

Rock Mass Classification for Open Pit Design at the Au-Ag Project Angostura, Colombia

Clasificación de los macizos rocosos para el diseño del tajo abierto en el proyecto de Au-Ag Angostura, Colombia

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Abstract

The Angostura gold-silver project, Department of Santander, Colombia, is currently in the feasibility stage, where a geotechnical study for the open pit design is required. Besides engineering-geological surface mapping, information of more than 275,000 m of exploration core drilling had to be evaluated for rock mass classification. Due to drill core destruction for geochemical analysis after geological logging, as well as due to limited time for the study, a tailor-made system had to be found. A correlation matrix was elaborated which enables the differentiation of rock mass types by use of logged, qualitative geological parameters (lithology, alteration type, alteration intensity, textural/structural features). Running the correlation matrix within the drillhole database gives the distribution of rock mass types for each individual drillhole. Although the rock mass types were defined before any systematic testing was carried out, subsequent laboratory and in-situ geophysical testing have confirmed the validity of the classification concept used in this project.

Resumen

El proyecto Angostura, esta localizado en Santander, Colombia. Actualmente está en la etapa de factibilidad, en la cual es necesario el estudio geotécnico del pit. En la clasificación del macizo rocoso además de la cartografía de superficie, se evaluó información de 275,000 m de núcleo. Debido al uso del núcleo para pruebas geoquímicas y el limitado tiempo para el estudio, fue determinado un sistema a la medida de las condiciones del proyecto. Se elaboró una matriz de correlación usando parámetros geológicos cualitativos (litología, tipo de alteración, intensidad de alteración y características texturales/estructurales). Aplicando la matriz a las muestras de núcleo en la base de datos, se obtuvo la distribución de los de macizo en el pit. A pesar de que los tipos de macizo fueron definidos antes de realizar pruebas de laboratorio, los posteriores ensayos de laboratorio y geofísicos realizados en el sitio, confirman la validez del concepto de clasificación del macizo rocoso usado en este proyecto.

1 INTRODUCTION

The gold-silver project Angostura, located approximately 40 km NE of the city of Bucaramanga (Department of Santander) and 370 km N of Bogotá, Colombia, is situated in the mountainous region of the Eastern Cordillera at an elevation between 2,600 m and 3,400 m above sea level.

The project is wholly-owned and developed by Greystar Resources Ltd. (Vancouver, Canada), which has been exploring

the Angostura area since 1995. Up to April 2008 more than 275,000 meters of exploration diamond core drilling (over 800 drill holes) have been carried out and exploration tunnels of more than 2.6 km were driven. A resource volume (measured and indicated) of more than 10.1 million ounces of gold has been defined up to this date. Currently, the project is in the feasibility stage, for which a geotechnical study is required. The major objectives of this study are to define rock mass types and rock mass parameters, optimize slope design of the open pit, support the design for the temporary and permanent infrastructure, and to

define geotechnical risks during and after mining. A particular challenge is the design of the main pit wall which will be more than 800 m high.

2 GEOLOGY AND ORE DEPOSIT MODEL

Host rock to the Angostura gold-silver deposit is mainly poly-metamorphic and deformed Precambrian gneiss of the Santander massif and younger intrusive rocks of Mesozoic and Tertiary age (Ward et al., 1973; Gutierrez and Clavijo, 2001). Precious metal mineralization is of the high sulphidation type and is associated with vein-like structures dominated by quartz (Hedenquist and Arribas, 1999). These silicified structures can reach thicknesses of more than 30 m. Besides silicification other types of alteration, such as sericitic and argillic alteration, strongly influenced the compounds of the host rocks.

The deposit is located at a fault jog of two regional NW-SE striking lateral faults, which are related to the overall tectonic frame of the extruding Maracaibo block (Taboada et al. 2000). Within the fault jog dilation occurred which favoured the ascent and circulation of hydrothermal fluids during ore-forming processes.

3 GEOTECHNICAL DATA ACQUISITION

3.1 Existing data

Particular to the geotechnical study is the fact that the project has already reached an evolved stage when this study started and a large geological database had already been built up. Existing data, in particular from extensive exploration core drilling, are predominantly covering information on lithology, alteration, textures, and mineralogy focusing on parameters necessary for defining ore deposit characteristics. However, data on engineering geological and rock mechanical properties are available to a limited extent only. In addition, physical revision of previous core drilling for geotechnical evaluation is not possible due to core destruction for geochemical analysis.

Rock mass characterization thus had to follow a tailored, systematic approach in order to fully integrate all existing geological information for further analysis and modelling. This new

approach, however, significantly differed from conventional rock mass type characterization concepts, where the bases to the definition of rock mass types are quantitative data (laboratory or in-situ testing; GSI or RMR).

3.2 Acquisition of new geotechnical data sets

Engineering geological and geotechnical mapping on surface was carried out according to ISRM classification systems (ISRM, 1978). Particular focus was given on the discontinuity systems in order to define structural compartments within the entire pit area. Discontinuity data were subsequently evaluated by kinematic analysis.

For evaluating geotechnically relevant information from more than 275,000 m of drilling, the drill core itself could not be analysed due to limited time for the study and due to destruction of drill core during cutting. Alternatively, a matrix system was elaborated which defines correlations between lithology, alteration type, alteration intensity, textural types and fracturing. All these qualitative data are logged by geologists on site before core destruction and are integrated into the geological database. Based on geological field mapping and on the correlation matrix five rock mass types have been defined (Table 1).

An algorithm was generated and implemented into the geological database. This concept enables a semi-automatic qualitative analysis of the logged drill core for geotechnical purposes.

Running the formula within the database gives the distribution of the rock mass types for each individual drill hole. This geotechnical information is imported into the company's exploration software package, which facilitates the elaboration of geotechnical sections and subsequent three-dimensional modelling of the rock mass types within the proposed pit area.

3.3 Rock mechanical data

In order to gain rock mechanical data for subsequent stability analysis, more than 70 drill core samples were tested (uniaxial and triaxial testing). For obtaining rock mechanical data of in-situ conditions, down-hole velocity logging was carried out.

Table 1

Rock Mass Type	Lithology	Alteration	Intensity of alteration	Textures / Structures
RM 1	Any rock type (without fault)	silicification	High, moderate	No features indicating deformation / tectonic overprint
RM 2	Any rock type (without fault)	Any alteration type + fresh, unaltered rock	No and/or weak alteration	No features indicating deformation / tectonic overprint
RM 3	Any rock type (without fault)	Any alteration type without silicification	Moderate, high	No features indicating deformation / tectonic overprint
RM 4	Any rock type (without fault)	Any alteration type	High, moderate, weak	Features indicating deformation (e.g. crushed, sheared, faulted, folded, sandy, broken, fractured,...)
RM 5	Fault Material	Any alteration type without silicification	High, moderate, weak	All types of textural and structural features

Correlation matrix defining rock mass types as classified by logged geological parameters.

4 RM CLASSIFICATION CONCEPT VERSUS TESTING – PRELIMINARY RESULTS

Preliminary evaluation of data obtained from laboratory and in-situ testing confirms the classification concept used at the project, with highly to moderately silicified material (RM 1) being characterized by high strength, a high angle of friction and a high modulus of deformation. RM 2 and RM 3 show intermediate values for rock mechanical parameters and in many cases do not differ significantly from each other. RM 4, due to its high degree of fracturing, can be easily distinguished in the in-situ down-hole velocity logging; laboratory testing results of core from RM 4 show a wide range, but are lower than RM 1 to RM 3. Fault zone material (RM 5) is clearly distinguished in the down-hole velocity logging.

5 CONCLUSIONS

Due to the fact that the geotechnical study stepped into the exploration/mining project at a very late stage, a large volume of previously obtained geological data had to be evaluated for geotechnical purposes.

The correlation matrix, combining information on lithology, alteration type, alteration intensity, and textural/structural features has shown to overcome the difficulty of reviewing more than 275,000 m of drill core information.

At the Angostura project, the concept of classifying rock mass types defined by the correlation matrix has been confirmed by rock mechanical laboratory and in-situ testing, where each rock mass type shows distinct rock mechanical parameters.

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