THE EXPLORATION AND BUSINESS CASE FOR DOING HYPERSPECTRAL CORE IMAGING AS PART OF AN ADVANCED-STAGE EXPLORATION PROGRAM: ANTAKORI CASE STUDY

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C.V.

El Dr. Heather es un geólogo explorador de campo con una gran experiencia en geología del Arqueano y de depósitos de oro, así como una amplia experiencia en exploración y descubrimiento de pórfidos sudafricanos de Cu-Au-Mo y de depósitos epitermales de Au-Ag. El Dr. Heather tiene una trayectoria demostrada en la elaboración de trabajos técnicos de alta calidad, que han dado lugar a la generación de valor y riqueza en el sector de exploración junior.

El Dr. Heather tiene 40 años de experiencia de campo en Norteamérica y Sudamérica. El Dr. Heather recibió un BSc. (con honores) en geología por la Universidad de British Columbia (Vancouver, Canadá) en 1982, un MSc. en geología por la Universidad de Queen's (Kingston, Canadá) en 1985, y es Ph.D. por la Universidad de Keele (Inglaterra) en 2001.

El Dr. Kevin B. Heather fue miembro fundador de Antares Minerals Inc., que cotiza en TSX, en donde dirigió la exploración que condujo al descubrimiento del depósito de alta ley, Haquira Este, en el sur de Perú, que se vendió a First Quantum Minerals en diciembre de 2010 por 650 millones de dólares canadienses.

El Dr. Heather es actualmente Director Geológico (CGO) de Regulus Resources Inc. (TSX-V: REG) y Aldebaran Resources (TSX-V: ALDE), siendo responsable a nivel corporativo de supervisar los aspectos técnicos de las actividades de exploración de ambas compañías.

Durante su carrera, el Dr. Heather ha participado en varios descubrimientos y ha trabajado en varios yacimientos minerales de clase mundial, como la mina El Indio Au-Ag-Cu (Chile), el depósito Pascua-Lama Au-Ag (Chile-Argentina), y el depósito Cerro Vanguardia Au-Ag (Patagonia, Argentina).

El Dr. Heather es "fellow" y conferencista honorario de la Society of Economic Geologists (SEG), cofundador y presidente de la organización benéfica "Fundación Mineros Contra El Cáncer", una organización benéfica con sede en Chile dedicada a ayudar a niños con cáncer, y sus familias, en situación económica vulnerable.

The Exploration and Business Case for Doing Hyperspectral Core Imaging as Part of an Advanced-stage Exploration Program: Antakori Case Study

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Resumen

Este artículo presenta el caso de exploración y negocios para realizar imágenes del núcleo hiperespectral como parte de un programa de exploración en etapa avanzada que utiliza el depósito de pórfido-skarn-epithermal Antakori Cu-Au-Ag, en el norte del Perú, como un caso de estudio. La racionalidad y la visión para realizar el escaneo del hiperespectral a gran escala sistemática se presenta junto con la forma en que se integra con otros conjuntos de datos geológicos, geoquímicos y de modelos de recursos en un modelo geo-metalúrgico holístico. La futura propuesta de valor agregado de incorporar el escaneo del núcleo hiperespectral en el flujo de trabajo regular de un proyecto de exploración de etapa temprana a avanzada es una "sin pensar" para Regulus Resources Inc. en su proyecto Antakori en el norte de Perú.

Abstract

This paper presents the exploration and business case for doing hyperspectral core imaging as part of an advanced-stage exploration program using the Antakori Cu-Au-Ag porphyry-skarn-epithermal deposit, northern Peru, as a case study. The rational and vision for doing hyperspectral core scanning on a systematic large-scale is presented along with how its integration with other geological, geochemical and resource model data sets into a holistic geo-metallurgical model. The future value-add proposition of incorporating hyperspectral core scanning into the regular work flow of an early- to advance-staged exploration project is a “no-brainer” for Regulus Resources Inc. at its Antakori project in northern Peru.

1. Introduction

Hyperspectral scanning of alteration minerals utilizing various instruments (e.g., PIMA, Terraspec ASD) has been a regular part of many company's exploration programs for years. More recently the advent of full core box scanning systems (e.g., Corescan, Terracore) has revolutionized the systematic collection of hyperspectral data from complete drill holes and potentially complete deposits.

This presentation aims to outline the benefits of incorporating full-scale, systematic hyperspectral scanning into the daily work flow at the early to advanced exploration stage based on experiences gained from the Antakori Cu-Au porphyry-skarn-epithermal project, Cajamarca Province, Northern Peru.

2. Background Information

2.1. Project Location

The project is located within the world-class Au-Cu-Ag belt of northern Peru. It is adjacent to the Tantahuatay high-sulphidation epithermal (HS) oxide heap leach Au mine (Compañía Minera Coimolache, Buenaventura-Southern Peru); and seven kilometers NW of the Cerro Corona porphyry Cu-Au mine (Gold Fields); and 32 km NW of the Yanacocha HS gold mine (Newmont-Buenaventura).

2.2. Geology

Antakori is characterised by calcic-skarn and porphyry-related Cu-Au-Ag mineralization (low As) overprinted by high-sulphidation Cu-Au-Ag mineralization (high As), and by carbonate-base metal Au-Ag-Pb-Zn-Cu mineralization (very low As). Mineralization is principally hosted in prograde and retrograde exoskarn in the Cretaceous Chulec and Inca Formations, as well as in quartz-anhydrite veinlets in quartzites of the Farrat Formation. Skarn mineralization is dominated by magnetite-chalcopyrite-pyrite. Additional mineralization is hosted within breccias and porphyry intrusions. The porphyry system responsible for the skarn mineralization has yet to be discovered, however alteration vectors and geophysical anomalies indicate several targets.

The Cretaceous rocks are locally overlain and cross-cut by Middle Miocene (12.7-13.2 Ma) intermediate to felsic volcanic and subvolcanic rocks of the Tantahuatay center of the Calipuy Formation, which hosts HS Au-Ag-Cu mineralization with enargite-tennantite-pyrite associated with strong advanced argillic alteration consisting of a complex assemblage of fine-grained while minerals which are difficult to determine with the naked eye or hand lens. The HS mineralization partially overprints the skarn along the southwest side of the property. The entire system is, in turn, locally overprinted by younger, carbonate-base metal Au-Ag-Pb-Zn-Cu mineralization and associated sericite-chlorite-clay alteration related to late stage rhyolite stocks and flow domes of Upper Miocene age (8.7-8.5 Ma).

2.3. Drilling and Resources

The Antakori Project, Cajamarca Province, Peru, continued to deliver outstanding drill results during the 2018 drill campaign. With a historical NI 43-101 inferred sulphide mineral resource (R0) of 295 Mt @ 0.36 g/t Au, 0.48% Cu and 10 g/t Ag (Southern Legacy Minerals; Wilson, 2012), based on 17,954 m of historical drilling in 70 holes, the current 2017-2018 drilling of ~20,000m will form the basis of an updated resource (R1) expected for early 2019.

3. Why Are We Doing Hyperspectral Scanning?

3.1. Preliminary Test Work

The Antakori Project by virtue of the complex superimposition of multiple mineralizing events with associated mica- and clay-rich alteration types lends itself well to the utilization of hyperspectral core scanning. Some limited test scanning was completed on 60 individual core samples representative of the various lithological, mineralization and alteration types across the Antakori deposit. Based on this preliminary work and the positive results garnered, Regulus Resources took the decision to enter into a business arrangement with Corescan Pty Ltd out of Perth Australia to install a dedicated hyperspectral scanning laboratory at Regulus' (Southern Legacy Peru SAC) Cajamarca core warehouse facilities. The lab was installed on site in early 2017 and at the time, it was the first lab operational in Peru; not to mention the only dedicated lab being used by a junior exploration company anywhere in the world. Approximately 37,000 m of core in 80 holes have been scanned at the time of this writing. A total of approximately 40 minerals are currently being systematically scanned for at Antakori and integrated with conventional visual alteration logging information.

3.2. Rational and Vision

The rational and vision behind the decision to incorporate Corescan hyperspectral scanning as part of the regular systematic work flow at Antakori is summarized by the following points:

- Identification of some alteration minerals is not obvious to the naked eye (or by hand lens), even to an experienced geologist's eye!
- Consistent identification of complexly mixed and/or overprinted alteration minerals.
- Systematic definition of both textural and temporal relationships of the complex mineral assemblages.
- Determination of detailed chemistry and crystallinity of various silicate, mica and clay mineral species (e.g., chlorite, alunite, epidote, white mica, etc.).
- Valuable in determining vectors to mineralization for exploration and resource expansion.
- Consistent collection of geotechnical information.
- Systematic mineralogical data (especially clays and micas) which may have important repercussions in "down-stream" activities such as:
    - Open pit mining (blasting & pit slope stability),
    - Underground block cave fracture density and infill mineralogy.
    - Crushing & grinding,
    - Metallurgical processing,
    - Tailings & waste disposal (acid mine drainage).
- Integration of all geological data sets, including the hyperspectral data, and the resource block model into a holistic geo-metallurgical model.

4. The Data

4.1. Misconceptions: Data Volume & Cost

Common concerns expressed by many in the exploration and mining community regarding the use of Corescan hyperspectral scanning are:

- the volume of data and how to manage it,
- the cost.

With respect to the volume of data, yes there is a lot of data generated, however the "heavy" data is processing is done on Corescan computers and the raw and resultant data stored on servers and backup tapes in Perth Australia. In addition, the data can be composited to whatever intervals the user wants to use. At Antakori we composite the hyperspectral data to different "resolutions" or intervals depending on the end objective of the data analysis.

For example, we routinely composite the numerical hyperspectral data to match our assay sample intervals, which allows us to do one-to-one comparisons and analysis of the Cu-Au grades and multi-element data with the results of the Corescan hyperspectral data. We also composite the hyperspectral data to match our resource model block size (10m x 10m x 10m) allowing integration eventually into the geo-metallurgical model. Finally, we also use the visual imagery (the pretty coloured images showing the spatial and textural distribution of individual minerals.

In terms of cost, the technology isn't cheap, however when put into a more global view of the costs to de-risk and advance a project, and the value of identifying potential issues early-on in the mining value-add chain, the costs are more easily reconciled. As an example, at Antakori the cost of completing ~35,000 m of hyperspectral scanning is roughly equivalent to a single 1,500m drill hole. Having the Corescan data will ensure that we put that 1,500m drill hole in the right place.

4.2. Understanding the Rocks & Data Integration

The value of Corescan hyperspectral data is only as good as the supporting data sets that it is integrated with. The fundamental foundation is a good detailed understanding of the rocks which comes from good observational logging and the development of accurate 4D geology (3D lithology, alteration, mineralization, structure and time relationships). These geological models are then integrated with systematic petrographic studies (both sulphide and gangue mineral studies using reflected and transmitted light petrography) and the Corescan hyperspectral data. This information can then be integrated with 4-acid multi-element geochemical data and mineralogical domains defined based on an array of different criteria. Ultimately this can be merged into the resource block model to define a more holistic geo-metallurgical model.

5. Holistic Geo-metallurgical Model

The geo-metallurgical model will provide the "backbone" to future, more advanced studies such as:

- What is the relative hardness, BWi and mill throughput rates of ore with a silicate matrix versus ore with a phyllosilicate matrix?
- If the sulphides were pre-concentrated in a floatation circuit, we need to know how clays and micas behave in this part of the processing cycle.

- If the ore goes to a heap leach pad, we need to know how the clays and micas behave on those pads.
- Assignment of mineralogy to blocks within the resource model to unable better mine planning and sequencing for the plant.

Having a geo-metallurgical model will allow us to:

- Enhance future targeting and resource expansion drilling,
- Predict possible mining, processing or geotechnical problems in advance,
- Design tests to quantify the potential risks,
- Spatially map the problematic zones within orebodies early in the exploration and evaluation chain.

6. Conclusions

The business case for early-stage application of systematic hyperspectral core scanning for a project like Antakori is still in progress, however initial results suggests that:

- Although initially thought to be more an exploration targeting/vectoring tool, its true value may lay in the many downstream uses of its data,
- When integrated with other data sets, it allows us to “bring forward” and realize something closer to the “true” processing variability of the potential ores and identify any inherent risks or opportunities.
- Early identification of geo-metallurgical risks provides the opportunity to react and solve potential issues, before they become “real” operational issues; which can translate into more robust project economics and improved NPV,
- Finally, the resulting models derived from the data integration will allow future drilling to be better targeted to areas where specific exploration, mining, processing, waste management questions need to be answered.

The future value-add proposition of incorporating hyperspectral core scanning into the regular work flow of an early- to advance-staged exploration project is a “no-brainer” for Regulus Resources Inc. at its Antakori project in northern Peru.

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