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METALS AND FLUID SOURCE USING PB ISOTOPES IN EUREKA-LA MARIANA JURASSIC EPITERMAL DEPOSIT, NORTHWESTERN DESEADO MASSIF, ARGENTINEAN PATAGONIA.

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INTRODUCTION

The Deseado Massif Geological Province (DM), in the Argentinean Patagonia, is characterized by an extensive middle to late Jurassic volcanism that covers approximately 35,000 km^2. Pankhurst, et al. (1998) joined the DM with the rest of Patagonian and Western Antarctic Jurassic volcanic rocks in a Large Igneous Province (LIP) called Chon Aike.

Associated with the late stage of this Jurassic volcanism, hydrothermal systems generated diverse epitermal deposits in the DM, mainly classified into the Low Sulphidation (LS) type (Schalamuk, et al., 1997).

Despite some new detailed works (Gonzalez Guillot, et al., 2004; Jovic, et al., 2004) the mineralization is characterized by quartz veins, hydrothermal breccias, veinlets and stockwork, with anomalies in precious metals, in some cases with economic importance, as Cerro Vanguardia Mine and Martha Mine.

Eureka-La Mariana (E-LM) area is located in the northwestern region (Fig. 1) and is one of the most outstanding epithermal projects in the DM. This study is focused on the determination of metals and fluid source from this Au-Ag deposit and its relationship with the middle to late Jurassic volcano-pyroclastic sequence that host mineralization.

Schalamuk et al. (1997) and Moreira et al. (2005) determinate for some epithermal deposits of central DM, an interval of Pb isotopes of 18.307-18.722 for $^{206}Pb/^{204}Pb$, 15.590-15.953 for $^{207}Pb/^{204}Pb$ and 38.290-39.527 for $^{208}Pb/^{204}Pb$, by analyzing five samples of galena and three of pyrite and sphalerite respectively.

GEOLOGICAL SETTING

REGIONAL GEOLOGY

The middle to late Jurassic volcanism that characterize the DM was regionally described as intermediate lava flows and volcanic agglomerates (Bajo Pobre Formation) covered by acidic pyroclastic deposits, with minor lava flows and domes (Chon Aike and La Matilde Formations), placed in gravens under an extensional tectonic setting.

The basement of those units is composed by igneous and metamorphic rocks of late Precambrian to Paleozoic age (Rio Deseado Complex), covered by Permian to Triassic continental sedimentary sequences (La Golondrina, La Juanita and El Tranquilo Formations), late Triassic-early Jurassic granitoids (La Leona Formation) and early Jurassic tuffs (Roca Blanca Formation).

The middle to late Jurassic succession is generally covered by Late Jurassic to early Cretaceous tuffs and tuffites (Bajo Grande and Baqueró Formations), Tertiary marine and continental sedimentary rocks (Patagonia and Santa Cruz Formations), Tertiary to Quaternary plateau basalts and fluvioglacial gravels.

LOCAL GEOLOGY

The E-LM area (Fig. 1) is characterized by a complex, interbedded, Jurassic volcano-pyroclastic sequence of basandesitic to rhyolitic composition. It was mapped with volcanic facies criteria (Lopez, 2006), avoiding formational names and using the Bahía Laura Complex (BLC) terminology, in order to show its complexity. Those rocks are partially covered by Tertiary sedimentary rocks and basaltic plateaux and Quaternary sediments.

The BLC is composed by intercalations of andesitic lava flows (Lower and Middle Andesitic Lava Flows) and dacitic ignimbrites. Andesitic and dacitic subvolcanic bodies are intruding this sequence. A new period of extrusive rocks took place, first rhyolitic domes, dikes and lava flows were emplaced, and then, a last andesitic lava flow (Upper Andesitic Lava Flows). The Jurassic BLC sequence ends with andesitic volcanic agglomerates, ash-fall tuffs and reworked/undifferentiated volcaniclastic rocks.

LS EPITERMAL DEPOSITS

The area comprises the westernmost part of the Cerro Negro Project (Oroplata S.A.). Mineralization in the area is well represented by different levels of the epithermal model, with shallow features as carbonate stromatolites (Guido et al., 2002) and silica sinter (Lopez et al., 2003), intermediate level structures as La Mariana South Vein (the only one without presenting sulfides) and Central Hydrothermal Breccia and deeper examples as Eureka North Vein, Northern Veinlets and La Mariana North Vein (Fig. 1). There are also many quartz veinlets and hydrothermal alteration zones.

Central Hydrothermal Breccia (CHB) consists in a 200 meters long and 2 meters wide structure, orientated N335°, filled by an hydrothermal breccia with vein fragments of crustiform texture, in a massive saccharoid quartz cement. The host rock is a silicified ignimbrite, that has abundant disseminated pyrite, but in association with later fractures.

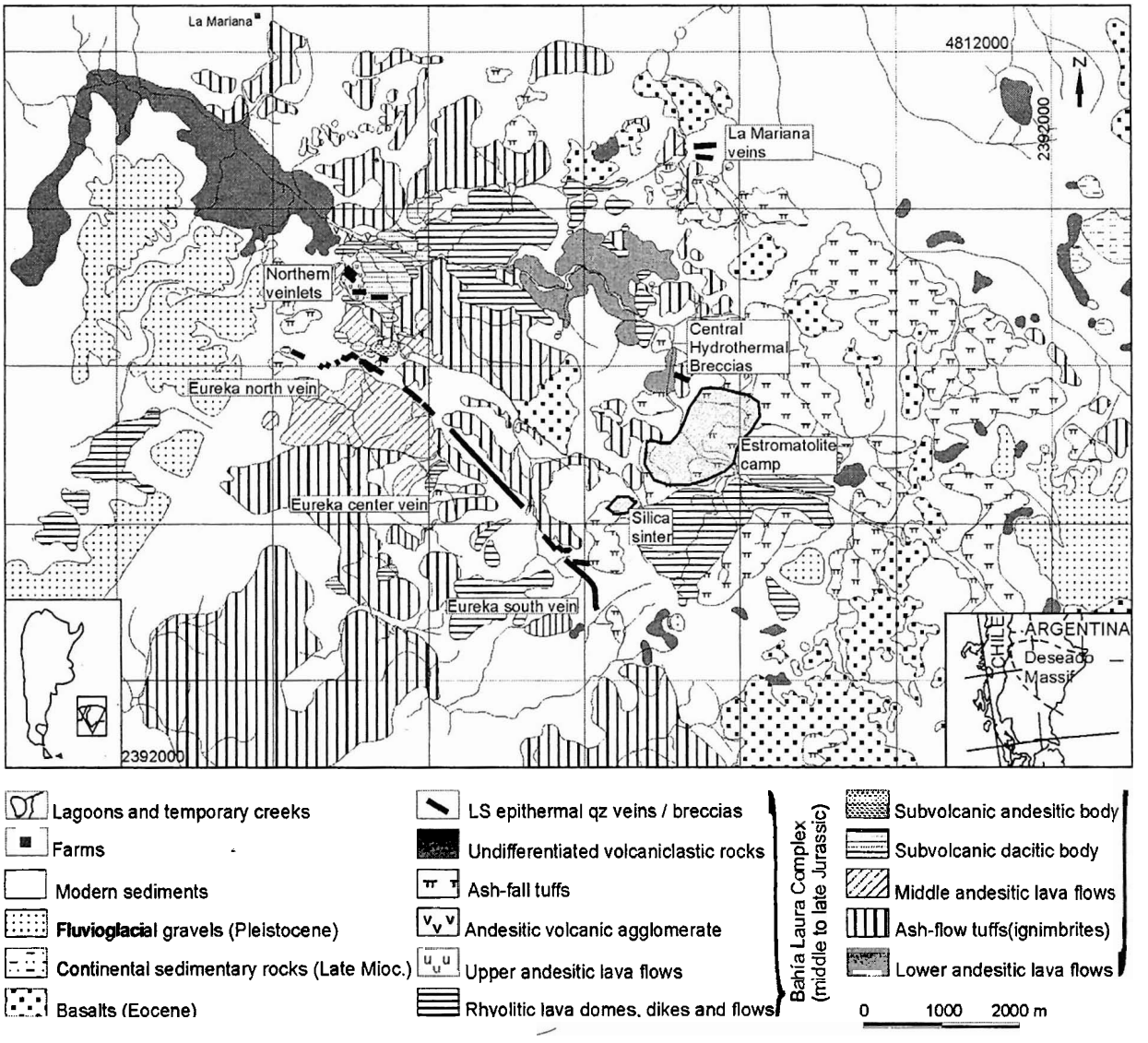

Figure 1: Geological and Mineralizations map

Eureka Quartz Vein (EuV) has general N 300° to 310° azimuth, and steeply dips (70° to 80°) to the southwest. It is 4,500 meters long, outcropping discontinuously through several aligned hills, displaced by perpendicular faults.

The main characteristics of the vein changes over its length that is why it was subdivided in three: north, center and south, showing deeper to shallower hydrothermal features respectively (Lopez, 2006).

Eureka north vein generally has a unique body of about 5, up to 25 meters wide filled by quartz and chalcedony, with crustiform, coloform, cockade and breccia textures, hosted in intensely altered andesitic lava flows. At the northwestern extreme of the vein, the host rock has disseminated pyrite. This part of the vein has the most important anomalies in Au and Ag.

Eureka center vein includes three branches from 1 to 3 meters wide each, mainly with brecciated texture, with angular clasts of the Eureka north vein pulses in a Fe-rich silica cement, and a later event of Fe-Mn oxides that took place inside the bands of the crustiform texture, or as the cement of a new hydrothermal breccia.

Eureka south vein is the most regular of the three segments. It has a width, from 1 to 2 meters and is composed by veinlets of quartz in some places with a singular densification, giving place to breccia texture,

with abundant host rocks clasts in an saccharoid quartz cement, hosted in ash fall tuffs.

The alteration patterns change taking into account the host rocks, but always forming a halo of 30 meters to each side of the vein. If the host rock is acidic in composition (tuffs, ignimbrites, etc.) the alteration assemblage consists in quartz, sericite, illite ± epidote, while if they are intermediate, the typical alteration mineralogy is chlorite, epidote, smectites, calcite, and zeolites.

Northern Veinlets (NV) consists in a group of veins and veinlets that are divided because of its composition in: filled by quartz or by carbonate.

The silicic ones are veinlets with two main orientations: NW-SE and E-W. They have 2 centimeters to 1 meter wide and up to 100 meters in length, with infilling of quartz with comb texture. The crossing veinlets produce some breccia textures. They generate propylitic + argillic or silicic + argillic alteration bands of 0.5 to 2 meters in width, depending on the intermediate or acidic composition of the host rocks.

In the other hand, the carbonate veinlets join in real veins of up to1 meter in width. The host rocks are intermediate, where propylitic is the main alteration, forming bands of 10 meters wide to each side of the vein. Veins are composed in 95% by calcite, but also quartz amethyst, adularia and pyrite are present.

La Mariana North Vein (LMNV) has N 260° azimuth; up to 2 meters in width and it is 200 meters long. Quartz is white to gray, and has typical epithermal filling textures: massive, saccharoid, crustiform and coloform banding and calcite pseudomorphs. Occasionally quartz is highly porous, with limonite filling the pores. There are many limonite patinas and patches and fine disseminated pyrite. It is hosted in gray to green fine air fall tuffs with intense alteration. It is possible to recognize argillized crystaloclasts and many limonite patinas and patches.

PB ISOTOPY

The lead isotopic compositions of sulphides and quartz from the samples of the main mineralizations in E-LM area are radiogenic and relatively homogeneous (Table 1) with $^{206}Pb/^{204}Pb$ ratios ranging from 18.343 to 18.460; $^{207}Pb/^{204}Pb$ from 15.599 to 15.631 and $^{208}Pb/^{204}Pb$ from 38.344 to 38.479. The Pb isotopic compositions cluster between the orogen and upper crust curves in the uranogenic diagram of the plumbotectonic model of Zartman and Doe (1981) (Fig. 2).

The host rocks display Pb isotopic compositions for $^{206}Pb/^{204}Pb$; $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$, between 18.474 – 18.662; 15.595 - 15.621 and 38.575 - 38.831 respectively. The lead isotopic signature of the intermedite rocks range from 18.474 to 18.621; from 15.595 to 15.603 and from 38.575 to 38.738 for $^{206}Pb/^{204}Pb$; $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ respectively. The present day average Pb isotopic compositions for host rocks are more radiogenic than the sulphides as expected.

Sample	Material	$^{206}Pb/^{204}Pb$	Error % (1σ)	$^{207}Pb/^{204}Pb$	Erro % (1σ)	$^{208}Pb/^{204}Pb$	Error % (2σ)
R375	Dacitic Subv Body	18.662	0.008	15.620	0.007	38.733	0.008
R434	Andesitic Subv. Body	18.497	0.020	15.595	0.018	38.638	0.019
R373	Lower andesitic flows	18.474	0.008	15.600	0.010	38.575	0.010
R377	Upper andesitic flows	18.621	0.012	15.603	0.008	38.738	0.008
R378	Dacitic Ignimbrite	18.597	0.009	15.621	0.007	38.729	0.008
R440	Rhyolitic Lava domes	18.645	0.007	15.621	0.007	38.831	0.006
R267	Eureka vein / qtz	18.368	0.012	15.604	0.012	38.372	0.014
R382	Eureka vein / py	18.343	0.015	15.599	0.011	38.344	0.012
R415	Northern Veinlets/ py	18.392	0.011	15.615	0.008	38.407	0.008
R422	LMNV / qtz	18.460	0.035	15.631	0.031	38.479	0.034
R447	LMNV / py	18.365	0.011	15.601	0.011	38.361	0.012
R445	CHB / py	18.400	0.008	15.628	0.007	38.452	0.008

Table 1: Lead isotopes results of Eureka-La Mariana area.

In the Pb-Pb diagram (Fig. 3) the field defined by analytical points from dacitic subvolcanic body, ignimbrite and rhyolite fall along an array that trends towards to mineralized structures Pb isotope compositions, while the Pb isotopic evolution line regression for the andesites do not intercept the Pb isotopes field for sulphides and quartz. Based on the evidences listed above it is possible to consider that the behavior of the Pb isotopic composition of sulphides suggest a mixing of Pb derived from crustal rock sources, but mainly with lead contribution from the acidic suite.

In the $^{206}Pb/^{204}Pb$ versus $^{207}Pb/^{204}Pb$ diagram, the analytical points from sulphide define a linear array, which intercept the Stacey & Krammers (1975) Pb isotopic evolution curve at approximately 200 Ma (Fig. 3). This Pb-Pb model age, despite of the low precision, suggest a jurassic age for the hydrothermal activity associated with the E-LM area. In addition, it was determined, for a sample of Lower Andesitic Lava Flows a model T_{DM} age of 1.2 Ga, that indicate the presence of older continental crust at the area, and the vNd value indicates an lower continental crust source for this rock (Lopez et al., 2006).

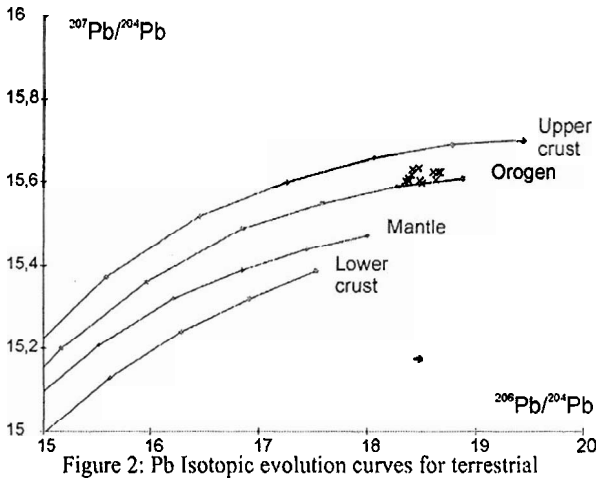

Figure 2: Pb Isotopic evolution curves for terrestrial geochemical reservoir by Zartman y Doe (1981).

CONCLUDING REMARKS

The results obtained in this work fall within the interval of Deseado Massif previous Pb isotopes (Schalamuk et al., 1997 and Moreira et al., 2005), but near to the minor values in the case of $^{206}Pb/^{204}Pb$ and $^{207}Pb/^{204}Pb$ ratios.

Considering our preliminary investigation of Pb-Pb and Sm-Nd isotopic systematics and field observations we may suggest that the main mineralizations cropping out in Eureka-La Mariana area, formed due to the development of widespread convective hydrothermal activity within upper continental crust with leaching of Pb and, probably gold, mainly from the acidic suite of host rocks (ignimbrite, dacitic subvolcanic body and rhyolitic rocks) or through a complex mixing of Pb from these rocks together a subordinate amount of Pb derived from the andesite.

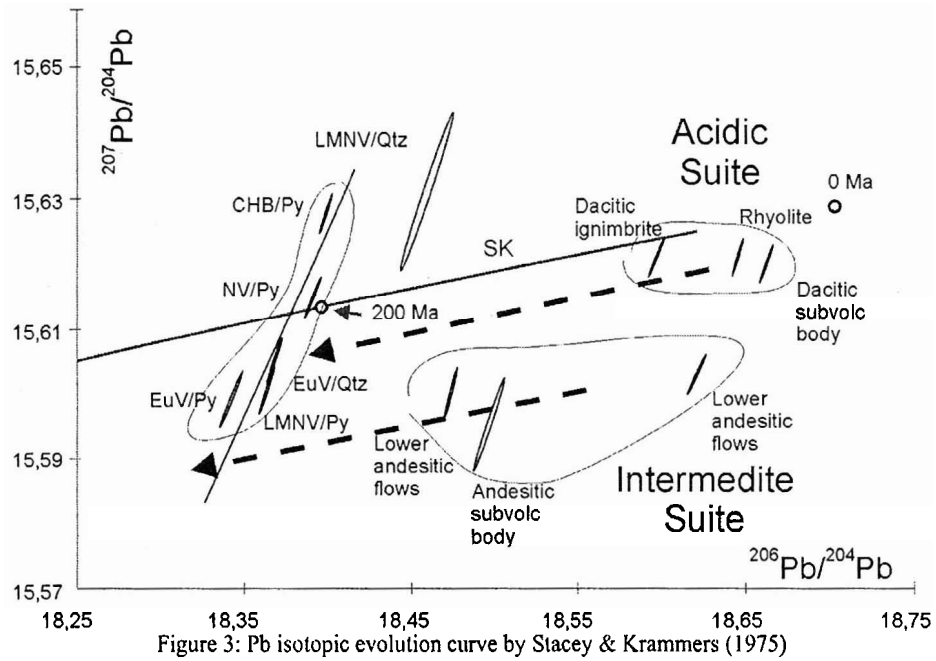

Figure 3: Pb isotopic evolution curve by Stacey & Krammers (1975)

Finally, the model age of 1.2 Ga from the Lower andesitic flows (Lopez, et al., 2006) is indicating a "Grenvillian" continental crust source for the this rocks, in agreement with the hypothesis of crustal Pb taking part in the mineralized fluids.

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RESUMEN

El área Eureka-La Mariana (E-LM) se ubica en el noroccidente de la Provincia Geológica Macizo del Deseado (MD), caracterizada por la presencia de una compleja secuencia volcano-piroclástica jurásica, basandesítica a riolítica en composición (Complejo Bahía Laura), donde se desarrolló mineralización hidrotermal con anomalías en Au-Ag, representada por diferentes niveles dentro del sistema epitermal de tipo baja sulfuración, con rasgos superficiales como estromatolitos carbonáticos o profundos como la veta Eureka Norte.

Facies volcano-piroclásticas jurasicas, así como las principales estructuras mineralizadas fueron analizadas por isótopos de Pb. Las composiciones isotópicas de los sulfuros y el cuarzo resultaron radiogénicas y relativamente homogéneas, dentro del intervalo registrado por los escasos datos previos correspondientes al centro del MD.

En el diagrama uranogénico del modelo plumbotectónico de Zartman y Doe (1981) se disponen entre las curvas del orógeno y la corteza superior. En este mismo gráfico, el campo de las mineralizaciones analizadas es interceptado por la tendencia del representativo de las rocas ácidas mientras que no ocurre lo mismo con el grupo de rocas intermedias.

La línea media de los valores de las mineralizaciones interceptó a la curva de Stacey & Krammers (1975) aproximadamente a los 200Ma indicando edad jurásica para la actividad hidrotermal del área.

Por lo tanto se interpreta que la mineralización se debió al desarrollo de una actividad hidrotermal a escala regional, dentro de la corteza superior continental, con lixiviación de Pb, y probablemente oro, de la suite ácida, o a través de una compleja mezcla de Pb de ésta última con una cantidad subordinada de Pb de la suite intermedia.