ASSESSMENT OF GIS ANDES: PREDICTIVE MAPPING OF NEOGENE GOLD-BEARING MAGMATIC-HYDROTHERMAL SYSTEMS IN THE CENTRAL ANDES

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KEY WORDS: Central Andes, GIS, gold deposits, epithermal, porphyry, favorability maps

INTRODUCTION

GIS Andes is designed by BRGM to be a homogeneous information system of the entire Andes Cordillera based on original compilations. It covers an area of 3.83 million km² and extends for some 8500 km from the Guajira Peninsula (Colombia) to Cape Horn (Tierra del Fuego). It has been conceived as a tool aimed primarily at the mining and academic sectors. For the former it will be an invaluable aid to mineral exploration and mine development. For the latter it will stimulate in the developing of new metallogenic models (Cassard, 1999). This contribution aims to quantitatively integrate the different regional datasets that exist in the GIS to provide the link between the tectonic development of the Andean margin and the spatial and temporal distribution of ore deposits. The integration of the data is achieved by the production of favorability maps, highlighting the regional metal potential. Due to the complex evolution of the Andean margin, to avoid ambiguities in the less constrained older history, and to incorporate data on the present morphology of the convergent margin, this study considers only one element, gold, in the youngest timeframe, the Neogene to Recent, in the best studied part of the belt, between 5° and 33°.

GIS ANDES DATASETS

GIS Andes contains numerous datalayers which can be subdivided into five main categories:

- Geographic datasets: a DCW® geographic base; three digital elevation models with a structural analysis of the detailed topography; and SPOT 4 VEGETATION® satellite imagery.

- Geological datasets; a geological synthesis at 1:2,000,000 scale; a present state of the geological coverage (presenting the distribution of more than 1100 georeferenced maps); and the distribution of the Holocene volcanism.
- Geophysical datasets; more than 50,000 seismic records; a 3-D model of the subduction plane; gravimetric layers (Bouguer anomaly, including isostatic correction and residual anomalies, vertical gradient calculation and structural analysis, and a gravity model of the Nazca plate); and heat flow information (251 oceanic and 239 continental datapoints).
- Geochemistry; a database with 3935 whole-rock analyses (which allows e.g. to identify zones of adakitic magmatic activity – a recent gold metallotect).
- Metallogeny; an ore deposit database under Access® with more than 3300 records and using new metallogenic lexicons; data on, mineralogy, fluid inclusions and isotopic data on the 350 main ore deposits; and a datalayer showing locations, main features and mining potential of the main mining districts and provinces.

FAVORABILITY MAPPING

Consideration of metallogeny at a continental scale requires knowledge of the parameters that may control, at this scale, the spatial and temporal distribution of the ore deposits. A "data association model" results from the search for pertinent relational criteria within existing databases through statistical analysis. Multicriteria processing (using SynArc®) of GIS Andes data has been employed to create maps presenting the favorability score for different parameters to magmatic-hydrothermal ore formation. The individual digital maps have been combined to result in a synthesized favorability map, also known as predictive map.

The interest of this study relates to "the metallogenic crisis" of gold in the Neogene (Sillitoe, 1991; Noble and McKee, 1999; Petersen, 1999; Oyarzun, 2000) characterized along the Central Andes by the occurrence of giant epithermal and porphyry gold deposits, e.g. the Yanacocha district (Peru) and El Indio belt (Chile), and the Maricunga belt (Chile) and Bajo de la Alumbrera district (Argentina), respectively. The studied corpus consists of 113 Neogene epithermal or porphyry gold deposits. In total the corpus contains 30% of all different ore deposits in this zone, representing 75% of the total stock metal. The applied method is an empiric approach which aims to search the GIS for relational properties between the ore deposit occurrences and other data from different layers in order to quantify their individual favorabilities for gold deposition (e.g. Knox-Robinson et al., 1997; Groves et al., 2000).

Five regional criteria have been extracted from the GIS and are applied based on their apparent association with the studied deposits. They are (see table 1);

- The lithology of the host rock,
- The contact between two different lithologies,
- The structural discontinuities (faults and lineaments),
- The modeled depth of the Wadati-Benioff zone,
- The modeled slope of the Wadati-Benioff zone (e.g. Fig. 1).

The criteria are assessed by a favorability score for every individual criterion (non, or poorly, favorable 0, favorable 1, highly favorable 2), based on their metal content per surface unit or per length unit, as summarized in the following table.

<table>
<tr><th>Criterion</th><th>Highly favorable
Score: 2</th><th>Favorable
Score: 1</th><th>Poorly favorable
Score: 0</th></tr>
<tr><td>Lithology</td><td colspan="2">Mainly Tertiary plutonic and volcanic rocks
Paleozoic plutonic and volcano sedimentary rocks</td><td>Sedimentary rocks
Mesozoic sequences</td></tr>
<tr><td>Lithologic contacts</td><td colspan="2">Boundaries of Tertiary igneous rocks
Paleozoic plutonic and volcano sedimentary rocks</td><td>Contacts between sedimentary rocks</td></tr>
<tr><td>Structural discontinuities</td><td>Transversal faults:
N080° to N100°E
N110° to N120°E</td><td>N050° to N060°E
N070° to N080°E
N160° to N170°E</td><td>Longitudinal faults:
N000° to N050°E
N060° to N070°E
N100° to N110°E
N120° to N160°E
N170° to N180°E</td></tr>
<tr><td>Depth of Wadati-Benioff zone</td><td>75 to 150 km</td><td>150 to 250 km
225 to 250 km</td><td>Areas over 250 km</td></tr>
<tr><td>Slope of Wadati-Benioff zone</td><td colspan="2">Flat areas:
Slopes from 8° to 22°</td><td>Steep areas</td></tr>
</table>

Table 1. Favorability values assigned to regional criteria which may contribute to the spatial distribution of magmatic-hydrothermal gold deposits.

PREDICTIVITY MAP

A final synthesized "favorability map" or "predictivity map" presents the cumulative favorability scores of the individual criteria (Fig. 2). As the resulting map has not been directly derived from the distributions of known ore deposits, the existing deposits allow us to verify the favorability scores.

The zones of high gold potential (favorability > 4) correspond to 65% of the known magmatic-hydrothermal gold deposits and to 95% of the total metal content (50% of the deposits and 71% of the metal content fall within a favorability >5, and 24% of the deposits and 51% of the metal content are located in the favorability regions > 6).

The gold districts of Portovelo (Ecuador), Yanacocha (Peru), Orcopampa (Peru), and the Maricunga belt (Chile) are particularly expressed in the highly favorable zones. Other important districts like El Indio (Chile) and Bajo de la Alumbrera and Agua Rica (Argentina) are less defined, but are still hosted by the highly favorable zones. The Bolivian districts of Kori Kollo and Tasna-Chocaya are clearly outside the favorability criteria and fall in the regions of average to low favorabilities.

Parallel to the verification of the predictivity map by the distribution of the known gold deposits, the map also indicates new favorable zones (e.g. east of Pierina (Peru), west of Bajo de la Alumbrera (Argentina), a favorable zone in southwest Bolivia). As for the areas with known deposits, these new areas are put forward by the assumptions and calculations as being sensitive in hosting undiscovered magmatic-hydrothermal gold deposits.

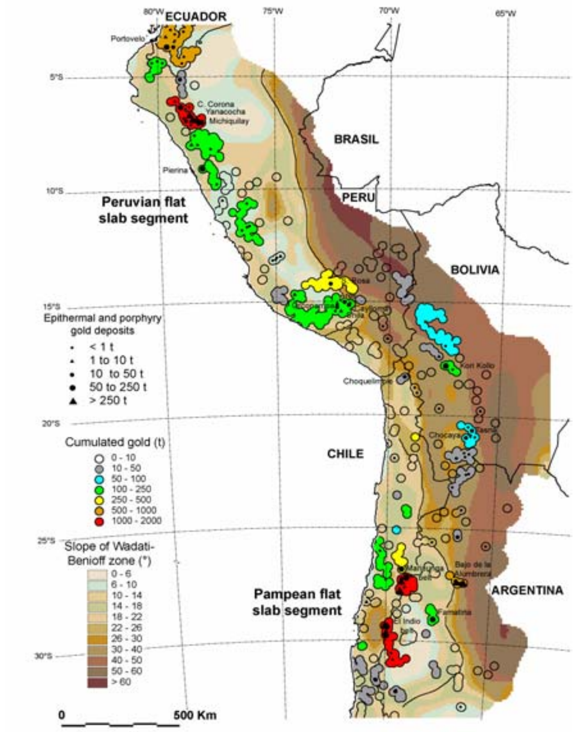

Figure 1. Location of gold districts with respect to the slope of Wadati-Benioff zone (in degrees)

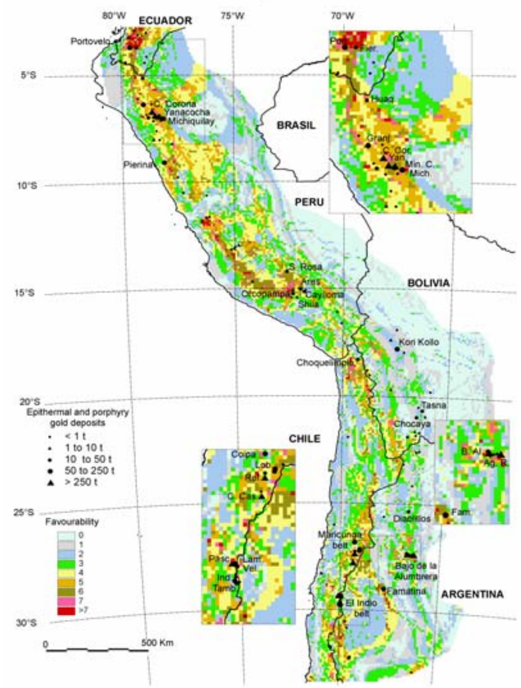

Figure 2. Predictivity map for epithermal and porphyry gold deposits

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