Jurassic magmatism and Au-Ag mineralization in the Deseado Massif (Patagonia Argentina): Lead and sulfur isotopic studies

P. Moreira, R.R. Fernández, I.A. Schalamuk, R.O. Etcheverry
Instituto de Recursos Minerales (INREMI), Universidad Nacional de La Plata, CICBA, Argentina

A.P. Rolando
Pará-Iso Laboratory, Instituto de Geociencias, Universidade Federal do Pará, Belém, Brazil

Abstract. Lead isotope analyses of volcanic rocks and hydrothermal minerals and sulfide isotope analyses of sulfurs from Au-Ag La Josefina prospect (Deseado Massif geological province, Argentina) are reported. Lead isotope ratios for sphalerite and pyrite have mean values of 18.48, 15.69 and 38.61 for $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$, respectively, and are similar to Pb isotope ratios for the Jurassic volcanic rocks of Bajo Pobre and Chon Aike Formations. $\delta^{34}S$ ‰ values of sphalerite, pyrite and galena cluster between 1.3 and 3.8 ‰, suggesting that the sulfur at La Josefina was primarily of magmatic origin. These results are interpreted to indicate that the Jurassic volcanic rocks are closely related with low sulfidation Au-Ag occurrences.

Keywords. Pb isotopes, S isotopes, epithermal deposits, Jurassic volcanism, Patagonia Argentina

1 Introduction

The Deseado Massif (DM) is located in the southern Argentinean Patagonia (Fig. 1). In this region, the most important unit is a volcanic complex of upper to middle Jurassic age with bimodal features marked by andesitic and rhyolitic magmas that conform the Bajo Pobre and Chon Aike Formations, respectively. These units crop out over more than half the area of a wide plateau. The geochemical analyses of the Jurassic volcanism show a calc-alkaline magmatism with a volcanic arc affinity.

These volcanic rocks are related to the early history of the Gondwana break-up and were deposited in the back-arc Patagonian Andes during a long period (187 to 144 My) of extension (Riley et al. 2000). The geotectonic environment of Patagonia in the Jurassic times was characterized by very slow subduction in the Pacific margin of Gondwana (Ramos 1988). Pankhurst et al. (2000) support the idea that the volcanic rocks were probably generated by a variety of mechanism, among which the melting of pre-existing continental crust was a dominant process.

These volcanic rocks host the Au-Ag veins of Cerro Vanguardia, the principal ore deposit currently in production, and also host the Ag-ore shoot worked in the Marta Mine, as well as some other important prospects like Manantial Espejo, Huevos Verdes-Cerro Saavedra-El Pluma, El Dorado-Monserrat, Cerro Negro and La Josefina. Most of these prospects (Schalamuk et al. 1997) correspond to the low sulfidation epithermal type of deposits. The last prospect, currently under exploration, is located in the central part of the DM and the mineralization is represented by Au-Ag bearing vein systems (up to 300 g Au/t).

The objective of this paper is to present the lead and sulfur isotopic data from samples of hydrothermal sulfides and volcanic rocks obtained at the La Josefina prospect.

There are few isotopic studies of the DM, only two lead isotope data for the Jurassic volcanic rocks are indicated by Kay and Gorring (1999) and five lead isotope measurements on galena from several ore deposits of the DM were showed by Schalamuk et al. (1997). Theses analyses show isotopic values between 18.48-18.72, 15.73-15.95 and 38.70-39.53 for $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$, respectively.

Isotope sulfur ratios carried out in samples from Au-Ag epitermal prospects (Cerro Vanguardia, Manantial Espejo, El Dorado-Monserrat and Cerro León) in the DM, were reported by Echavarría (1997), Schalamuk et al. (1998) and Jovic et al. (2004). The $\delta^{34}S$ values range between –2.8 and 4.2 ‰, indicating a magmatic source for the sulfur.

2 La Josefina geology

The La Josefina prospect (Fig. 1) includes lower Paleozoic low grade metamorphic muscovitic schists, metavolcanic and calk-silicate rocks with minor magnetitic levels and tourmalinites of La Modesta Formation (Moreira et al. 2005).

The Bajo Pobre and Chon Aike Formations represent the Jurassic volcanic rocks. The Bajo Pobre Formation, mainly andesitic-dacitic rocks, include porphyritic and aphanitic flows partially self-brecciated, porphyries, sills that intrude the low angle dip schist of the La Modesta Formation, and ring-dikes surrounding rhyolitic domes. The Chon Aike Formation cover approximately a 60 % of the area. The lower member outcrop on the west part, and consists of crystal-rich quartz-feldspar-biotite welded ignimbrite with some flatten pumice-rich levels that was dated at 153.2 ±3.6 My (K/Ar on biotite; Arribas et al.

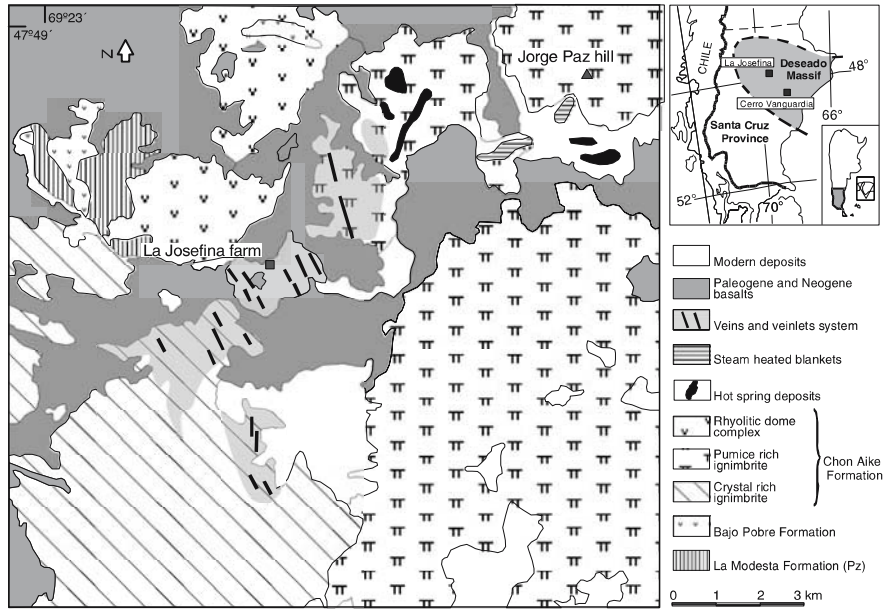

Figure 1: Geology and location of La Josefina prospect.

1996). On the eastern part dominate a welded pumice-rich, crystal-poor welded ignimbrite whose lower levels carrying 5-20 cm crystal-rich-ignimbrite lithic fragments, whereas in the upper levels these lithics are smaller and sporadic. A rhyolitic dome-complex outcrops on 10 km^2 in the north-northwest of the area and some smaller rhyolitic domes extend to the northwest, both with slowly propylitic, pyritic and argillic patch of hydrothermal alteration. These domes intruded the Paleozoic metamorphic rocks (La Modesta Formation).

Paleogene and neogene basaltic flows cover the Jurassic volcanic rocks.

3 La Josefina Au-Ag epithermal ocurrences

The mineralization at the La Josefina prospect consists of system of low sulphidation epithermal veins and veinlets filled mainly by quartz and chalcedony with minor adularia, barite and platy calcite. The primary assemblages are composed by native gold, electrum, specularite and pyrite, arsenopyrite, galena with freibergite inclusions, sphalerite, chalcopyrite and bornite and a supergenic association consist in limonites, chalcocite-covelite, cerusite-anglesite and malachite.

These occurrences are distributed in a curved belt about N-S 12 km long and between 500 and 1200 m wide. The age of the mineralization is not well constrained; a Rb-Sr errorchron gave an age of 156 ± 2 My (Fernández et al. 1999). The veins are spatially associated with superficial epithermal occurrences, like hydrothermal eruption breccias, silica sinter terraces, geyserites, carbonate stromatolitic deposits, and steam heated blankets, mainly to the north of the prospect.

4 Samples and results

4.1 Samples

The samples collected for the lead isotopic study of the La Josefina prospect consisted in intermediate-acid Jurassic volcanic rock from Bajo Pobre and Chon Aike Formation (feldspar separates) and hydrothermal minerals from veins (pyrite and sphalerite). The isotopic Pb composition were determinate on 13 samples in the Pará-Iso Laboratory, Instituto de Geociencias, Universidade Federal do Pará, Belém, Brazil.

Seven sulfide paragenetic samples, including separates of pyrite (3), sphalerite (3), and galena (1), were analyzed for their sulfur isotope composition. Analyses were carried out at the Stable Isotopic Service from Salamanca University (Spain). The results are given as $\delta^{34}S$ ‰ values relative to the CDT standard.

4.2 Results

The analyses of Pb in samples from La Josefina prospect are summarized in the Table 1 and plotted in the Zartman and Doe (1981) diagrams (Fig. 2).

The volcanic Jurassic samples have an average ratios of $^{206}Pb/^{204}Pb$= 18.44, $^{207}Pb/^{204}Pb$= 15.65 and $^{208}Pb/^{204}Pb$= 38.50 and the elongate trends in the general cluster indicate mainly an orogenic model fit, suggesting variable mixing of lead from different sources, mainly model upper crust and to a lesser extent model mantle and lower crust reservoirs.

The Pb isotopic compositions of pyrite and sphalerite from La Josefina are near $^{206}Pb/^{204}Pb$= 18.48, $^{207}Pb/^{204}Pb$=

Table 1: Lead isotope composition of volcanic rocks and sulfides from La Josefina.

	Sample	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
Chon Aike Fm	2728	18.543	15.712	38.722
	2719	18.475	15.659	38.563
	2762	18.307	15.59	38.29
	2862	18.494	15.67	38.558
	2800	18.48	15.656	38.566
	2705	18.515	15.653	38.573
Bajo Pobre Fm	10bp	18.424	15.64	38.475
	2733	18.391	15.626	38.405
	2760	18.424	15.64	38.475
	2795	18.397	15.621	38.414
py	1678	18.496	15.68	38.611
	1693	18.416	15.633	38.46
sph	1681	18.541	15.762	38.769

Table 2: $\delta^{34}S$ ‰ values of La Josefina Au-Ag occurrence

Sample	Mineral	$d^{34}S_{CDT}‰$	Yield %
1678	py	3.1	64.9
1677	py	3.8	81
1725	py	2.7	69.8
1681	sph	13.1	92.7
1687	sph	2.1	82.8
1687 bis	sph	2	84.7
1699	ga	1.3	90.2

15.69 and $^{208}Pb/^{204}Pb$= 38.61. The lead isotope composition of these sulfides are in general slightly more radiogenic than the volcanic host rocks.

The analyses of $\delta^{34}S$ ‰ are summarized in the Table 2. Sulfur samples in La Josefina show $\delta^{34}S_{mineral}$ values between 1.3 and 3.8 ‰. The $\delta^{34}S$ high value for sphalerite (13.1 ‰) demonstrate an overall increase. This could be explained by changes of the hydrothermal fluid pH produced by the interaction with the volcanic rocks.

5 Conclusions

The $\delta^{34}S$ values of pyrite, sphalerite and galena indicate that their sulfur was derived from a magmatic sulfur source with scarce supergene activity. Pb isotope ratios of pyrite and sphalerite, are most similar to those of the volcanic rocks and suggest that they are the likely source.

The correspondence of both sets of values with the orogenic growth curve of Zartman and Doe (1981) suggests further that varied sources contributed to the lead of the magma.

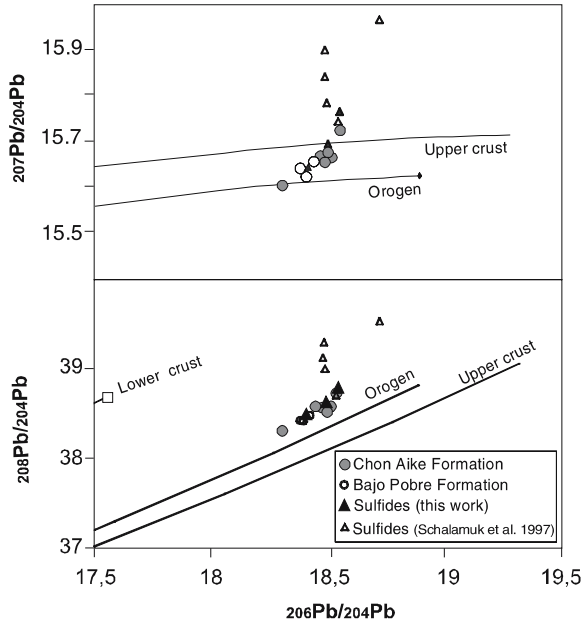

Figure 2: Detailed $^{206}Pb/^{204}Pb$ versus $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ plots of lead isotopes from La Josefina samples.

Lead isotopes obtained from galena samples by Schalamuk et al. (1997) although have slightly higher values, do not show significant differences from the samples studied here. The $\delta^{34}S$ results in La Josefina are similar to those in several ore deposits in the DM.

Based on these features, there is a genetic link between the DM low sulfidation epithermal deposits and the bimodal magmatism of the Bajo Pobre and Chon Aike Formation.

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References

Arribas Jr A, Schalamuk I, de Barrio R, Fernández R, Itaya T (1996) Edades Radimétricas de Mineralizaciones Epitermales Auríferas del Macizo del Deseado, Provincia de Santa Cruz, Argentina. In: XXXIX Congresso Brasileiro de Geología, pp 254-257

Echavarría LE (1997) Estudio geológico-minero del área El Dorado-Monserrat, Departamento Magallanes, provincia de Santa Cruz. Tesis Doctoral Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata. Unpublished

Fernández R, Echeveste H, Tassinari C, Schalamuk I (1999) Rb-Sr age of the La Josefina ephitermal mineralization and its relation with host volcanic rocks. Macizo del Deseado, Santa Cruz Province, Argentina. In: 2º Simposio Sudamericano de Geología Isotópica, pp 462-465

Jovic SM, Guido D, Tiberi P, Schalamuk I (2004) Cerro Leon, una variación del modelo epitermal de baja sulfuración del Macizo del Deseado. In: VII Congreso de Mineralogía y Metalogenia, pp 225-230

Kay SM, Gorring ML (1999) Evolution of the Patagonian Mantle: evidence from isotopic studies of Tertiary to recent plateau lavas. II South American Symposium on Isotope Geology, pp 556-565

Moreira P, González P, Fernández R, Echeveste H, Schalamuk I, Etcheverry R (2005) El basamento de bajo grado de las Estancias La Modesta y La Josefina, Macizo del Deseado, Provincia de Santa Cruz. Revista de la Asociación Geológica Argentina 60-1

Pankhurst RJ, Riley TR, Fanning CM, Kelley SR (2000) Episodic silicic volcanism in Patagonia and the Antarctic Peninsula: chronology of magmatism associated with the break-up of Gondwana. J Petrol 41: 605-625

Ramos V. (1988) Late Proterizoic-Early Paleozoic of South America. A collisional history. Episodes, 11:168-175

Riley T, Leat P, Pankhurst R, Harris C (2000) Origin of large volume rhyolitic volcanism in Antartic Peninsula and Patagonia by crustal melting. J Petrol 42: 1043-1065

Schalamuk I, Echeveste H, Etcheverry RO, Ametrano S (1998) Metalogénesis del yacimiento "Manantial Espejo", Macizo del Deseado, provincia de Santa Cruz. In: Academia Nacional de Ciencias Exactas, Físicas y Naturales, Anales 50: 217-236

Schalamuk I, Zubia M, Genini A, Fernández R (1997) Jurassic epithermal Au-Ag deposits of Patagonia, Argentina. Ore Geol Rev 12: 173-186

Zartman RE, Doe BR (1981) Plumbotectonic-the model. Tectonophys 75: 135-162