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Geology of the Cretaceous Lascano-East intrusive complex: magmatic evolution and mineralization potential of the Merín basin, Uruguay

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Abstract. The Merín basin is a Cretaceous aborted-rift in eastern Uruguay and it is composed of sub-alkaline Paraná basaltic flows and shallow intrusions, rhyolitic ignimbrites and associated mildly alkaline to alkaline intrusions and volcanic rocks. Ten lithogeochemical igneous units and one sedimentary formation are identified and range in age between 133 and 127 Ma. Four sub-circular intrusive complexes from 20 to 30 km in diameter are identified based on positive gravity and cospatial aeromagnetic anomalies. Whereas the outcropping Valle Chico complex is mainly composed by mildly alkaline syenites, drilling at Lascano-East revealed mostly alkaline gabbros and trachyte dikes/lavas. The Lascano-West and San Luis complexes are concealed and only inferred because of the geophysical anomalies. Hydrothermally altered rocks together with sparse gold and copper anomalies were identified in the central zone of the Lascano-East intrusive complex. The only other evidence of mineralization in the basin is a series of fluorite veins enriched in tungsten, barium and yttrium cutting the Precambrian basement near the basin edge. However, the mineralization potential of the Merín basin includes niobium, zirconium, phosphate, uranium, thorium and rare earths based on common ores of mineralized complexes from Brazil and Namibia.

Keywords. Cretaceous, Uruguay, Merín basin, Paraná, intrusive complexes

1 Introduction

The bimodal Paraná - Etendeka large igneous province erupted in the early Cretaceous (e.g., Renne et al. 1997). This province is dominated by tholeiitic basalt with minor rhyolites and has been linked to the Tristan da Cunha mantle plume through the Rio Grande Rise and the Walvis Ridge (O`Connor and Duncan 1990). Contemporaneous and younger intrusive complexes are described in Brazil, Bolivia, Paraguay, Uruguay and Namibia.

In the early Cretaceous, aborted rifting of the Precambrian basement in eastern Uruguay resulted in the formation of the Santa Lucía and Merín basins. The Merín basin is filled with a 1-2 km thickness of sub-alkaline bimodal volcanic and intrusive rocks of the Paraná rocks. Mildly alkaline to alkaline intrusions intrude the Parana sequence and are associated with volcanic rocks. Four circular positive gravity and coincident aeromagnetic anomalies lie in the basin along a north-east trend (Fig. 1). The anomaly on the southwest coincides with, a group of syenite outcrops of the Valle Chico complex. The two central anomalies at Lascano-East and Lascano-West have sparse outcrops of Paraná basalts flows, rhyolitic ignimbrites, flows and breccias, and granodiorite granophyres dikes and sills.

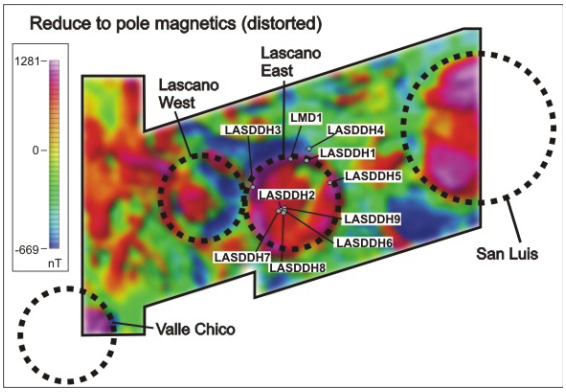

Figure 1. Airborne reduced to pole magnetic image from OMI survey, showing the location of inferred intrusive complexes and drillhole collars in the Merín basin (simplifed from Ellis and Turner 2006).

Different hypothesis have been proposed to explain the gravity and magnetic anomalies, and these includeconcealed mafic intrusions similar to Bushveld or Trumpsberg, several kilometers of basalt lava fill, and caldera structures within the Paraná rhyolite sequence (e.g., Reytmayer 2001; Rossello et al. 1999).

This work reconstructs the volcanic stratigraphy, and outlines the geometries of intrusions of Lascano-East complex based on 801 whole-rock major and trace element geochemical analyses, isotopic ages, and contact relations obtained from new drill core samples. These samples result from the first drilling campaign in the Lascano-East anomaly between 2002 and 2008 by Orosur Mining Incorporated (OMI). Reconnaissance mapping and limited geochemical surface sampling from the rest of the Merín Basin were used to make correlations.

Drilling by OMI at Lascano-East also encountered hydrothermally altered rocks with weakly anomalous copper and gold concentrations. We describe the

hydrothermal alteration assemblages and associated mineralization using trace element geochemistry, short wave infrared spectroscopy and X-ray diffractometry. The mineralization potential is also assessed by comparison with broadly coeval complexes from Brazil and Namibia.

2 Stratigraphy, intrusion geometry and magmatic evolution of the Merín basin

Stratigraphic observations throughout the Merín basin, calibrated with isotopic ages are summarized in Figure 2. The identified lithogeochemical units were grouped into sub-alkaline, mildy alkaline and alkaline associations. The only sedimentary rocks are conglomerates named as the Quebracho Formation.

The Paraná-like sub-alkaline to mildly alkaline basaltic lavas of the Treinta y Tres A and B types and some Santa Lucía basalts erupted first, mostly between ~ 133 to 131 Ma throughout the basin. The voluminous, sub-alkaline, Lavalleja rhyolitic ignimbrite eruptions followed between ~130 to 128 Ma, and are inferred to be related to circular caldera collapses at Lascano-East and Lascano-West. The felsic volcanism at Valle Chico was a bit younger and dominated by the Aiguá rhyolitic lavas (~128 to 127 Ma). At least some sub-alkaline to mildly-alkaline basaltic magmatism continued during and after this period, in particular at Lascano-East. The last event includes mildly alkaline and alkaline mafic to felsic intrusions into extrusive centers at ~128 to 127 Ma.

While Valle Chico was dominated by the intrusion of syenites, Lascano-East was dominated by gabbros and trachytes. The alkaline dikes and sills encountered in drilling to 1 km depth are inferred to be the upper part of deeper mafic alkaline intrusions responsible for the gravity anomalies. The youngest and least voluminous igneous rocks are the Arrayán olivine basalts that erupted synchronous with the deposition of the Quebracho Fm. conglomerates and are inferred to be younger than ~127 Ma.

3 Hydrothermal alteration-mineralization in the Lascano-East complex

Hydrothermally altered rocks were only identified in the drill holes in the central zone of the complex (e.g., LASDDH2, Fig. 1) where the mildy alkaline Santa Lucía gabbro sills and Lascano alkaline gabbro to trachyte dikes were also identified. This observation suggests that the alteration and mineralization might be linked to these intrusions.

Potassic alteration (K-feldspar added) and younger superimposed intermediate argillic alteration (smectite-chlorite added) were identified on the basis of alkali element gains and losses in subalkaline to mildly alkaline felsic rocks. Pyrite, quartz-pyrite and fluorite veins cut altered Lavalleja rhyolitic ignimbrites that contain disseminated pyrite and local weak gold (11 ppb), bismuth (8 ppm), thallium (7 ppm) and molybdenum (6.5 ppm) anomalies.

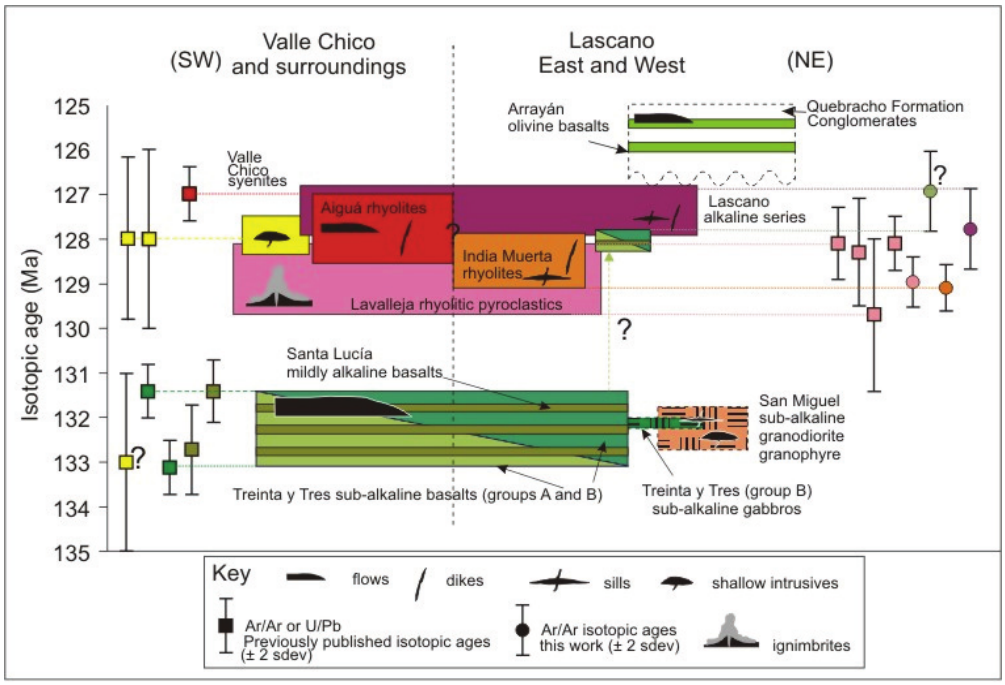

Figure 2. Synthesis of the magmatic evolution of igneous rocks in the Merín basin according to their geographic distribution, showing emplacement styles and relative age of lithogeochemical units based on cross-cutting relation calibrated with available isotopic ages (Stewart *et al.*, 1996; Lustrino *et al.*, 2005; Muzio *et al.*, 1999; Kirsten *et al.*, 2001 and this work).

Local potassic alteration was identified in Santa Lucía basalts as K-feldspar rims around plagioclase phenocrysts and sparse fine-grained hydrothermal K-feldspar replacing the aphanitic groundmass. These rocks are also cut by the altered Lascano alkaline series dikes and by one Santa Lucía gabbro sill. The contact zone of

the Santa Lucía sill with the Santa Lucía basalts includes a 5 meter intercept with up to 813 ppm Cu associated with millimetric to one centimeter wide quartz-chalcopyrite-pyrite veins. Below this contact, sparse millimetric to one centimeter quartz-pyrite veins cut the altered Santa Lucía basalts in a zone of anomalous molybdenum (14 ppm).

5 Mineralization potential of the Merín basin

The only exposed intrusive complex of the basin, the Valle Chico complex, does not present mineralization in outcrop.

The only other mineralized zone in the Merín basin includes fluorite-quartz-manganite-epidote-barite veins cutting the Precambrian granite-gneiss basement near the southern faulted edge of the basin (reserves of ca. 4500 tonnes at 80% CaF_2, Bosse et al. 1982). At least some of these veins are enriched in yttrium (ca. 0.5%, Rossini and Arana 2000). Two samples obtained during this work are anomalous in tungsten (100 ppm) and barium (4434 ppm). Quartz veins with tabular calcite blades replaced by quartz were identified nearby.

Based on results from this work and the comparison with similar age mineralized complexes in the Paraná – Etendeka province in Brazil and Namibia (Fig. 3), the potential mineralization can be divided into three main types: 1) magmatic-hydrothermal gold, copper and molybdenum in the wall-rock roof of Lascano-East alkaline intrusions; 2) fluorite, tungsten, barium and yttrium in fluorite veins in the basin edge; 3) niobium, zirconium, phosphate, uranium, thorium and rare earths in inferred and concealed carbonatites or other alkaline rocks.

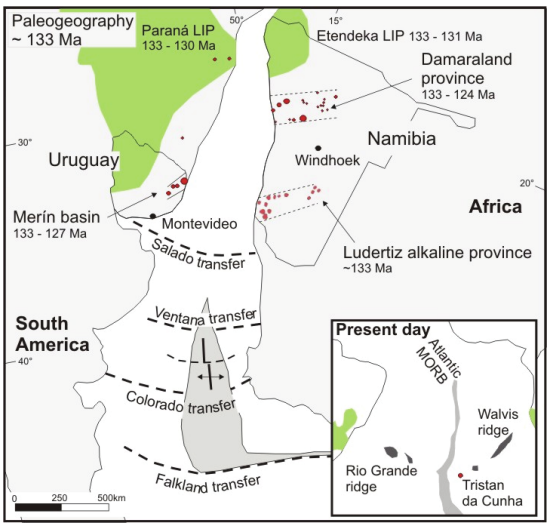

Figure 3. Paleogeographical reconstruction (Franke et al. 2007) of the breaking up of Gondwana at ca. 133 Ma and showing location of broadly coeval magmatism.

The erosion levels of the Merín basin are shallower than over most of the mineralized alkaline complexes in Namibia, with the possible exception of the Valle Chico complex. Limited erosion might have allowed preservation of the hydrothermally altered roof wall rocks to deep and concealed intrusions of the Merín basin. Such concealed hydrothermal zones could host disseminated and vein mineralization.

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