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Genesis of the La Espingarda kaolin deposit in Patagonia

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ABSTRACT

The La Espingarda kaolin deposit was formed by "in situ" alteration of sub-alkaline rhyolites belonging to the Jurassic Marifil Formation. Three altered volcanic lithofacies were identified: a porphyric biotitic ignimbrite (RPB), a coarse lithic ignimbrite (ILG), and a fluidal intrusive rhyolite (RFI).

The kaolinization covers an ellipsoidal surface area of ~20,000 m^2, with the alteration intensity decreasing downwards and disappearing at 8–12 m from the surface. In two mine sectors small stockworks of fine quartz veins appears (<3 m^2). The deepest alteration is related to two fault zones where the three volcanic units are in contact. There is no lateral clay zoning at the faults. The mineralogical composition is kaolinite ± halloysite ± illite + quartz + feldspars + Fe-hydr(oxides). At least three kaolinite generations were identified. The first is pervasive; the second appears as a filling of vugs in the quartz veinlets that crosscut the pervasively altered rocks; and the third occurs as pure kaolin veins without quartz vein cross cuts. During the alteration processes almost total alkali cations were leached. The argillized lithofacies showed Ni enrichment and Cu, Sr, and Ba depletions.

The main weathering genesis for La Espingarda is supported by the deposit morphology, its location in topographic lows, the paleoclimatic record, its simple mineralogical composition; vertical zonation, the kaolinite veins isotopes ($\delta^{18}O$ ‰ 18.3; δD ‰ −59.0), and the trace element distribution.

A steam heated water activity produced some kaolinite overprint according to one isotopic value and the S and P contents slightly higher in the kaolinized rocks. Neither Au, Ag, As, Sb, Hg, or Ba epithermal pathfinders' anomalies nor drill data support the existence of any metallic mineralization at the kaolin blanket bottom.

In Patagonia hydrothermal kaolinite manifestations are located around and beneath silicified, erosion-resistant hills and include some of the following minerals: dickite, alunite, pyrophyllite, or pyrite and have As, S, Ba, and Ag trace elements within the range of weak geochemical anomalies.

1. Introduction

In Patagonia, Southern Argentina, there is an extended Triassic–Jurassic Gondwana Rhyolite Province that contains primary kaolin and epithermal gold deposits (Schalamuk et al., 1997; Domínguez and Cravero, 1999; Sotarello et al., 2002; Sillitoe, 2004; Rubinstein and Gargiulo, 2005). The rocks of this Gondwana Rhyolite Province have different regional names, being the Marifil Formation (Malvicini and Llambias, 1974) at the deposit area.

These rhyolites contain numerous primary kaolin deposits that supply clays to the ceramic industry. The main deposits are located along the Lower Valley of the Chubut River, although some others as Lote 8, Cº Rubio, Blanquita and Equivocada, are also important. There are also secondary "Ball Clay"-type kaolin layers in younger sedimentary sequences linked to them. The rhyolites also contain numerous epithermal gold deposits some of which are at present under or will be in exploitation in the near future such as Cerro Vanguardia (Zubia et al., 1999); Veta Martha (González Guillot et al., 2004), Huevos Verdes, Manantial Espejo, and Esquel (Sillitoe et al., 2002) among others.

This work focuses on the study of the geology and genesis of "La Espingarda" kaolin deposit located near Dique Ameghino, in Chubut Province. This mine presents an excellent opportunity for a geologic–genetic study because it is in a mature production stage having several exposed mine faces and drilling records that allow a detailed alteration study. Three lithofacies have been altered and each one has its own kaolinite identity. In the deposit, new observations and careful detailed determinations indicate that weathering was the principal kaolinite formation environment.

Since kaolinite can form under weathering or hydrothermal conditions, it is important to distinguish its genesis because, in the last case, the kaolinite manifestations are blankets for precious metal deposit exploration (Bethke, 1984; Hedenquist et al., 2000). Recently, the kaolinite halo

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in the Blanquita, Equivocada and C° La Mina deposits have been confirmed to be hydrothermal (Marfil et al., 2005; Ducart et al., 2006).

Faced with this evidence, the idea of a genetic relation between residual kaolinites and epithermal deposits is once again being considered. This study shows that the kaolinite blanket at "La Espingarda" and others with similar geology do not have any exploration potential for precious metal discovery.

The origin of primary kaolin deposits in Patagonia has been a topic of scientific discussion for a long time: Angelelli and Stegman (1948) and Oliveri and Terrero (1954) found evidence that supports a weathering origin, but Hayase (1969) and Maiza and Hayase (1975) proposed that such deposits were formed by hydrothermal fluids. Romero et al. (1975) linked the genesis to underground water circulation and Logan et al. (1992) concluded that they were formed by hydrothermal fluids without discarding overimposed weathering. Based on isotopic determinations, Domínguez and Murray (1995) attributed the genesis of kaolin to weathering conditions, although restricted hydrothermal influences could not be ruled out.

2. Regional geology

Major Argentinean primary kaolin deposits are located in the lower valley of the Chubut river. Along the valley there are more than 400 kaolin mines that provide about 60% of the country's total production (i.e. 60,000 tons/year). The mines are located between Dolavon and Dique Ameghino embracing an area of 2500 km^2, being one of the deposits of La Espingarda (9000 tons/year) that has more faces exposed to study its geology.

The lower valley of the Chubut River is located south of the Macizo de Somuncura (Stipanicic and Methol, 1972) and its geology is characterized by a Proterozoic metamorphic basement intruded by Permo-Ordovician granites that are covered extensively by the rhyolitic vulcanites from the Marifil Fm according to Sacomani and Panza (1998) (Fig. 1).

Major outcrops at La Espingarda are rhyolitic ignimbrites, lava flows, and tuffs. Besides the prevalence of rhyolite, geochemical studies reflect a wide rock composition embracing the whole rhyolite-basalt series (Uliana et al., 1985). The rhyolites were formed during Lower to Middle Jurassic time based on K–Ar radiometric ages of 158–210 Ma (Rapela and Pankhurst, 1993; Page et al., 1999). All the primary kaolin deposits appear along a regional discordance worked on the rhyolites overlaid by the younger sedimentary rocks.

Cretaceous continental deposits of the Chubut Group and the Danian Salamanca Fm marine sandstones with kaolinite layers, unconformably cover the rhyolitic vulcanites (Lesta and Ferello, 1972). In both cases the paleontological records indicate warm and humid climates (Bertels, 1973; Malumián, 1983; Pothe de Baldis, 1984). The Eocene Río Chico Fm (Simpson, 1933), the Eocene–Oligocene Sarmiento Fm (Spalletti and Mazzoni, 1977), the Upper Pliocene Montemayor Fm (Yllanes, 1979), and the Rodados Patagónicos (Windhausen, 1921) complete the stratigraphic column.

The oldest tectonic activity registered in this area corresponds to basement fissures that facilitated volcanic Jurassic spills during the Gondwana initial separation steps. The fissure formation was prior to the opening of the Atlantic Ocean and the volcanic processes are closely tied to this event (Ramos and Pesce, 1979). Blocks limited by faults are the dominant structural feature in this region which affects the Marifil Fm in a significant way.

3. Materials and methods

The kaolin deposit morphology was defined using geological field methods and the results of 84 holes totaling 503 m of drilling. The drill grid was approximately 25 m and the hole was finished when the sludge turned into fresh rock.

The petrographic, mineralogical, X-ray and chemical analyses comparing fresh, intermediate, and highly altered rocks were performed on typical point samples of each lithological unit (>10 samples).

Clay mineralogical composition was investigated on the point samples and also on a bulk mining sample (>80 kg) of each lithological unit by X-ray powder diffraction performed on both whole rock and <2 μm fractions randomly oriented using a Rigaku-Denki Geigerflex Max III C diffractometer ($2°2\theta\ min^{-1}$, graphite-monochromated Cu K_α radiation). The mineralogical composition was confirmed by its response to the glycolation-heated treatments on the oriented samples. The quantitative mineralogical composition was achieved using both normative calculations and X-ray pattern interpretation applying the generalized reference intensity ratio (RIR) and assuming a theoretical composition for kaolinite, quartz, and feldspars as well as a mean composition for illite. The kaolinite crystallinity was determined on <2 μm fraction obtained by washing, following the method proposed by Hinckley (1963). Because quartz is always present, even in <2 μm fractions, the Stoch index (Stoch, 1974) was used as recommended by Aparicio and Galán (1999). Clay microstructure was observed by scanning electron microscopy (SEM, JEOL 35 CF) using small fragments mounted on Cu holders and coated with an Au–Pd alloy. The halloysite presence was suspected by the X-ray pattern and was confirmed by its tabular morphology on SEM–TEM images of the bulk samples. Its abundance was estimated from the images.

Chemical analyses of major, minor and trace elements (including REE) were performed also at ACTLABS — Canada by Instrumental Neutron Activation Analysis (INAA), Inductively-Coupled Plasma Optical Emission Spectrometry (ICP-OES), and X-ray Fluorescence Spectrometry (XRF). Carbon and sulphur concentrations were determined by IR absorption (Leco CS225, ASTM E 1019).

Fluid inclusions were studied in the quartz veins. Micro thermometric measurements were carried out using doubly-polished wafers of 100–300 μm on a Linkam heating–freezing stage with a −180 to 600 °C working range mounted on an Olympus BX50 microscope with ×10–×25 oculars and UTK50/0.63 Leitz objectives. Calibration was obtained with standards in the 400 °C range, and with CO_2 and pure H_2O for freezing. The salinity of fluid inclusions was determined from the final melting temperature of ice (Tm) using Bodnar's equation (Bodnar, 1992).

The kaolinite isotopic analyses were performed on pure <2 μm samples at Actlabs — Canada (Protocol N° 21188D). The procedures of Clayton and Mayeda (1963) were used for O extraction. The D^{18} extraction was made at 1400 °C in platinum crucibles and the water reacted with U for the H acquisition. A Finnigan Spectrometer was used.

4. Deposit geology

The kaolinized area is found at the bottom of a small valley (Figs. 2 and 3) and in the quarry the dominant outcrops correspond to the flows, ignimbrites, and tuffs of the Marifil Fm. Resistant sandstones of the Salamanca Fm protected the soft kaolinized rocks.

In the volcanic complex four different lithofacies were recognized and described as porphyric biotite ignimbrite (RPB), coarse lithic ignimbrite (ILG), intrusive rhyolitic flow (RF), and fall tuffs (FT).

RPB ignimbrite is reddish with porphyric textures and, in hand samples, fractured angular quartz crystals, feldspars and subordinate biotite in a glassy re-crystallized groundmass were observed. Glassy shards without fluidal evidence were observed under the microscope. Texturally, it is a massive highly cohesive non-welded ignimbrite (Fig. 4).

ILG ignimbrite is pinkish when fresh and yellowish-brown on weathered surfaces. It is a massive lapilli volcanic breccia with poorly selected lithic–pumiceous fragments. It contains RPB lithoclasts included in a vitreous quartz–feldspar re-crystallized glassy texture