MICA
Minerals Intelligence Capacity Analysis

# *FACTSHEET*

# Types of drilling in mining

Drilling activities to raw materials achievement

## Scope (conceptual model & main characteristics)

Drilling activities at mine sites are very diverse and are used for two main purposes, exploration which aims to obtain very detailed information about the formations below ground surface and production to facilitate the labors of ore extraction. There are a large number of different types of drilling and this factsheet covers the two basic methods which are most commonly used, rotary drilling and rotary percussive drilling.

*Rotary drilling methods used include:*

- Auger drilling, in this drilling system, rock is cut and broken with a simple blade bit mounted on the end of a rotating string of rods. The broken rock can be collected in two ways. In the bucket auger, the rock is collected in a small barrel behind the bit which, when full, is simply pulled from the ground to be emptied. In the other system, called a screw auger, the broken rock is passed to the surface by a spiral screw thread along the rod string.

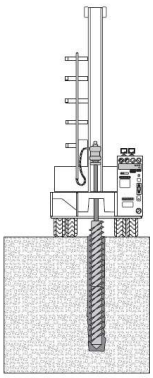

Fig. 1 Auger drilling
(Sandvik Tamrock, 1999)

- Rotary drilling with blade bit or roller-cone bit, in this case the bit attacks the rock with energy supplied to it by a rotating drill stem. The drill stem is rotated while a thrust is applied to it by a pulldown mechanism using up to 65% of the weight of the machine. The bit breaks and removes the rock by either a ploughing-scraping action in soft rock, or a crushing and chipping action in hard rock, or a combination of the two. Compressed air or water is supplied to the bit via the drill stem. The air/water cools the bit and provides a flushing medium for the cuttings. The drill rigs typically operate in the vertical position although many types can drill up to 25 to 30 degrees inclination.

Fig. 2 Rotary drill rig

- Diamond core drilling, this method provides core samples and the name refers to the drill bit which has small diamond inserts. A hollow coring bit is attached to a core barrel that collects the sample into an inner tube as the bit penetrates the formation. There are two ways to get the core sample out when the inner tube is full. In conventional coring, the complete core barrel must be drawn up to the surface, which means that all drill rods must be pulled out of the hole. In wire-line coring, the inner tube is lifted to the surface and lowered back to the barrel through the drill rods with a winch. This method saves time because the drill rods stay in the hole. The rig consists of a high-speed rotation unit (over 1000 rpm), a feed system, which provides smooth and consistent pressure on a bit, and a diesel engine that powers the unit. Drill rod handling is manual because it uses shorter and lighter drill pipes than rotary drilling. Coring drills are equipped with a water pump for flushing cuttings to the surface between the hole wall and drill pipe.

Fig. 3 Diamond core rig

*Percussion drilling methods,* the rock is made to fail by means of a piston that delivers rapid impacts to the drill stem, thereby transferring energy to the drill bit. The 'blows' to the rock downhole are delivered by the bit while a rotational device ensures that the bit impacts a new rock surface with each blow. A feed force is applied to maintain rock/bit contact. Compressed air is used to remove or flush the drill cutting from the hole, thereby advancing the hole depth at an efficient rate. The piston

can either be mounted out of the hole (OTH) or down the hole (DTH) for quiet and efficient drilling. DTH hammers ten to drill straighter holes at greater depth as compared to OTH drifters and are efficient in hard rock-types.
Reverse air drilling is another type of percussion drilling that uses a double-wall drill pipe. Compressed air is forced between the inner and outer tube down to the bottom of the hole. The air cleans the face of a bit and brings the sample cuttings through the center hole of the inner tube up to the surface. Drilling can be performed with either a tricone bit or DTH hammer depending on the formation.

Fig. 4 Percussion drill rig

| Contexts of use, application fields | -> contexts (e.g., environmental, economic, social assessment)<br>-> which types of stakeholder questions are concerned?<br>-> link to published studies that implement the method |
|---|---|

In a 'mineral context' drilling activities are mainly focused into the exploration and production of minerals resources. The contexts of use and application fields are:
.- Auger method is often used for site investigation, environmental and geotechnical drilling and sampling into weathered or poorly consolidated material providing a soil sample.
.- Rotary drilling is one of the most popular drilling technique for large surface mines where large diameter holes are used in blasting. It is used in soft rock materials or to drill through the top layer of decomposed rock and soil to get a fresh rock sample from the bedrock below.
.- Core drills perform best in consolidated formations. Diamond coring drills are small in size compared to rotary drills and are therefore well suited for remote exploration sites. Some are small enough to be transported by helicopter to areas without access roads.
.- Air percussion drilling is used for penetrating hard rock types to depths around hundreds of meters, both for investigation and blasting. Reverse air drilling provides uncontaminated chip samples and performs in all formation types. It is used basically for investigation.

| Input parameters | -> which parameters are needed to run the method |
|---|---|

Not applicable

| Type(s) of related input data or knowledge needed and their possible source(s) | -> which types of data are needed to run the method, from which sources could they come…<br>-> could be qualitative data or quantitative data, and also tacit knowledge, hybrid, etc. |
|---|---|

As mentioned above drilling methods are applied in two main types of activities:
Exploration, the information is obtained in the field survey works carried out in the area considered mineral target. Basically the data consist of a geological mapping of the area and a prognosis of rock types and thickness expected.
Production/blasting, drilling requirements are known from previous drilling works in the same area and in others cases, for new areas, drilling requirements are weighted carefully before selecting the appropriate drill rig to meet all the needs at one operation. Considerations include geology and surface terrain condition, total drill-hole depth, production requirements, type of explosives, fragmentation size requirements and operating costs.

| Model used (if any, geological mathematical, heuristic…) | -> e.g., geological model for mapping<br>-> e.g., mathematical model such as mass balancing, matrix inversion, can be stepwise such as agent -based models, dynamic including time or quasidynamic specifying time series…<br>-> can also be a scenario |
|---|---|

When we talk about exploration, with all available data obtained from geological and geochemical mapping, and together with the study of surface outcrops can be used to outline a terrain model, essential to choose the places where perform subsequent boreholes. The interpretation of the information gained from the boreholes will enable us to carry out a 3D- geological model to collect the values of mineral concentration and distribution in the rock mass. If we talk about production, we have the preliminary 3D-geological model and the orebody is well known and the drilling works are focused to extract it.

| System and/or parameters considered | -> **the system can be described by its boundaries**. These can refer to a geographic location, like a country, or a city, the time period involved, products, materials, processes etc. involved, like flows and stocks of copper, or the cradle-to-grave chain of a cell phone, or the car fleet, or the construction sector, or the whole economy…<br>-> **parameters** could possibly refer to geographic co-ordinates, scale, commodities considered, genesis of ore deposits and others… |
|---|---|

The start of drilling works suppose to have been passed the previous stage of prospecting. This means that it has identified the area where mineralization can be, in the case of exploration, and the exact location of mineralization is known, in the case of production. This implies in both cases a significant reduction in the area considered at the beginning of the mining project, which most projects have a local scale and it is limited to the area occupied by the mineralization and the necessary facilities for processing.

| | |
|---|---|
| Time / Space / Resolution /Accuracy / Plausibility… | -> to which spatio-temporal domain it applies, with which resolution and/or accuracy (e.g., near future, EU 28, 1 year, country/regional/local level…)<br>-> for foresight methods can also be plausibility, legitimacy and credibility… |

Drilling works aim to identify the location and quality of a mineral for extraction and processing. Boreholes remain where they were made without temporal or spatial variation. Once confirmed the viability of the mining project boreholes may disappear as a result of production jobs but there is no loss of information because samples (cuttings, chips, cores) obtained during drilling are preserved and have been properly described and classified.

| | |
|---|---|
| Indicators / Outputs / Units | -> this refers to what the method is actually meant for. Units are an important part but that is most of the time not sufficient to express the meaning. For example, **the indicators used in LCA express the cradle-to-grave environmental impacts of a product or service**. This can be expressed in kg $CO_2$-equivalent. But also in €. Or in millipoints. Or in $m^2$year land use.<br>-> for foresight methods the outputs are products or processes |

The output of a borehole is a log sheet where all observations are recorded graphically and numerically against a selected scale. Graphical logging is a powerful and flexible technique which supports detailed observation and its use is really important for all first stage exploration drilling. With all the information obtained from the boreholes is possible to build a 3D geological model to the desired scale that will define the ore body and by its geological and structural interpretation the resource will be estimated.

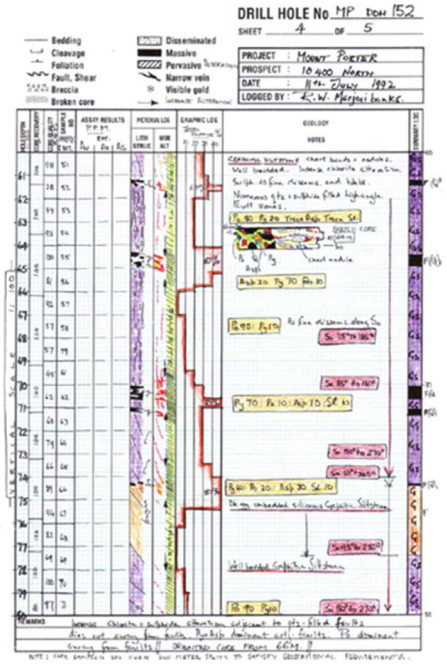

Fig. 5 Log sheet. R. Marjoribanks (2010)

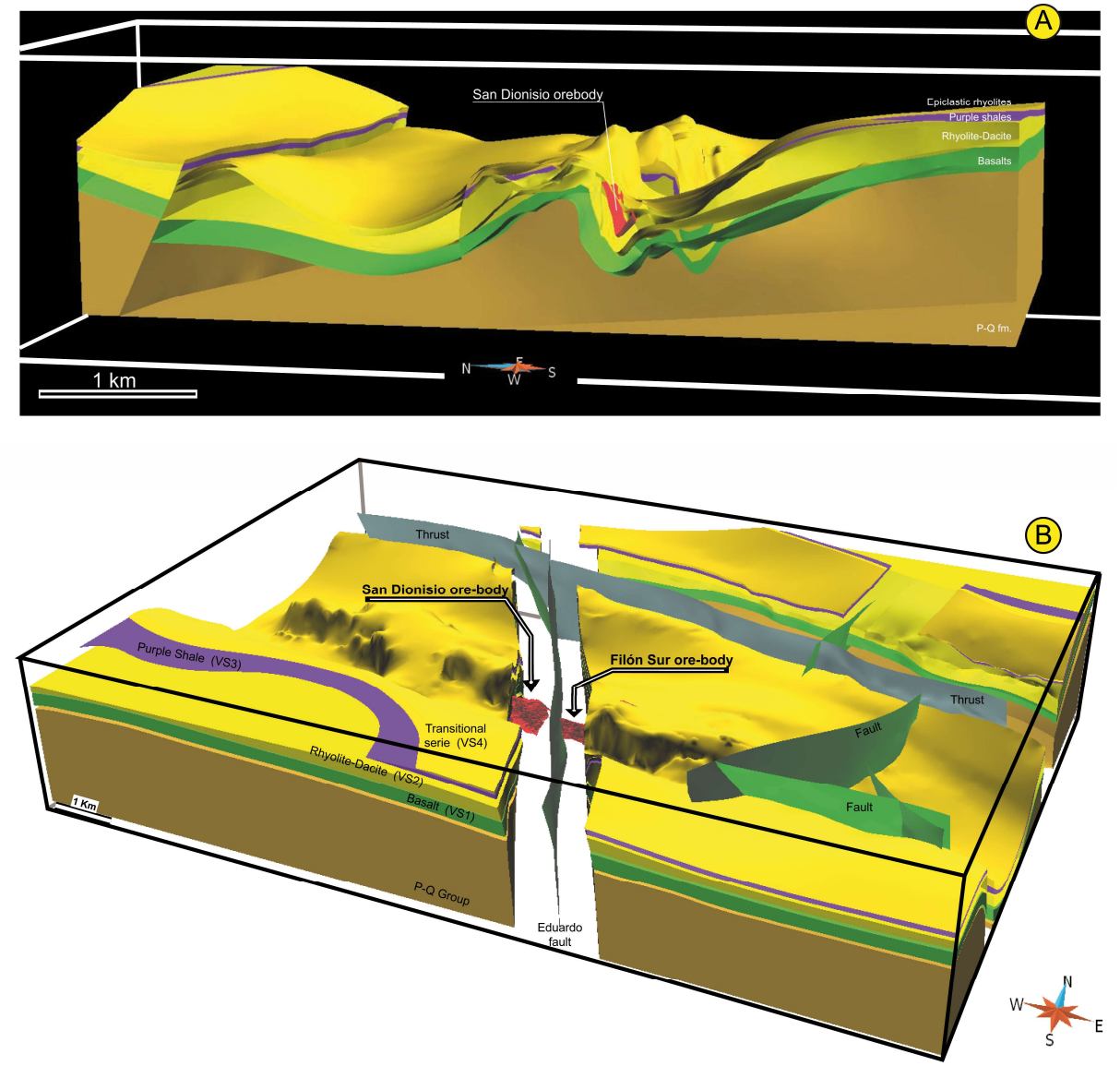


Fig. 6 3D geological model. IGME 2015

| Treatment of uncertainty, verification, validation | -> evaluation of the uncertainty related to this method, how it can be calculated/estimated |
|---|---|

The 3D geological models are reliant on the information of boreholes that have been made by an expert in the field, it is a highly interpretive process and the errors associated with it can be very difficult to quantify as they will be reliant on the quality of the boreholes and whether the expert's interpretation is accurate. Usually the 'field work' is supervised by a senior expert that can evaluate the quality of the information and also detects uncertainties or mistakes.

| Main publications / references | -> e.g. , ILCD handbook on LCA, standards (e.g. , ISO)<br>-> can include reference to websites/pages<br>-> references to be entered with their DOI |
|---|---|

LÓPEZ, C., LÓPEZ, E. & AYALA, F. J. (1995). *Drilling and blasting of rocks*. Taylor & Francis.

MARJORIBANKS, R. (2010). Geological Methods in Mineral Exploration and Mining 2sd edition, Springer.

SANDVIK TAMROCK CORP. (1999) Rock excavation handbook.

UNIVERSITY OF ARIZONA. Mining and Geological Engineering (2003). Rock excavation.

| Related methods | -> List of comparable methods, their particularities…<br>-> link to one or several other existing fact sheet(s) |
|---|---|

FS Ground investigation
FS Resource estimation of primary minerals
FS Exploration phases (overview; phases; methods)
FS Exploration phases (time; cost; surfaces)

| Some examples of operational tools (CAUTION, this list is not exhaustive) | -> e.g., software… Only give a listing and a reference (publication, website/page…)<br>-> **should be provided only if ALL main actors are properly cited** |
|---|---|

►

| Key relevant contacts | -> list of relevant **types** of organisations that could provide further expertise and help with the methods described above. |
|---|---|

Geological Survey of Spain.
Mining School of Technical University Of Madrid.
Atlas Copco, machinery manufacturer.
Sandvik Coromat, machinery manufacturer.
Boart Longyear, mining machinery manufacturer.