GEOLOGY, GEOCHEMISTRY AND GEOCHRONOLOGY OF INTRUSIVE ROCKS IN THE YANACOCHA DISTRICT, NORTHERN PERU

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ABSTRACT

Yanacocha is a world-class mining district in Northern Peru with more than 50 million ounces of gold. This study focuses on the geochemical (major, trace and rare earth elements, Pb, Sr, Nd isotopes) and temporal evolution (U-Pb zircon dating, Ar-Ar dating of hornblende and biotite) of porphyritic intrusions of the district and their association with hydrothermal activity.

The porphyritic rocks are andesitic to rhyolitic in composition and contain hydrous and anhydrous mineral phases (plagioclase + amphibole + biotite ± quartz ± pyroxene). They are characterized by typical subduction-related features (Nb and Ta negative anomalies, LILE enrichment) and by steep REE patterns with no Eu negative anomaly, suggesting evolution in the amphibole stability field and outside plagioclase stability field.
The rocks show a steady increase of SiO_2 contents and more evolved isotopic signatures (e.g., ε_{Nd} from +2.6 to 0) going from the older (~12 Ma) to the younger (~10 Ma) ones, suggesting evolution of mantle-derived magmas by AFC processes through assimilation of crustal rocks and fractionation of amphibole but not plagioclase.

Ore minerals have Pb isotopic compositions ($^{206}Pb/^{204}Pb$=18.668–18.818, $^{207}Pb/^{204}Pb$=15.611–15.681, $^{208}Pb/^{204}Pb$=38.574–38.783) overlapping and more radiogenic than those of the porphyritic rocks ($^{206}Pb/^{204}Pb$=17.818–18.666, $^{207}Pb/^{204}Pb$=15.547–15.611, $^{208}Pb/^{204}Pb$=37.635–39.544), suggesting a significant non-magmatic upper crustal Pb contribution.

INTRODUCTION

High Sulfidation Deposits of the Yanacocha volcanic field occur within the Northern Andean Orogenic belt (Figure.1). Volcanic rocks overlie folded Cretaceous sediments in the Yanacocha district and range in age from ~19.5 to 11.2 Ma with compositions from andesite to dacite. At least three pulses of late dacite intrusions and domes from ~10.8 to 9.9 Ma led to the formation of the largest high-sulfidation Au deposits at Yanacocha and were followed by the emplacement of rhyodacite to rhyolite intrusions and domes. By ~8.4 Ma, a final explosive eruption released a rhyolite ignimbrite after which volcanism and magmatic activity ended (Longo, 2005).

LITHOLOGY

A period of early dacite intrusions with quartz + hornblende + biotite phenocrysts (Longo, 2005) and porphyritic intrusions, andesitic in composition with plagioclase + amphibole + pyroxene, occur as plugs, dome and lava-dome complexes in sequence in the west of Yanacocha district.

Quartz-bearing intrusions cut many of the deposits, including Cerro Yanacocha and El Tapado in the centre and east of Yanacocha district. These intrusions are quartz-feldspar porphyritic rocks, generally with aplitic-textured groundmass. They consist of approximately 30 per cent phenocrysts, including quartz

(3-5 per cent), plagioclase (18-23 per cent), biotite and hornblende (7-9 per cent), and accessory titanite. Multiple phases of these intrusive rocks are recognized, especially at Cerro Yanacocha where phases rich in copper and in quartz veins are cut by unmineralized phases. Dacite intrusive rocks are locally referred to as Yqp (Yanacocha quartz porphyry).

The youngest intrusions have a rhyolitic composition. These rocks occur as dykes, often cutting Yp (Yanacocha porphyry) in the east of Yanacocha volcanic field.

Figure.1: Location map of the Yanacocha Mining District located in the Yanacocha Volcanic Field (YVF) in northern Peru. The figure displays the locations of various Porphyry Cu-Au and other Au and base metal systems (from Longo, 2005).

GEOCHEMISTRY

Compositional variations of the YVF rocks are typical of a subduction-related calc-alkaline rock suite that evolved by crustal contamination and fractional crystallization. The major element oxide data form a coherent trend from older medium-K andesite to younger high-K andesite, high-K dacite, and rhyolite, and display lower MgO content with increased SiO2 through time. Trace elements display enrichments in the large ion lithophile elements (e.g., K, Rb, and Ba) and depletions in the heavy rare earth elements with increased SiO2 content and support the hypothesis that Yanacocha evolved as part of a greater calc-alkaline rock suite.

REE spectra are characterized by variably steep LREE to HREE transitions and by the absence of negative Eu anomalies suggesting that plagioclase fractionation was limited (especially when considering the intermediate and felsic terms).

Late magmas were dacite and rhyolite that carry an adakite-like signature as displayed by the Sr/Y ratio whose compositional variations are part of the larger calc-alkaline suite (Figure.2). This latest felsic episode contains the mineral assemblage quartz-magnetite-sphene characteristic of highly oxidized magmas and developed porphyritic domes and intrusions of isolated dacite porphyry plugs spatially and temporally associated with the largest ore deposits at Yanacocha.

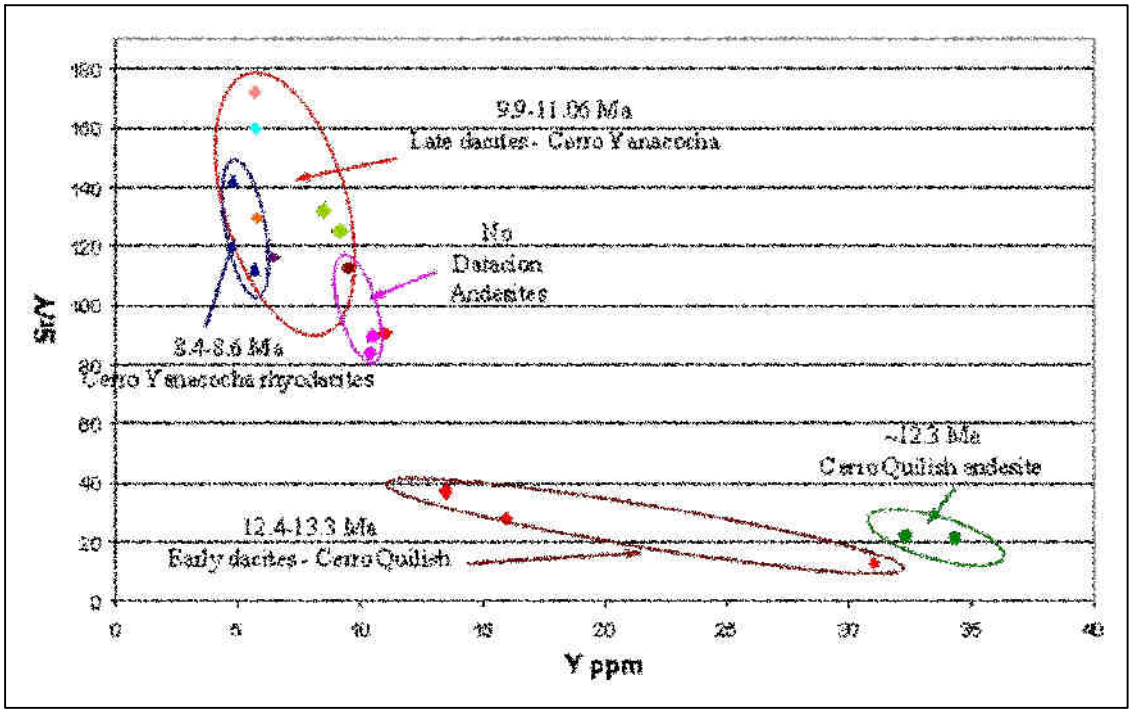

Figure.2: Sr/Y versus Y plot illustrating the field of adakites and cal-alkaline rocks. An adakite-like signature is displayed in the later intrusive rocks.

DISCUSSION AND CONCLUSIONS

- Geochemistry of magmatic system evolving through time (13.3-8.4 Ma) and space (10 km):
  - More SiO2-rich through time (SW-NE)
  - More evolved Sr and Nd signatures through time
  - Higher Sr/Y (adakitic signatures)
    - First, (13.3 -10.78 Ma), no plagioclase fractionation: MIXING
    - Second, (10.78 -8.4 Ma), plagioclase fractionation: recharge + AFC) ◊ changing depth of magma evolution

- Ore Pb = mixture of magmatic and basement lead leached by magmatic fluids. At Yanacocha (the largest ore body) clear association of ore Pb with magmatic Pb of spatially associated intrusives corresponding to the recharge + AFC evolution stage.

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