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Short Note

Geochronology of Mexican mineral deposits. V: the Peñón Blanco epithermal deposit Durango

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Abstract

The low sulfidation epithermal deposits of the San Juan de Mogotes mineralized area in the Peñón Blanco district, central-eastern Durango, were dated in this study at 31.29 ± 0.08 Ma (adularia from crustiform veins, $^{40}Ar/^{39}Ar$ plateau age). Therefore, these deposits belong to the most productive metallogenic epoch—Oligocene—and are found in the most heavily mineralized region of Mexico—the western half of the Mesa Central, particularly around the San Luis–Tepehuanes fault zone and near its confluence with the Transversal de Parras (or Parras Transversal zone). At that time and in this region epithermal deposits and tin veins in association with fluorine-rich rhyolites (highly differentiated rhyolites) were the dominant types of deposits, and both occurred at a district scale, which is the case of the Peñón Blanco district, among others. Such characteristics suggest a possible genetic link between both types of deposits, research that would need to be specifically addressed in the future.

Keywords: Peñón Blanco, Durango, Mexico, epithermal deposits, low sulfidation, $^{40}Ar/^{39}Ar$ ages, adularia.

Resumen

Los depósitos epitermales de baja sulfuración del área mineralizada de San Juan de Mogotes en el distrito de Peñón Blanco, Durango centro-oriental, son fechados en este estudio en 31.29 ± 0.08 Ma (adularia de vetas crustiformes, edad de meseta $^{40}Ar/^{39}Ar$). Por lo tanto, estos depósitos pertenecen a la época metalogenética más productiva—oligocénica—y se encuentran en el área más densamente mineralizada de México—la mitad occidental de la Mesa Central, particularmente alrededor de la zona de falla de San Luis–Tepehuanes y cerca de la confluencia entre ésta y la Transversal de Parras. Durante dicha época y en esta región, las tipologías dominantes de yacimientos minerales son los depósitos epitermales y las vetas de estaño en asociación con riolitas ricas en flúor (riolitas altamente diferenciadas), y ambas tipologías se encuentran también a escala de distrito, que es el caso del distrito de Peñón Blanco, entre otros. Tales características sugieren un posible nexo genético entre ambas tipologías, tema que necesitaría ser investigado específicamente en el futuro.

Palabras clave: Peñón Blanco, Durango, México, depósitos epitermales, sulfuración baja, edades $^{40}Ar/^{39}Ar$, adularia.

1. Introduction

The Peñón Blanco district in eastern-central Durango state (north-central Mexico) consists of several mineralized areas that contain epithermal deposits, named Yerbanís, Cerro Blanco, and San Juan de Mogotes (also known as La Esperanza) (Servicio Geológico Mexicano, 2003, 2004, 2005). The San Juan de Mogotes mineralized area contains silica sinter deposits that are associated with underlying kaolinized and alunitized rocks (Servicio Geológico Mexicano, 2003) that constitute an advanced argillic alteration assemblage, possibly as a result of steam-heated grounds. Such evidence was interpreted to be associated with low sulfidation epithermal deposits (Servicio Geológico Mexicano, 2003), which include the Lorena, Ángeles, Providencia and Guadalupe veins. Also, the San Juan de Mogotes area includes Sn and Hg showings (Servicio Geológico Mexicano, 2003), and exploration surveys conducted by Exploraciones Mineras Parreña S.A. de C.V. revealed significant Au and Ag concentrations in association with the aforementioned veins (Santiago Olavide, written communication, 2007). This area lies in the vicinity of the Avino-Zaragoza district, which contains tin veins associated with fluorine-rich rhyolites dated at 29.6 ± 0.1 Ma (Rb-Sr; Huspeni *et al.*, 1984), as well as Au-Ag, polymetallic (Ag-Au-Pb-Zn-Cu) and fluorite epithermal veins (Servicio Geológico Mexicano, 2003, 2013), the dominant type of deposits in this district. Au-Ag and polymetallic+fluorite epithermal deposits in Mexico tend to belong to the low and intermediate sulfidation subtypes, respectively (Camprubí and Albinson, 2006, 2007).

The study region, near the central part of the western half of the Mesa Central, as part of the most productive metallogenic epoch (Albinson *et al.*, 2001; Camprubí *et al.*, 2003; Camprubí, 2013), is particularly rich in Oligocene mineral deposits (Figure 1). Metallogenesis during the Oligocene was associated with the most prominent ignimbrite flare-up in the Sierra Madre Occidental silicic large igneous province (Camprubí *et al.*, 2003; Ferrari *et al.*, 2005, 2007). This region is found around the confluence between the westernmost Parras transversal zone and the northwestern ending of the large San Luis–Tepehuanes fault zone (Nieto-Samaniego *et al.*, 2005, 2007; Camprubí, 2013). Since the Late Cretaceous, many mineral deposits formed around this confluence, including an uncanny variety and quantity during a short period in the Oligocene (see Figures 8 and 13 in Camprubí, 2013).

In this paper, we present the first $^{40}Ar/^{39}Ar$ ages for low sulfidation epithermal deposits at the Peñón Blanco district, with the aim to better understand the metallogenic evolution of the heavily mineralized region of the northwestern part of the San Luis–Tepehuanes fault zone, in eastern Durango.

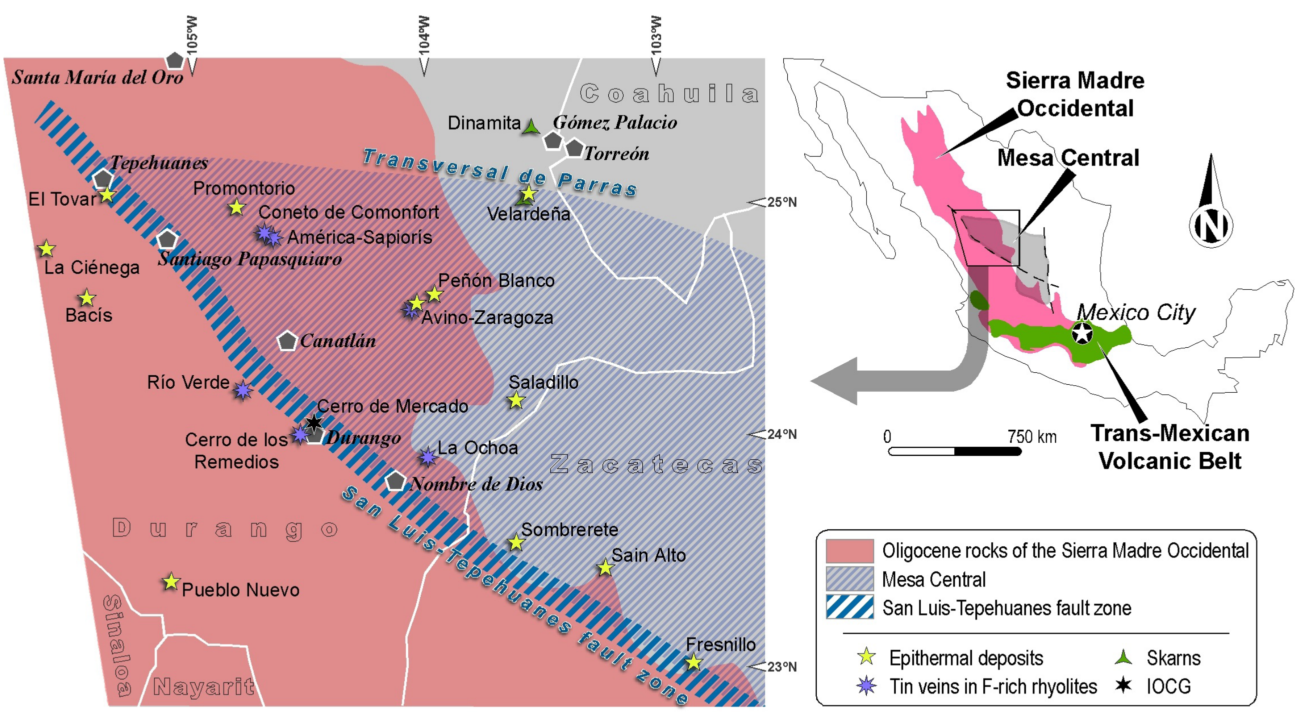

Figure 1. Simplified geological map of the westernmost ending of the Mesa Central in central Mexico, showing the approximate extent of the Oligocene volcanic rocks of the Sierra Madre Occidental silicic large igneous province (based on Ferrari *et al.*, 2005, 2007), the approximate extent of the San Luis–Tepehuanes fault zone (based on Nieto-Samaniego *et al.,* 2005, 2007), and the ore deposits that were formed during the Oligocene (based on Camprubí, 2013). The term 'skarns' stands for sulfide (non-iron oxide) skarns whereas 'IOCG' stands for the 'clan' of iron oxide copper gold deposits, or magmatic-hydrothermal iron oxide deposits, which includes iron oxide skarns. Cities are indicated by gray pentagons.

2. Methods and results

A pure mineral separate of adularia from epithermal vein material from the San Juan de Mogotes mineralized area in the Peñón Blanco district was dated by $^{40}Ar/^{39}Ar$ geochronology (Figure 2 and Table 1). The analyzed sample (SJ-4) corresponds to adularia crystals within crustiform quartz bands in low sulfidation mineralization from the Lorena vein. The vein material was ground down to particles that ranged in size from 250 to 180 µm and were separated using heavy liquids and hand picking to a purity of > 99 %. The sample was washed in acetone, alcohol, and deionized water in an ultrasonic cleaner to remove dust and then re-sieved by hand using a 180-µm sieve.

Aliquots of the adularia sample (~ 20 mg) were packaged in copper capsules and sealed under vacuum in quartz tubes. The sample aliquots were then irradiated in package number KD53 for 20 hours in the central thimble facility at the

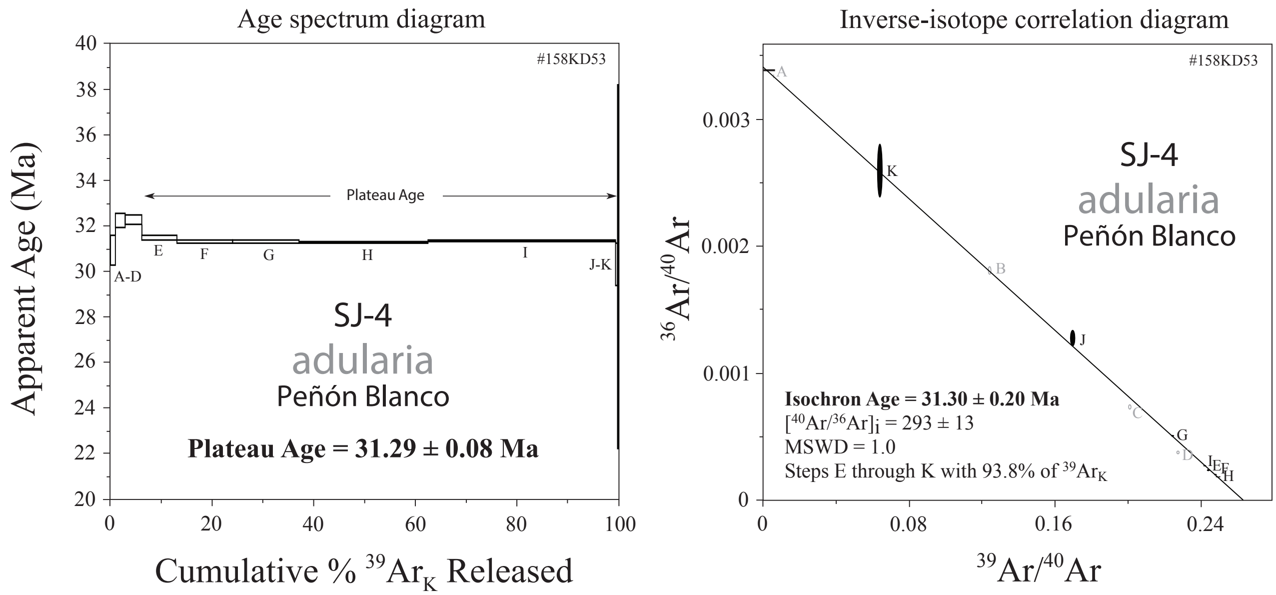

Figure 2. $^{40}Ar/^{39}Ar$ age spectrum and isochron for the SJ-4 adularia sample from the Lorena vein in the San Juan de Mogotes mineralized zone of the Peñón Blanco mining district, central-eastern state of Durango.

Table 1. $^{40}Ar/^{39}Ar$ step-heating data for the San Juan de Mogotes epithermal deposits, Peñón Blanco, Durango.

Step	Temp. °C	$\%^{39}Ar$ of total	Radiogenic Yield (%)	$^{39}Ar_k$ (moles)	$^{40}Ar^*/^{39}Ar_k$	Apparent K/Ca	Apparent K/Cl	Apparent Age (Ma)	Error (Ma)
SJ-4	***Adularia***	*(Peñón Blanco)*	*J = 0.004605 ± 0.25%*		*wt = 2.34 mg*	*#158KD53*			
A	600	0.2	1.7	7.27E-17	2.832	***	20	23.38	± 8.12
B	700	0.9	46.7	3.72E-16	3.751	14	100	30.90	± 0.64
C	800	1.8	78.6	7.22E-16	3.908	28	181	32.18	± 0.31
D	900	3.3	89.1	1.32E-15	3.916	***	417	32.24	± 0.18
E	1000	6.9	93.2	2.79E-15	3.818	***	962	**31.44**	**± 0.10**
F	1100	10.9	94.7	4.41E-15	3.796	138	1667	**31.26**	**± 0.07**
G	1200	13.1	85.3	5.24E-15	3.795	303	671	**31.26**	**± 0.08**
H	1300	25.4	94.1	1.02E-14	3.794	217	328	**31.25**	**± 0.05**
I	1400	36.9	92.1	1.49E-14	3.804	229	2083	**31.33**	**± 0.05**
J	1500	0.5	62.5	2.06E-16	3.675	***	26	**30.28**	**± 0.96**
K	1650	0.1	23.5	2.44E-17	3.659	***	5	**30.15**	**± 7.99**
Total Gas		100	90.9	4.02E-14	3.803	219	1206	31.32	
		93.8% of gas on plateau in 1000 through 1650°C steps				**Plateau Age = 31.29 ± 0.08 Ma**			

Ages calculated assuming an initial $^{40}Ar/^{36}Ar = 295.5 \pm 0$.
All precision estimates are at the one sigma level of precision.
Ages of individual steps do not include error in the irradiation parameter J.
No error is calculated for the total gas age.

TRIGA reactor (GSTR) at the U.S. Geological Survey in Denver, Colorado. The monitor mineral used in the package was Fish Canyon Tuff sanidine (FCT-3) with an age of 27.79 Ma (Kunk *et al.*, 1985; Cebula *et al.*, 1986) relative to MMhb-1 with an age of 519.4 ± 2.5 Ma (Alexander *et al.*, 1978; Dalrymple *et al.*, 1981). The type of container and the geometry of the sample and standards were similar to that described by Snee *et al.* (1988).

The adularia sample was analyzed at the U.S. Geological Survey Thermochronology lab in Denver, Colorado, using the $^{40}Ar/^{39}Ar$ step-heating method and a VG Isotopes 1200B mass spectrometer fitted with an electron multiplier. For additional information on the analytical procedure see Kunk *et al.* (2001). The analyzed sample yielded a plateau age at 31.29 ± 0.08 Ma and it is supported, within analytical error, by the less precise isochron age at 31.30 ± 0.20 Ma.

3. Discussion and conclusions

The age for adularia sample SJ-4 from vein material of the epithermal deposits at the San Juan de Mogotes mineralized area in the Peñón Blanco district is 31.29 ± 0.08 Ma (early Oligocene). This is the first age determination on mineralization material from this region and time span (Table 2), and corresponds to the range of ages that is most characteristic for Cenozoic ore deposits in Mexico. Not only does this deposit belong to the most metallogenetically productive epoch, but also to the region that contains the highest concentration in magmatic-hydrothermal ore deposits in Mexico; that is, the western portion of the Mesa Central, particularly in the vicinities of the San Luis–Tepehuanes fault zone, during the Oligocene (Camprubí, 2013). The metallogenic importance of this time and space frame is illustrated by the occurrence of what is currently the largest silver deposit in the world (Fresnillo, in Zacatecas).

The dominant types of deposits in the western half of the Mesa Central during the Oligocene are epithermal deposits and tin veins in association with fluorine-rich rhyolites (Figure 1). The possible genetic link between Au-Ag or polymetallic epithermal deposits with tin veins associated with fluorine-rich rhyolites (including Sn-Hg-F-Sb deposits), and the associated fluorite hydrothermal veins, remains to be characterized. Such is also the case of the

Table 2. Hydrothermal mineral deposits in central-eastern Durango, with similar ages to those in the Peñón Blanco district.

Sample	Mineral district	Coordinates	Type of deposit	Additional information	Age (Ma)	Method	Mineral	Source
	Indé		Epithermal fluorite and polymetallic deposits (IS?)		38.39 ± 1.84	Ar/Ar* (plateau)	Biotite	Tuta *et al*. (1988)
	La Ciénega		Epithermal polymetallic deposits (IS)		<30.0?	K-Ar*	w.r.	Labarthe (1996), *in* de la Garza *et al*. (2001)
	Río Verde		Sn veins associated with F-rich rhyolites		32.3 ± 0.3	Rb-Sr*	w.r.	Huspeni *et al*. (1984)
SJ-4	Peñón Blanco	24º40'06.93" N 104º06'21.44" W	LS Au-Ag epithermal veins	Lorena vein, San Juan de Mogotes area. The district contains scant Sn veins	31.29 ± 0.08	Ar/Ar** (plateau)	Adularia	This study
	El Tovar		Epithermal polymetallic deposits (IS?)		31.3	K-Ar*	w.r.	Clark *et al*. (1979)
	La Ochoa		Sn veins associated with F-rich rhyolites		31.04 ± 0.36	K-Ar*	w.r.	Huspeni *et al*. (1984)
					31.08 ± 0.35			Tuta *et al*. (1988)
					31.0 ± 0.4			
					31.1 ± 0.3			
					29.6 ± 0.4			
	Cerro de los Remedios		Sn veins associated with F-rich rhyolites		31.0 ± 0.4	K-Ar*	w.r.	Tuta *et al*. (1988)
					28.3 ± 0.3			
	América-Sapiorís		Sn veins associated with F-rich rhyolites		30.3 ± 0.7	Rb-Sr*	w.r.	Huspeni *et al*. (1984)
	Avino-Zaragoza		Sn veins associated with F-rich rhyolites	The district consists dominantly of polymetallic IS epithermal deposits	29.6 ± 0.1	Rb-Sr*	w.r.	Huspeni *et al*. (1984)
	Bacís		LS-IS polymetallic epithermal deposit		27	K-Ar	?	Smith (1995)
	Coneto de Comonfort		Sn veins associated with F-rich rhyolites	The district consists dominantly of Ag-Au LS epithermal deposits	Oligocene to Miocene			Ponce-Sibaja & Gutiérrez-Tapia (1978)

Key: IS = Intermediate sulfidation; LS = low sulfidation; w.r. = whole rock. Asterisks (*) denote that the analyzed samples correspond to host rocks, whereas double asterisks (**) denote that the analyzed samples correspond to hydrothermal minerals.

southeastern ending of the Mesa Central in San Luis Potosí (Camprubí, 2013), in which topaz rhyolites are conspicuous (Leroy *et al.*, 2002; Rodríguez-Ríos *et al.*, 2007, 2013). Fluorite is a common mineral within or in association with epithermal deposits in the study region, either forming individual veins (*e.g.*, Clark *et al.*, 1977) or as an accessory mineral (Servicio Geológico Mexicano, 2013). No causality between the occurrence of highly differentiated fluorine-rich rhyolites (Leroy *et al.*, 2002; Rodríguez-Ríos *et al.*, 2007, 2013) and fluorite-rich epithermal deposits has been soundly interpreted to date, but it is a likely hypothesis for future studies. Central and eastern Durango poses as an ideal region for research about possible genetic links between epithermal deposits and tin veins associated with fluorine-rich rhyolites due to their close time and space distribution (Clark *et al.*, 1977; Huspeni *et al.*, 1984; Tuta *et al.*, 1988; Camprubí, 2013). This is also the case for the Sombrerete and Sierra de Chapultepec deposits in Zacatecas (Albinson, 1988), which are epithermal and tin vein deposits, respectively, also associated with the San Luis–Tepehuanes fault zone (Figure 1; Camprubí, 2013). Such correspondences occur even at the district scale, which is the case of the grouping of deposits at Avino and Coneto de Comonfort, both dominantly epithermal deposits (Ponce-Sibaja and Gutiérrez-Tapia, 1978; Servicio Geológico Mexicano, 2003, 2013), and scant tin veins are also found in the Peñón Blanco district itself (Servicio Geológico Mexicano, 2003). The formation of tin veins associated with fluorine-rich rhyolites continued briefly into the Miocene as the volcanic activity of the Sierra Madre Occidental silicic large igneous province shrunk dramatically southwards prior to the opening of the Gulf of California and the rearrangement of volcanism into the Trans-Mexican Volcanic Belt (Camprubí, 2013). Tin vein deposits were abundantly accompanied by epithermal deposits in that case as well (see Figures 9 and 10 in Camprubí, 2013).

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