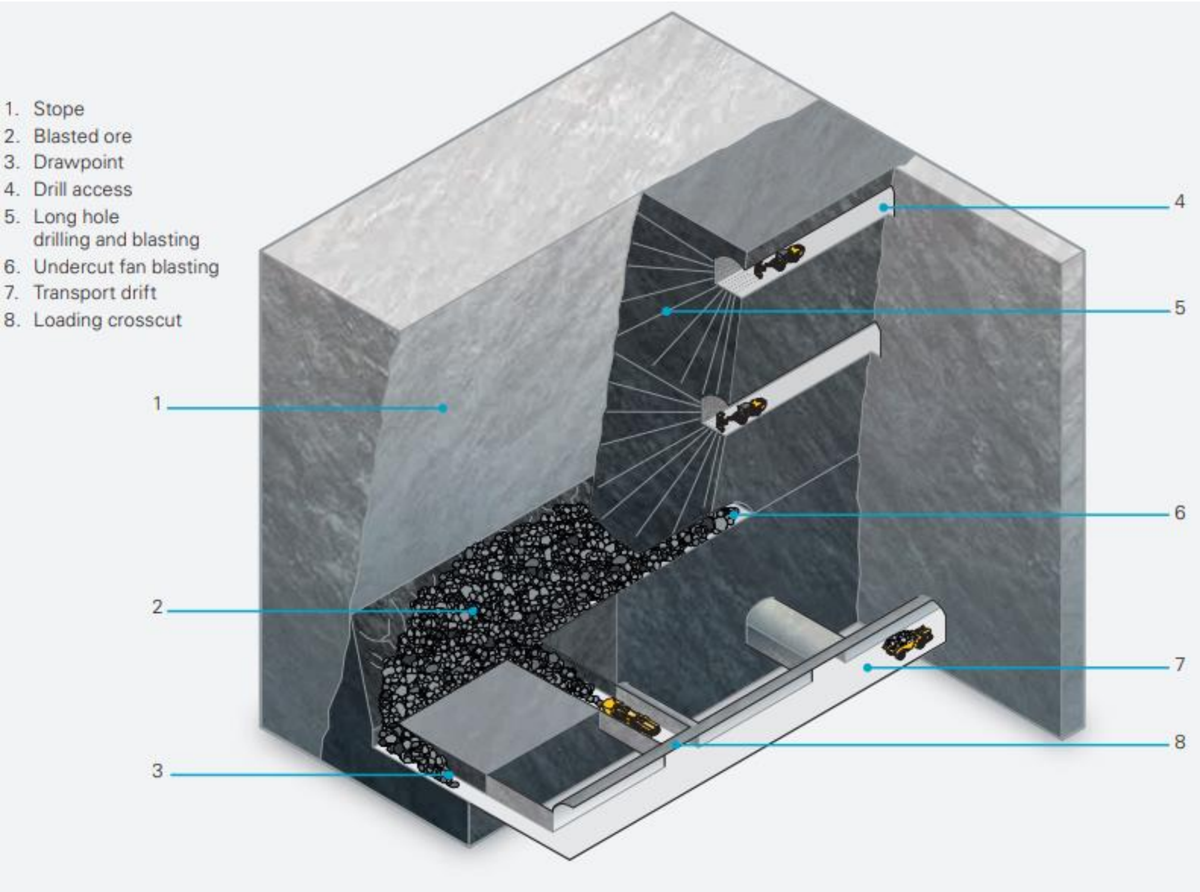

Figure 1: In the sublevel open stoping method, backfill will be used when each stope has been mined out for stability reasons. The stopes may be separated by vertical beams and crown pillars.

Sublevel stoping is the collective term used for the mining of large, steep orebodies with a dip generally exceeding 50º. The technique is based on the principle of allowing blasted material to be transferred by force of gravity to a lower level for loading and haulage.

It is a versatile and productive method that can be applied effectively in massive orebodies with a high mineral content covering many square kilometres, as well as to small- to medium-sized orebodies with limited mineralization. Used primarily for large-scale mining, sublevel stoping is based on the principle of blasting out large voids (stopes) and leaving waste rock intact in the hanging wall and footwall, as shown in Figure 1.

There are four main variations of the sublevel stoping method:

- Sublevel open stoping
- Bighole stoping
- Shrinkage stoping
- Vertical crater retreat

Sublevel open stoping

Sublevel open stoping (SLOS) is used for mining large orebodies with a steep dip, regular shape and with well-defined ore boundaries, and where the footwall inclination exceeds the angle of the repose. The rock, in both the hanging wall and footwall, should be competent and stable, and the host rock mass should be of high quality. SLOS recovers the ore in large open stopes, which are usually backfilled to create pillars to enable recovery of ore pillars. The pillars are normally shaped as vertical beams across the orebody, and horizontal sections of ore are also left as crown pillars.

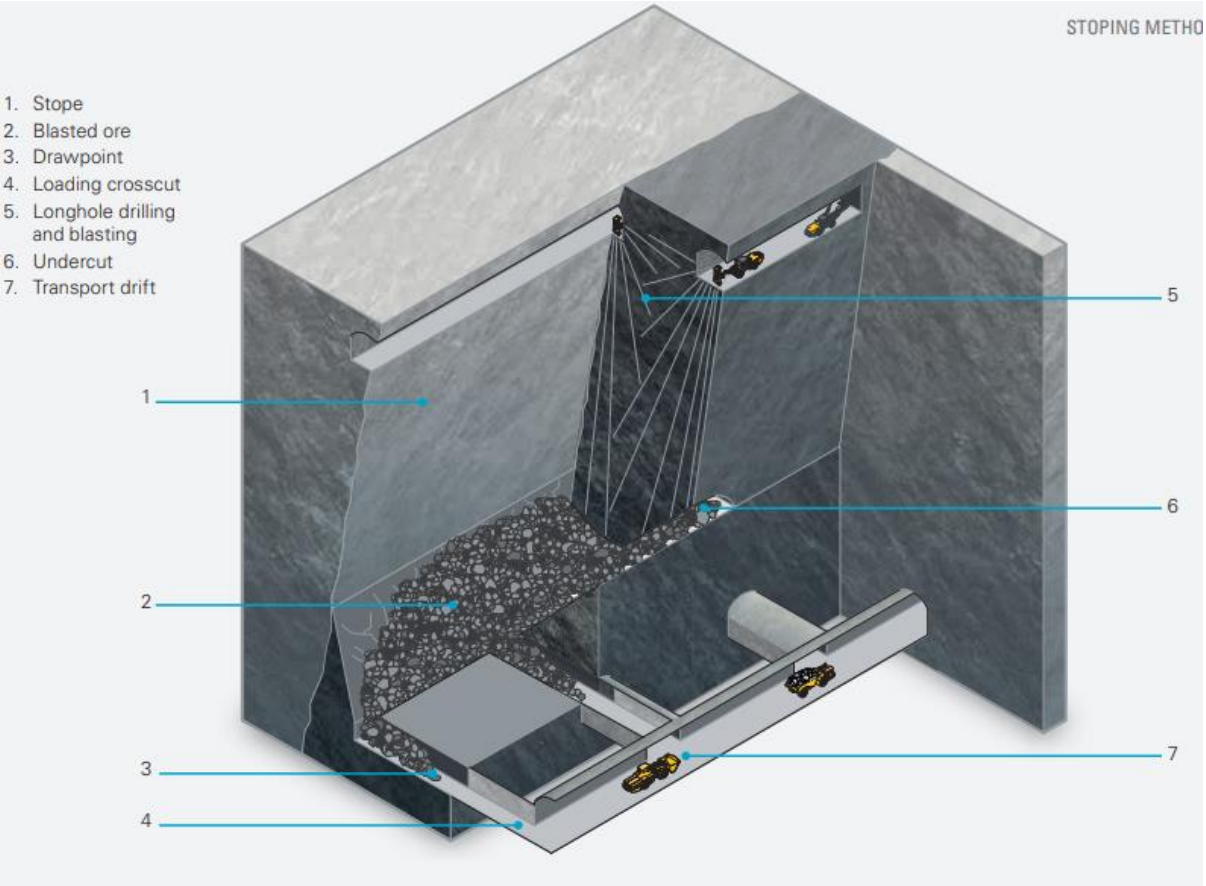

Figure 2: Alternative drill and blast pattern for open-stope mining. Drilling along the rim of the orebody may yield a better ore recovery and possibly less dilution.

Sublevel drifts are located within the orebody between the main levels for long hole drilling. The drill pattern accurately specifies where the blastholes are collared, and the depth and angle of each hole. Drawpoints are located below the stope to enable safe mucking out by LHD vehicles, which tip the material into an adjacent orepass or into trucks or rail cars for haulage.

In more narrow orebodies, a trough-shaped stope bottom is typical with loading drifts at regular intervals. Nowadays, the loading level can be integrated with the undercut, and mucking out performed by a remote controlled LHD working in the open stope. This reduces the amount of drift development in waste rock. If the orebody is wider, the method is to develop crosscuts through the orebody that are mined and backfilled in very well-defined sequences to achieve stability and to keep up the productivity.

A good example of how this method has been put to skillful use is the Lappberget orebody at the Swedish mine Garpenberg, where the ore can be 60 m wide through considerable vertical distances. Here, sublevel stoping using a system of primary and secondary stopes progressing upwards has proven to be a reliable solution. The primary stopes are 15 m wide and 20 m high and are filled with paste made from concentrator tailings and mixed with about 5% cement.

The 20 m wide secondary stopes are filled with development muck without cement. High precision drilling is necessary to get optimum ore recovery and fragmentation.

Sublevel stoping has several advantages. It is a good, selective mining method and a common choice in areas where surface disruption is not permitted by using, for example, a caving method. It also enables the orebody to be divided into different stages with a multitude of stopes in operation on different levels at the same time.

Rill mining

Rill mining is a special mining method that can be described as a modified version of sublevel stoping. It was first developed when mining the relatively small Tyskgården orebody at Garpenberg, where large quantities of development muck had to be accommodated underground as hoisting was the only method used for transporting the ore.

The method involved drilling 10 m wide cut-off slots across the orebody using up-holes, which were then blasted in one single firing starting from the center. Seven 127 mm holes were left uncharged to provide sufficient expansion for the remaining 64 mm holes. After the slot had been opened, 70° up-hole fans consisting of eight approximately 17 m long holes were blasted into the void.

As shown in Figure 3, three rows comprising a total of 24 holes are blasted simultaneously. After each blast is mucked out, new waste is discharged into the stope forming a 45° rill (hence the method's name) into the drawpoint.

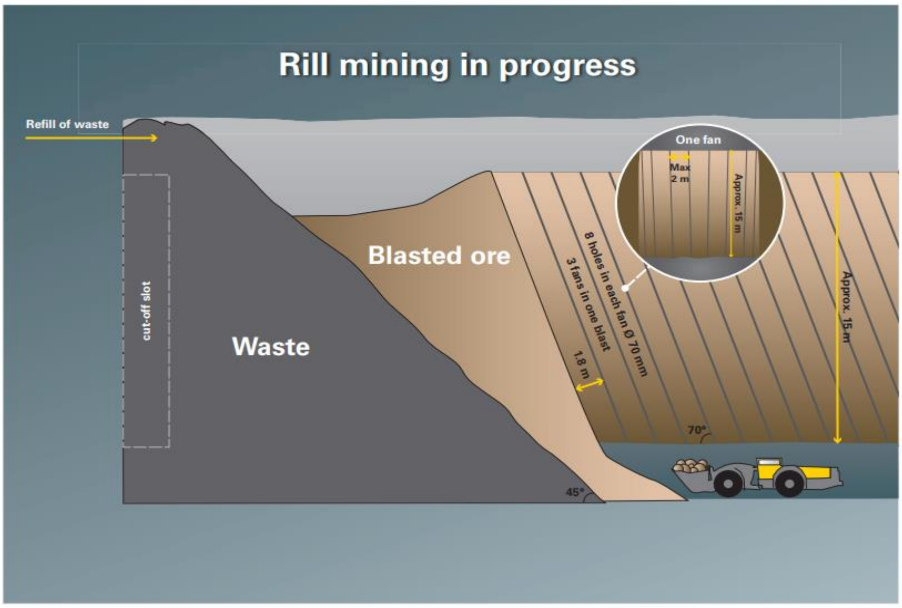

Figure 3: Rill mining is a method that involves the simultaneous blasting of holes to create a 45° "rill" in the drawpoint. It was first developed at the Swedish mine Garpenberg and facilitates the mucking-out process in mines where hoist shafts are not installed.

Bighole stoping

Bighole stoping is an upscaled variant of sublevel open stoping using longer, larger diameter DTH blastholes ranging from 140 up to 165 mm (see Figure 2).

The blast patterns are similar to those used in SLOS but with holes up to 100 m long. A pattern with 140 mm blastholes will break a rock slice 4 m thick with 6 m toe spacing. DTH drilling is more accurate than tophammer drilling, allowing the vertical spacing between sublevels to be extended from an absolute maximum of 40 m in SLOS mining to 60 m in big hole stoping.

However, the risk of damage to the rock structures has to be taken into account as the larger holes will contain more explosives. Side rock stability is also important to consider as it must be very competent to allow this kind of scale. During mining, the ore can also be used to stabilize the sidewalls of the stopes, and this technique is particularly common in shrinkage stoping and vertical crater retreat mining. In these methods, the surplus of the blasted ore is mucked out after blasting, and the major part is left in the stope while mining continues and is then mucked out at a later stage when all blasting is completed.

Shrinkage stoping

In shrinkage stoping, a traditional mining method less common today, ore is excavated in horizontal slices starting from the stope bottom and advancing upwards. As mentioned earlier, part of the blasted ore is left in the stope to serve as a working platform and to give support to the stope walls.

Blasting swells the ore by about 50%, which means that a substantial amount has to be left in the stope until mining has reached the top section, after which final extraction can take place.

Shrinkage stoping can be used for orebodies with steep dips, comparatively stable ore and sidewall characteristics, regular ore boundaries and ore unaffected by storage. (Some sulphide ores oxidize and generate excessive heat.)

The development consists of haulage drifts and crosscuts for mucking at the stope bottom, drawpoints and undercuts, and a raise from the haulage level passing through the undercut to the main level to provide access and ventilation to the working area.

Drilling and blasting are carried out as overhead stoping. The rough pile of blasted ore prevents the usage of mechanized equipment, making the method labor-intensive. As such, working conditions are hazardous, and a large part of the ore has to be stored until final extraction. Despite these drawbacks, shrinkage stoping is still a method that could be used, especially in small-scale operations.

Vertical crater retreat

Vertical Crater Retreat (VCR) applies to orebodies with a steep dip and competent rock in both ore and host rock. Part of the blasted ore will remain in the stope over the production cycle, serving as temporary support for the side rock (see Figure 4). This mechanized method can be regarded as a considerably safer form of shrinkage stoping, as no men have to work inside the stope.

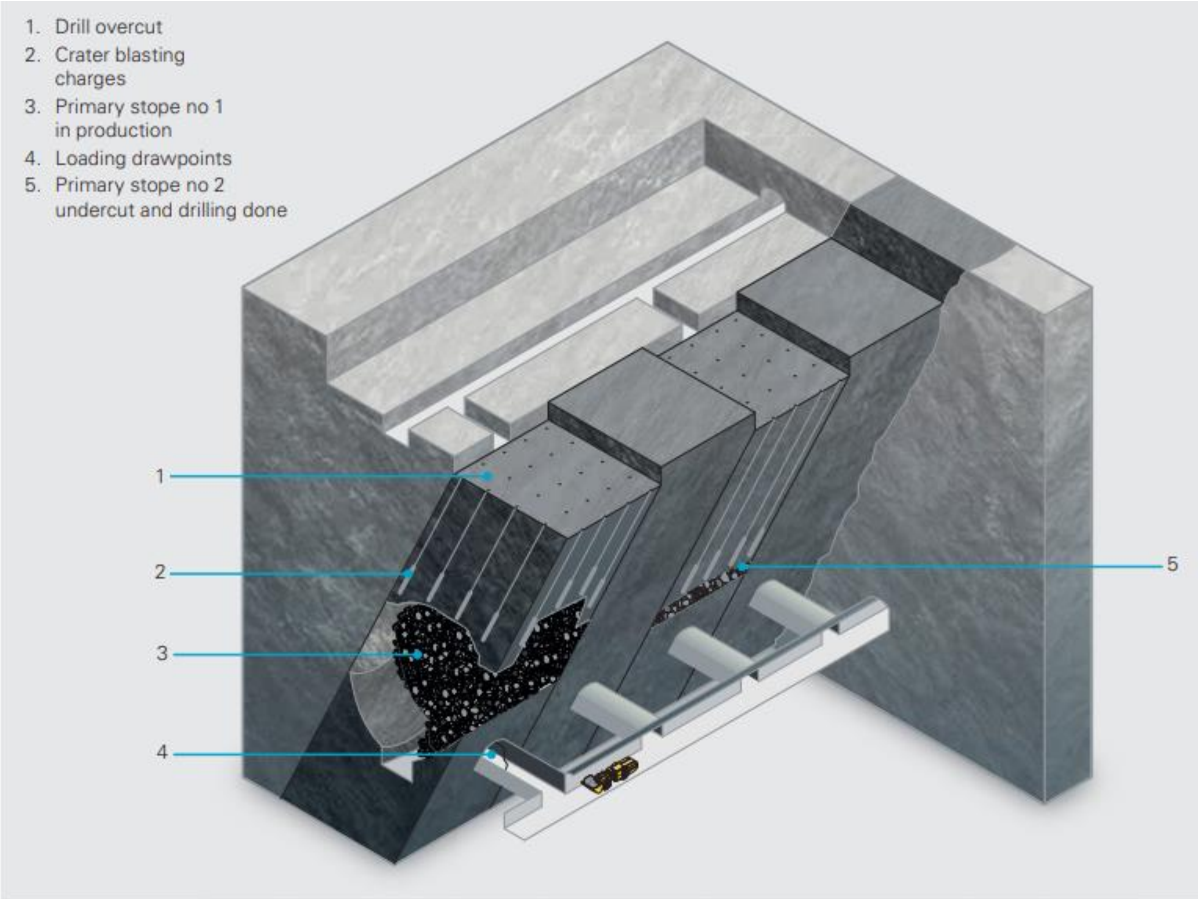

Figure 4: Mining by use of the vertical retreat method (VCR). It is an alternative method to shrinkage mining and provides a safer working environment.

VCR was originally developed by the Canadian mining company INCO and uses the crater-blasting technique with powerful explosives in large-diameter holes. Concentrated spherical charges are used to excavate the ore in horizontal slices from the stope bottom upwards.

The ore gravitates to the stope bottom drawpoints and is removed by loaders. Each stope is cleaned out before backfilling with cemented hydraulic fill. Development for VCR stoping consists of a haulage drift along the orebody at the drawpoint level, a drawpoint loading arrangement underneath the stope, an undercut and an overcut access for drilling and charging. The ore in a stope block is drilled from the overcut excavation using DTH drill rigs. Holes, mainly vertical, are drilled downwards, breaking through into the undercut. Hole diameters vary from 140–165 mm, commonly spaced on a 4 m x 4 m grid.

From the overcut, powerful spherical charges are positioned by a skilled crew in the lower section of the blast hole and at specified distances from the stope roof. The hole depth is measured, and it is stemmed at the correct height. Explosive charges are lowered down each hole and stemmed, usually to blast out a 3 m slice of ore that falls into the space below. VCR charging is complex and its techniques have to be mastered in order to avoid damaging the surrounding rock.

The Role of raises

In the production areas, raises are often used as openings to accommodate the initial blast and start up the stoping process. If these raises are not opened by raise borers, they are created by long hole drilling. In this case, accurate long hole drilling is critical to obtain good fragmentation.

This is usually done by Simba drill rigs specially designed for long hole drilling, equipped with TH or ITH drill hammers depending on the type and length of the opening to be created. In addition, this process requires a long hole charging unit (up or down).

The prerequisites for selecting a sublevel stoping method are:

- Large, steep orebody (smaller than normally selected for caving methods)
- Limited environmental impact (use of backfill avoids disruption on the surface)
- Good productivity
- Safety
- Low dilution

As in most forms of mining, stopping methods are selected based on the geology of the orebody, the grade of ore and the characteristics of the surrounding rock, where technical challenges and costs are weighed against each other.

The main issue here is that all stopping variants are based on gravity, which is of great benefit to the bottom-line economics when setting up a viable mining operation.