Increasing resource efficiency through Sonic Drilling

Abstract
Subsurface ore deposits (up to about 50 m depths), such as Nickel laterites and Aluminium-rich bauxites, placer diamond and gold deposits in tropical and permafrost regions, are heterogeneous at orebody scale. This is related to mixtures of loose and solid, soft and hard materials of variable grain sizes leading to contrasting physical properties. Conventional drilling is often impossible or does not reach complete and coherent sampling. Sonic drilling (Eijkelkamp SonicSampDrill) with specially developed core shoes and rigs for these environments achieves coherent drill cores with over 95% recovery rates in a short time (e.g. permafrost region: 25 holes of about 11 m in 2.5 days). For example, in a Siberian subsurface alluvial gold deposit close to Magadan, the LargeRotoSonic crawler was able to sample clay layers hosting fine gold and gold dust. This finding contributed to a significant increase of the Au reserves. In alluvial diamond deposits in NE Angola, thanks to the CRS-V CompactRotoSonic crawler equipped with the AquaLock piston sampler high grade alluvial channels could be targeted and significantly helped to increase diamond production and extend Life of Mine.

1. Introduction

In order to increase natural resource efficiency such as metals and diamonds from subsurface deposits, rapid, reliable drilling methods leading to high quality sampling with improved logistics, reducing water consumption and minimized waste are needed.

Figure 1: Drilling in the cycle of exploration- mining and processing.

Efficient exploration, mining and processing relies on optimized geomodels. The smart definition of mineralogical, chemical and geotechnical key parameters is based on geometallurgical studies. These parameters compromise optimal ore and metal recovery, low (to zero) waste, low environmental impact, low energy/time consumption during beneficiation and saleable products.

High quality drill cores are indispensable to perform systematic sampling for statistical mineralogical and chemical studies, interpretation, geomodeling and decision making during exploration campaigns, process design development or optimization (Figure 1). The systematic logging of drill cores is actually more and more driven by on-line-on-mine-real-time analyses. Therefore, cost-intensive drilling must bring out high recovery rates, coherent undisturbed and complete cores to obtain reliable data being used for resource and reserve estimates, and metallurgical test work.
Conventional diamond drilling methods are time, cost and water intensive. Sub-surface ore deposits, such as Ni (Co-Sc) laterites, bauxites, alluvial gold, diamond, titanium oxides, zirconium are difficult (or impossible) to drill presenting low core recovery rates and/or partial drill core destruction (Sarala, 2015; Uludag, 2010). These terranes are heterogeneous in grain size, partly loose, and highly variable at vertical and horizontal scale. Fine grain size sediments such as clays are often lost, but can host e.g. economic gold (Nesterenko et al. 2013). This leads to erroneous models and decision making.

Sonic drilling meets the highest technological standards and is more and more used for complex sub-surface ores, as this technology provides undisturbed cores in a short time span (=50m/day) with low failure rate and low waste.

Four successful case studies from subsurface ore deposits in arctic, desert and tropical climates, are presented in the context of the main problems related to drilling in sub-surface ore deposits.

2. Sonic drilling

Sonic drilling has been used for more than 40 years, and is more and more developed for soil environments with special developments of rigs and tools. Sonic drilling on soils significantly reduces friction on the drill string and drill bit due to liquefaction, inertia effects and a temporary reduction of porosity of the soil. During core barrel advancement no fluids, air or muds are used. This combination makes penetrating a large range of soils easy.

Depending on the climate and geological environment, LargeRotoSonic or CompactRotoSonic drills are operated. For further details see: http://www.sonicsampdrill.com

3. Alluvial Gold in Permafrost Regions

The Far East of Siberia, 700 km north of Magadan, represents a permafrost region, rich in placer gold, which is mined at surface and underground. The sediments are composed of sand, gravel and clay. Coarse grained gold occurs in sands, fine grained (0.25-1 mm) and gold dust (< 0.1 mm) in the clay layers. The gravel beds are in part formed by glaciers. Permafrost soils are subject to thawing in summer from the surface to a variable depth, from 30 cm to several hundreds of meters. The surface layer down to several meters, which experiences repeated freezing and thawing is called the "active layer". The active layer slowly expels its water during the thawing periods of several months, causing a morass, or a rough surface consisting mainly of rock fragments. Hydrolaccoliths (pingos) are frequent.

Sonic drilling was performed on an ancient mining area as reconnaissance drilling using the LargeRotoSonic with the AquaLock piston sampler. Even at -40°C vibration is still possible. Boreholes (4 m depths) were performed down to the interface with the basement gneiss at a 10-12 m spacing. Twenty-five boreholes were drilled in only 2.5 days at a consistent speed of 15m/10h shift. Sonic drill tools were tested and best recoveries were obtained with Sonic Duo (dry) and an 8" core and 10" casing. For the first time the clay layer with fine gold and gold dust could be recovered. Traditional drilling technologies imply a sampling forecasting error of up to 30%. Sampling by Sonic technology leads to more precise gold location forecasting and to reliable mining planning, as gold poor and gold rich areas could be precisely localized. A significant OPEX reduction could be achieved as only gold rich areas will be mined. Gold recovery could be increased of about 50%. At present 80 m/24h have been drilled since the beginning of 2017 with increased production during May to July (94 m/24h).

Figure 2: Container hosting the LargeRotoSonic Drilling Rig in the permafrost region of Far East Siberia hosting alluvial Au deposits.
4. Alluvial Diamonds

North-Eastern Angola is famous for gem quality alluvial diamonds originally derived from kimberlite. Mining in many areas of Calonda formation gravels comprised of channelized ancient river systems hosting variable thicknesses, and grades of diamond deposits, as well as variable diamond quality. The channels are located beneath metric to decametric overburden often composed of clay and sand layers. The present landscape is hilly with variable thicknesses of overburden on slopes and valleys. The diamonds typically occur in 0-5 m thick gravel layers, overlying the bedrock located from 3 to +50 m depth. The objectives of drilling are twofold: firstly prospecting to locate diamond-bearing gravels, and determine their thickness and depth below surface, and secondly to direct production activities to maximize profitably, and extend mining block life. Drilling results allow accurate measurement of overburden, diamond bearing gravel thicknesses to the bedrock, and their composition. The CompactRotoSonic drill spacing usually commenced at 200 m, or 100 m in areas of potential interest, reducing further to 50 m or less once gravels of interest are found. Typically, 1,500-2,000 m is drilled each month working 12 hour days 5 days a week, with depths varying between 5 and 25 m. These methods have successfully led to the preferential targeting of high-grade channels.
Figure 5: Full core recovery showing the gravel bed and country rocks (Sonic drilled in alluvial diamond prospects, NE Angola).

Sonic drilling contributed to high grade and high value diamond production during the last 4 years. A second CRS-V CompactRotoSonic crawler and support truck is currently being purchased, and neighboring diamond mining companies have also purchased similar units.

5. Nickel Laterites-Bauxites

Nickel laterites (0.5 to 3 % Ni) and bauxites (Al rich 35-65 % Al) are tropical (paleo- or modern) soils. Ni-laterites form on serpentinized peridotites, while bauxites present paleo soils developed, or having been transported on (to) granitic or carbonate–clay bearing rocks (Karst). These soils are the product of alternating rainy and dry seasons, leading to leaching and accumulation of metals as concretions or veins, or metal sequestration in rock matrix minerals. These ore types present heterogeneous materials both in grain size (micrometric to centimetric) and in mechanical (hard and soft), and physico-chemical properties. Moreover, laterites can host up to 40-50 wt.% of water.

Ni-laterites representing about 60 % of the world’s Ni production (Butt and Cluzel, 2013), were essentially mined for garnierite ore occurring in saprolite and/or tectonic breccia at the bottom of the laterite profile at the interface with the protolith (serpentinized peridotite). At present, many Ni laterite ores of lower grades (1- 2 wt.%, cut-off grade about 0.8 wt.%) and higher mineralogical complexity are mined. Laterites may host also Cobalt and the high-tech element Scandium (SE Australia) of up to about 500 ppm (Emsley, 2014; Chassé et al. 2015). In these ores, Nickel, Cobalt and Scandium are locked in phyllosilicates and/or oxy hydroxides dispersed in the rock matrix. Intensive geometallurgical studies are required to define comminution parameters and to design the processing flow sheet.

Sonic Drilling tests were performed on the Weda Bay Ni laterite deposit (Halmahera, Moluques Islands, Indonesia ERAMET Group). Nickel occurs heterogeneously in saprolites of variable compositions including a high amount of swelling clay minerals (smectite) mixed and partly intergrown with serpentine minerals. CompactRotoSonic with AquaLock piston sampler (70 mm core diameter) was used on a 12.5 x12.5 m grid with depths varying from 14 to 16 m. The core production was 40-60 m/day. Although these sonic drill tests reach significantly improved recovery rates on, major development is still needed. This can be done thanks to EU funds for the H2020 SOLSA project (www.solsa-mining.eu).
A project on bauxite was performed in South American Surinam, hosting part of the richest bauxites in the world. These bauxites represent about 72% of the country’s export. A sonic drilling campaign was performed close to the capital, Paramaribo at Lelydorp. Bauxite (Karst deposits) occurs below an overburden layer, which was dredged away for drilling. Drilling started with a clay layer composed of kaolinite (10 m borehole spacing) with drilling depths of 15-18 m. CompactRotoSonic with Aqualock sampler was used (dual wall) without any use of water (only air). About 100% core recovery was achieved. Resource estimates of bauxite (sensu-stricto), but also metal rich red clays were significantly improved.

6. Major drilling challenges in subsurface environments

The challenges during drilling, exploration and geometallurgical parameter evaluation and ore beneficiation in the above described heterogeneous sub-surface layers impact the economics and choice of the mining method. These factors are clayey layers and lenses, heavy mineral concentrations (Au, diamond, Ti, Zr) and the presence of trapped ground water. It is difficult to estimate the hardness of different sampling interval and the degree of induration in e.g. mineral sand deposits during logging. Operators rely on the observation of drilling pressures and penetration rates as well as chip/sand logging. Furthermore, pulverization by the drill bits and disaggregation during sample return make it difficult to identify indurated layers (Jones, 2006). These conditions are unfavorable for RAC drilling as indurated or lateritized materials impede the blade and penetration. Alternating wet - dry ground conditions, such as in permafrost or tropical climates, create sample hang up in drilling and sampling equipment. High water inflow may be coupled with fluidized sand creating excess sample, causing rod jamming. Finally, plastic and swelling clays may block inner tubes and, also impede the blade. At extreme heavy mineral concentrations, downhole contamination may occur, or layers of economic interest may be diluted by layers of non-economic interest.
7. Forthcoming solutions for optimizing mining and processing

If this first step of sampling, the drilling, is of low quality, the second step of material characterization will enhance errors, as these errors will impact sample quality for geometallurgical parameter determination, and sampling for testwork. Moreover, it will lead to erroneous and incomplete geomodels.

At present on-line-on-mine-sensors system are developed worldwide, to speed-up exploration and processing and to reach almost real time decision making (www.solsa-mining.eu, www.realtime-mining.eu). Part of these expert system will operate on drill cores, such as SOLSA SONIC DRILL combined with SOLSA ID, providing systematic mineralogical and chemical analyses on drill cores. These Big Data will be converted into smart actionable data. Complete and undisturbed drill cores are critical for these data to be actionable.

Sonic drilling rig and tools are under constant development to respond to the challenges of heterogeneous high water bearing metal bearing soils and alluvial deposits. This equipment significantly enhances gradually the drill core quality. Geometallurgical studies (systematic mineralogical, chemical analyses and key parameter determination) will lead to more accurate geomodels and thus more accurate resource and reserves estimates for the mining and industries. Geometallurgical tests (magnetic separation, conductivity tests, grain size distribution, density, flotation.) will equally be of high quality to anticipate dysfunction during processing.

Sonic Drilling protects the environment leaving about 70 % less waste. It uses little or no water and is ideal to operate in dry climate regions. The equipment is compact and easy to use in remote areas.

References:


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