Deseado Massif hot spring deposits (Late Jurassic, Patagonia, Argentina) and their association with epithermal systems

D.M. Guido[1], *and Campbell, K.A.*[2]

1. CONICET and Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, Instituto de Recursos Minerales (INREMI), Calle 64 y 120, La Plata (1900), Argentina. Email: diegoguido@yahoo.com

2. School of Environment, The University of Auckland, Private Bag 92019, Auckland 1142, New Zealand.

INTRODUCTION

The Deseado Massif volcanic and epithermal province is located in the northern portion of the Santa Cruz province, southern Argentinean Patagonia (Fig. 1). It is a 60,000 km^2 geological unit recording an extensive Middle to Late Jurassic bimodal calc-alkaline volcanic event demarcated by the Bahía Laura Complex (BLC), consisting of andesites, intermediate to acidic primary volcanics, and late acidic reworked volcanic rocks (Guido & Campbell, 2011).

The metallogenical province hosts economic gold and silver-bearing, mainly low sulphidation, epithermal deposits within the BLC, with 10 active mines, and one more recently closed, together with four more advanced projects with 43-101 reports on their published resources (Fig. 1).

Geothermal systems are of interest to economic geologists because they may vectorize towards low - to intermediate - sulphidation epithermal mineralization (Sillitoe, 1993; Sillitoe, 2015). Geothermal fluids emit from spring vents, cooling and producing chemical precipitates as they discharge (~100°C to ambient) along channels, into pools, over terraces, and finally spreading out in their distal reaches to create hydrothermal influenced wetlands, cherts and silicified lacustrine sediments (Guido and Campbell, 2011; Sillitoe, 2015).

The Deseado Massif hosts numerous low to intermediate epithermal systems together with fossil geothermal features, represented by quartz veins, widespread hydrothermal silicification and hydrothermal breccias hosted within the acid to intermediate volcanic rocks that are capped in several places by calcareous travertine and siliceous sinter chemical hot spring precipitates, hydrothermal eruption breccias and other epithermal paleosurface features. They formed generally at the top of the volcanic sequence within fluvial to lacustrine reworked strata of the BLC, together with intermediate to silicic lava domes, all of which are related to local and regional structural lineaments (Guido & Campbell, 2011).

These hot spring deposits were formed in a mature and quiescent phase of the volcanic activity during the Late Jurassic (Guido, 2004). There are a total of 23 published paleo-hot spring sites in the Deseado Massif (Fig. 1), some of which have been studied in detail to determine their geologic and facies associations (Guido and Campbell, 2009; Guido et al., 2010, Guido and Campbell, 2012, 2014, 2017). They show a close relationship with epithermal mineralization, as was pointed out by Guido and Campbell (2011), with hot spring localities and significant epithermal deposits (mines and advanced projects) located in four regional NNW and WNW structural belts. The Northern and Northwestern belts, in particular, concentrate most of the geothermal and epithermal occurrences, supporting the hypothesis that Jurassic hydrothermal fluid flow was strongly influenced by the most dominant and long-active geological boundaries in the region, the outer limits of the Deseado Massif 'horst' itself (Guido and Campbell, 2011).

The aim of this contribution is to describe in detail the particular Deseado Massif epithermal systems with preserved close (less than 5 km) fossil geothermal deposits, and the possible exploration implications.

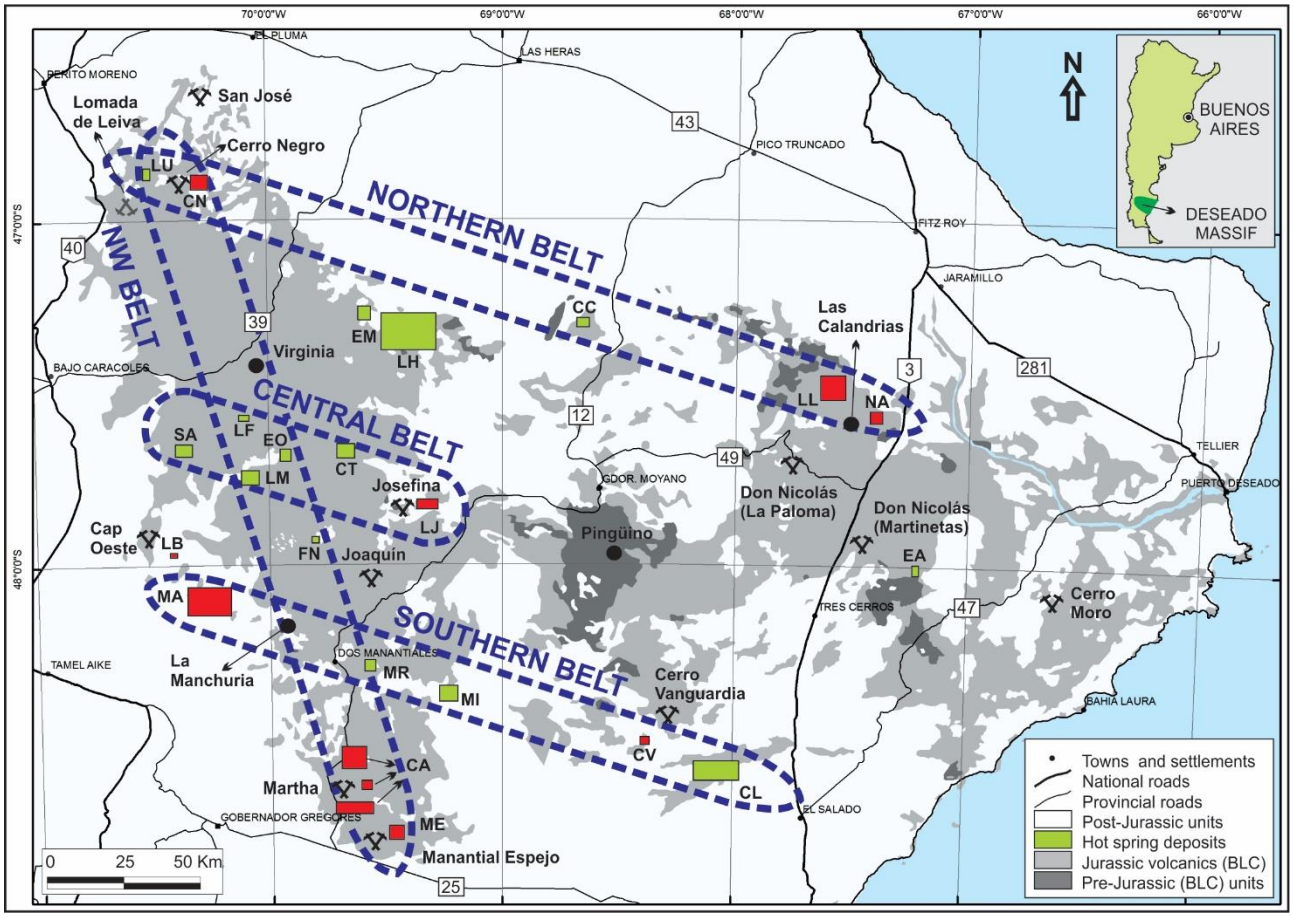

FIG 1 – Deseado Massif province summarized geological map with location of hot spring deposits, epithermal mines and advanced projects (black dots). Red polygons show hot spring-related epithermal systems. Modified from Guido and Campbell (2011).

DESEADO MASSIF HOT SPRING-RELATED EPITHERMAL MINERALIZATION

Reconnaissance surveys (Guido and Campbell, 2011, and references therein) delineated 23 hot spring localities (Fig. 1) for the Deseado Massif, of which 8 are sinter deposits (NA: Cañadón Nahuel, SA: San Agustín, LJ: La Josefina, LB: La Bajada, MA: La Marciana, MR: La María, CV: Cerro Vanguardia, CL: Claudia), 9 are travertine deposits, some subsequently silicified (LU: La Unión, CN: Cerro Negro, CC: Cerro Contreras, EM: El Macanudo, LM: La Marcelina, MI: Monte Illiria, ME: Manantial Espejo, LH: La Herradura, CA: Cerro 1 Abril), and 6 are cherts and/or silicified rocks (LL: La Leona, LF: La Flora, EA: El Águila, EO: Esperanza Oeste, CT: Cerro Tornillo, FN: Flecha Negra).

Considering the most significant mineralization of the Deseado Massif (the 11 mines and the four advanced projects) and delimiting those deposits with a close spatial relationship with related geothermal features, we identified a total of 8 hot spring localities proximal to epithermal mineralization. Table 1 summarizes these localities, and delineates whether they are sinter or travertine in composition, and indicating the dominant facies in relationship to a vent area (proximal to distal), and the characteristics of the spatially-related mineralization: name, size (in million ounces of gold equivalent, using 70 as Ag/Au ratio), Ag to Au ratio, and distance between the closest vein and the paleo-hot spring area.

Processing this information, it is possible to determine that 35% of the hot spring localities so far identified within the Deseado Massif are related to relevant mineralization (mines or advanced projects), and 75% of these hot spring-related epithermal mineralization areas are actually in production.

In addition, 54% of the Deseado Massif mines have evidence of spatially-related (<5 km to the closest vein) hot spring deposits. Considering the size of the deposits, the three largest epithermal deposits of the province (Cerro Vanguardia, Cerro Negro and Manantial Espejo) have extensive fossil geothermal fields with dominant travertine proximal facies. Finally, the Ag/Au average ratio is higher in epithermal systems with related travertine (Ag/Au: 489) as compared to those related with sinter (Ag/Au: 19)

Sinter Locality	HS type	Facies	Mine-Advanced project	Size (Moz Au eq.)	Ag/Au	Closest vein (km)
Cerro Vanguardia	S	Proximal	Cerro Vanguardia mine	11	16	5
Cerro Negro	T	Proximal	Cerro Negro mine	7	8	0
Manantial Espejo	T	Proximal	Manantial Espejo mine	3	60	0
La Bajada	S	Distal	Cap Oeste mine	1.8	25	3
Cerro Primero de Abril	T	Distal	Martha mine	0.3	1400	5
La Josefina	S	Distal	Josefina mine	0.2	18	2
Cañadón Nahuel	S	Distal	Las Calandrias project	0.5	17	5
La Leona	S	Distal				

TABLE 1 – Summary of the hot spring-related epithermal mineralization in the Deseado Massif (mines and project data taken from www.sedar.com).

CONCLUSIONS

The Deseado Massif has about the same number of sinters and travertine chemical precipitate deposits, but a larger quantity of shallow siliceous deposits when we include cherts and silicified volcanic rocks, supporting the overall neutral alkali chloride dominant nature of the hydrothermal fluids.

About one-third of the hot spring localities, and half of the active Deseado Massif epithermal mines, are in close spatial relationship (<5 km). Therefore, defining Jurassic paleosurfaces can be considered as a relevant prospective tool.

Finally, larger (i.e., a proxy for long-lived fluid flow and/or geographically extensive hydrothermal activity) and proximal hot spring deposits contain most of the gold and silver resources, highlighting the importance of proper discrimination of facies assemblages within the Deseado Massif hot spring deposits, that can also be used to vectorize in prospecting the region.

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