

Supplementary Material for:

Metallogenic model of the Eocene Santa María and Antares Zn-Pb(-Ag) skarn deposits, Velardeña Mining District, Durango, Mexico

Néstor Cano^{1,*}, Antoni Camprubí², Eduardo González-Partida³, Ana K. González-Ambrocio¹, Pura Alfonso⁴, Daniel P. Miggins⁵, Edith Fuentes-Guzmán^{1,2,6}, Edith Cienfuegos-Alvarado^{2,6}, and Alexander Iriondo³

¹Programa de Posgrado en Ciencias de la Tierra, Universidad Nacional Autónoma de México. Ciudad Universitaria, 04510 Coyoacán, CDMX, Mexico.

²Instituto de Geología, Universidad Nacional Autónoma de México. Ciudad Universitaria, 04510 Coyoacán, CDMX, Mexico.

³Centro de Geociencias, Universidad Nacional Autónoma de México. Blvd. Juriquilla 3001, 76230 Juriquilla, Qro., Mexico.

⁴Departament d'Enginyeria Minera, Industrial i TIC, Universitat Politècnica de Catalunya. Av. de les Bases de Manresa 61–73, 08242 Manresa, Catalonia, Spain.

⁵College of Earth, Ocean, and Atmospheric Sciences, Oregon State University. Ocean Administration Building, 104, 101 SW 26th St, Corvallis, OR 97331, United States.

⁶Laboratorio Nacional de Geoquímica y Mineralogía. Ciudad Universitaria, 04510 Coyoacán, CDMX, Mexico.

*Corresponding author (NC): nacanoh@comunidad.unam.mx

The Supplementary Material contains:

1. SUPPLEMENTARY FIGURES

1.1 Photomicrographs of gangue assemblages from the Santa María skarn deposit

1.2 Photomicrographs of gangue assemblages from the Antares skarn deposit

1.3 Photomicrographs of fluid inclusions from the Santa María skarn deposit

1.4 Photomicrographs illustrating the thermochemical behavior of a representative ore-stage fluid inclusion in sphalerite

1.5 Photomicrographs of fluid inclusions from the Antares skarn deposit

1.6 Infrared spectrum of ore-stage fluorite with abundant fluid inclusions

1. SUPPLEMENTARY FIGURES

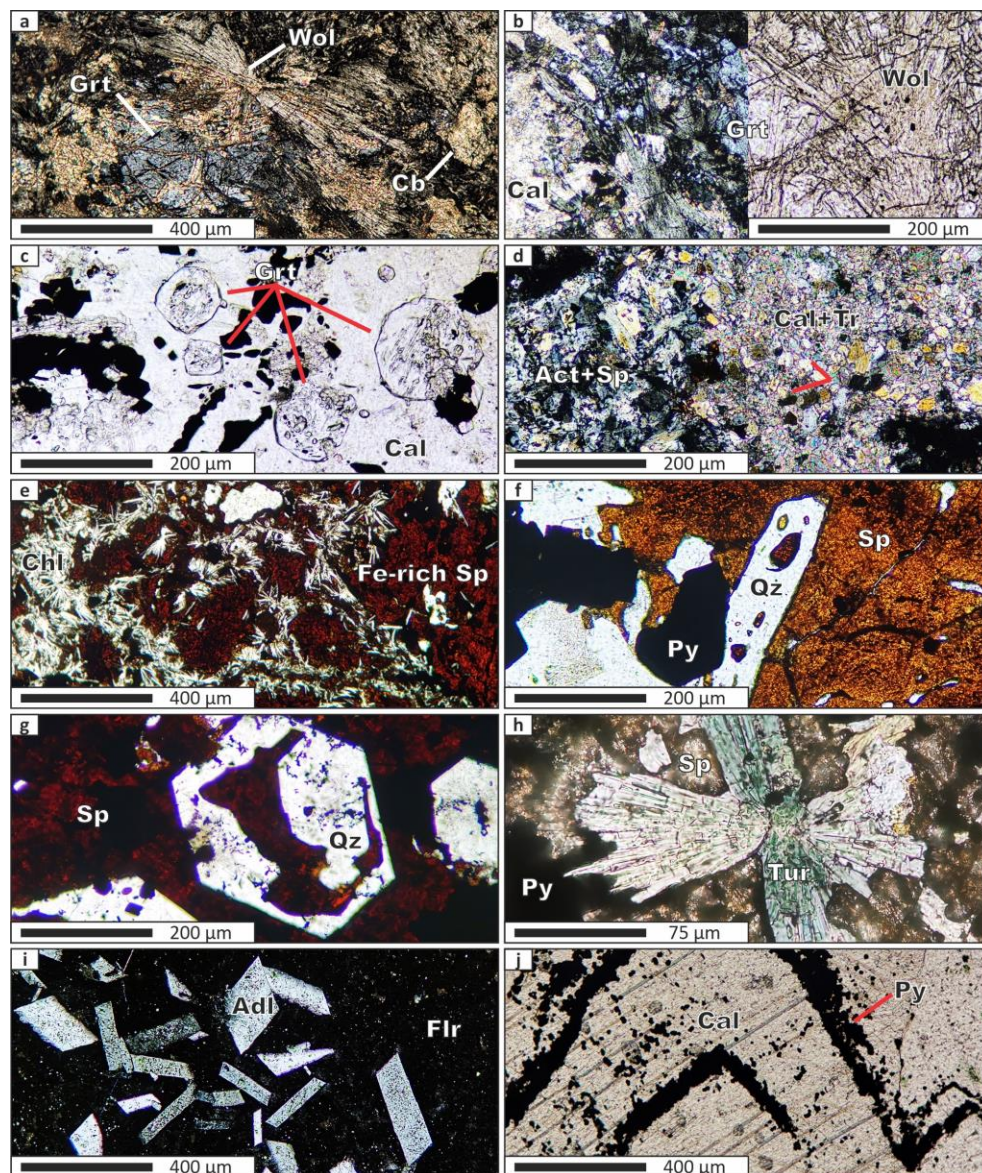


Fig. S1 Photomicrographs of gangue assemblages in the Santa María skarn deposit. **a** Garnet overprinted by acicular wollastonite, both replaced by calcite. **b** Garnet and wollastonite altered to calcite. **c** Garnet poikiloblasts surrounded by calcite. **d** Calcite + tremolite masses embedding actinolite + sphalerite patches. **e** Chlorite intergrown with Fe-rich sphalerite. **f** Sphalerite associated with pyrite and quartz. **g** Sphalerite crosscutting euhedral quartz. **h** Radial tourmaline aggregates intergrown with Fe-poor sphalerite and pyrite. **i** Euhedral adularia embedded in fluorite. **j** Zoned calcite with pyrite rims. Key: Act = actinolite, Adl = adularia, Cal = calcite, Cb = carbonate, Chl = chlorite, Flr = fluorite, Grt = garnet, Py = pyrite, Qz = quartz, Sp = sphalerite, Tr = tremolite, Tur = tourmaline, Wol = wollastonite

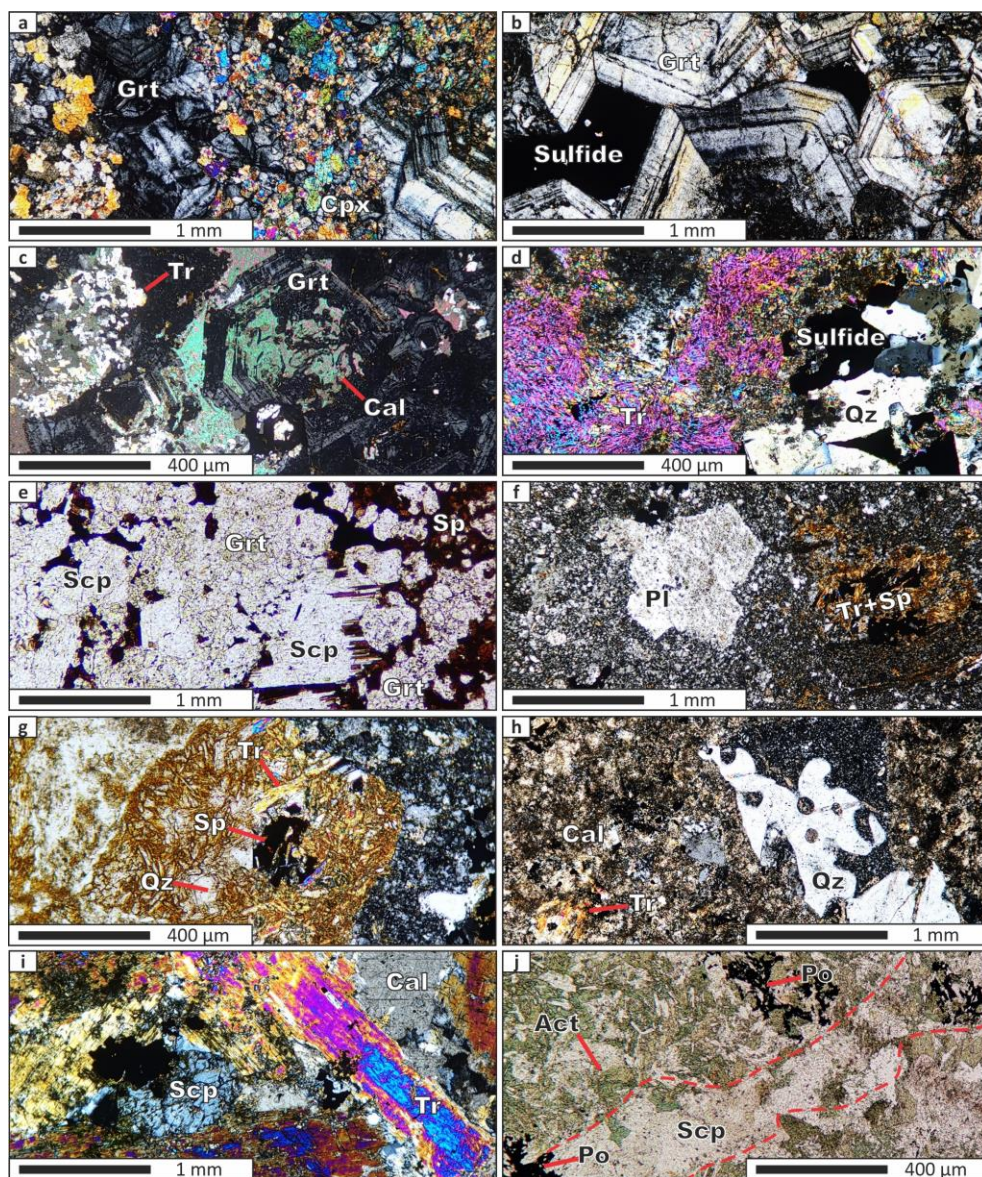


Fig. S2 Photomicrographs of gangue assemblages in the Antares skarn deposit. *Exoskarn*: **a** Garnet overprinted by clinopyroxene aggregates. **b** Zoned garnet with sulfide intercrystalline fillings. **c** Garnet replaced by calcite and tremolite. **d** Massive tremolite associated with quartz and sulfides. *Endoskarn*: **e** Scapolite + sphalerite overprinting garnet aggregates. **f** Tremolite + sphalerite pseudomorph after ferromagnesian phenocryst. Notice plagioclase phenocryst in the vicinity. **g** Tremolite + sphalerite + quartz pseudomorph after ferromagnesian phenocryst. **h** Resorbed quartz phenocryst embedded in a calcite + tremolite matrix. **i** Coarse tremolite + calcite crosscutting scapolite crystal. **j** Aplite replaced by actinolite + pyrrhotite, and crosscut by scapolite + pyrrhotite veinlet. Key: Act = actinolite, Cal = calcite, Cpx = clinopyroxene, Flr = fluorite, Grt = garnet, Pl = plagioclase, Po = pyrrhotite, Qz = quartz, Scp = scapolite, Sp = sphalerite, Tr = tremolite, Tur = tourmaline

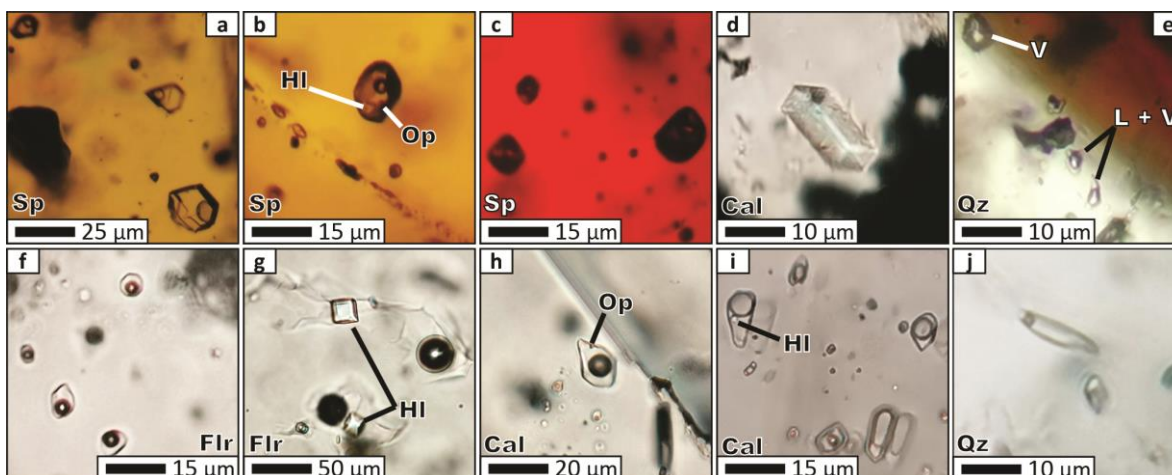


Fig. S3 Photomicrographs of fluid inclusions from the Santa María skarn deposit. **a–c** Two and three phase (L + V ± S) fluid inclusions in sphalerite (Fe-rich and Fe-poor): in **a** displaying negative crystals; in **b** the inclusion contains two trapped solids, halite and an opaque solid. **c** L + V fluid inclusions occupying negative crystals in sphalerite. **d** Rhombohedral liquid + vapor fluid inclusion in calcite. **e** Liquid- and vapor-rich fluid inclusions hosted by quartz, suggestive of boiling processes. **f** Typical L + V primary fluid inclusion of the ore stage in fluorite. **g** Scarce large and irregular liquid + vapor + daughter halite fluid inclusions in fluorite, showing necking. **h** Fluid inclusion consisting of liquid + vapor + an opaque trapped solid, representative of the main FIA in the post-ore calcite veins. **i** Boiling assemblage in post-ore calcite veins. Notice the variation in F and the occurrence of halite daughter crystals. **j** Oval shaped L + V secondary fluid inclusion in quartz (late stage). Key: Cal = calcite, Flr = fluorite, HI = halite, Op = opaque mineral, Qz = quartz, Sp = sphalerite

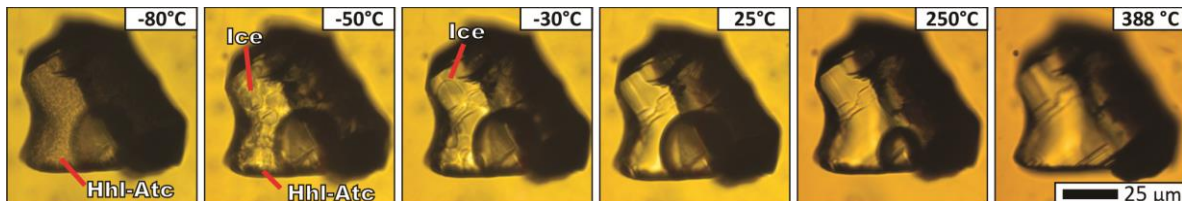


Fig. S4 Photomicrographs illustrating the thermochemical behavior of a representative ore-stage fluid inclusion in sphalerite. Atc = antarcticite, Hhl = hydrohalite

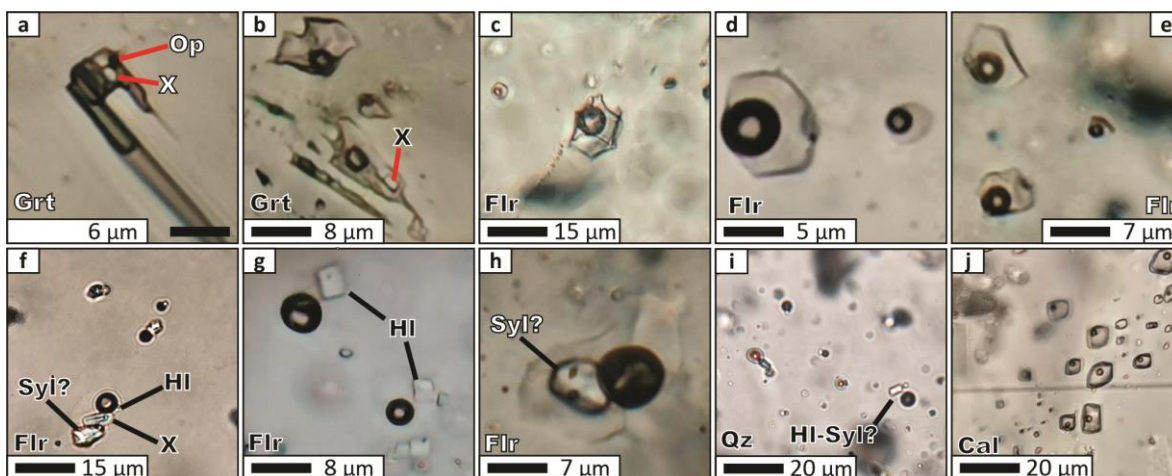


Fig. S5 Photomicrographs of fluid inclusions from the Antares skarn deposit. **a–b** L + V and L + V' + solids fluid inclusions in garnet. **c–e** Liquid + vapor fluid inclusions in ore-stage fluorite, in **c** showing necking. **f–j** Various fluid inclusions in fluorite and quartz. Key: Grt = garnet, Flr = fluorite, HI = halite, Op = opaque mineral, Qz = quartz, Syl = sylvestrite, X = unknown

cubic shape (i.e., negative crystal). **f–h** Three-phase and multisolid fluid inclusions in ore-stage fluorite, containing halite, sylvite, and an unknown tabular solid. **i** Secondary multisolid fluid inclusions in quartz, containing daughter crystals of halite and sylvite. **j** Late secondary fluid inclusions in calcite. Key: Cal = calcite, Fl = fluorite, Grt = garnet, Hl = halite, Op = opaque minerals, Qz = quartz, Syl = sylvite, X = unidentified mineral

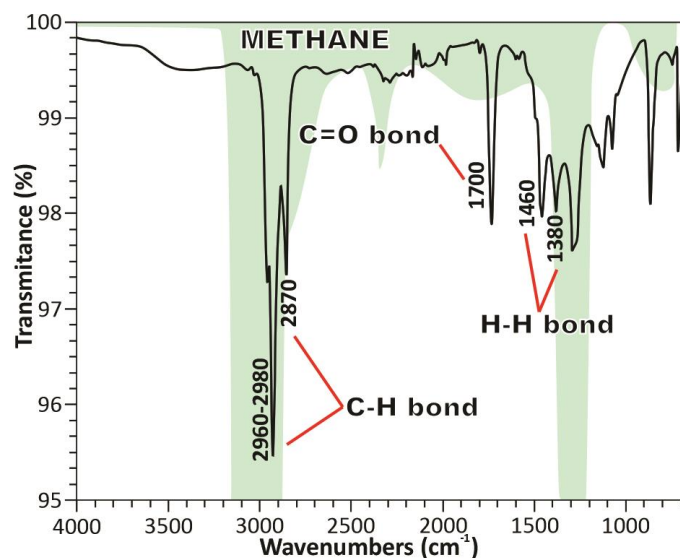


Fig. S6 Infrared spectrum of ore-stage fluorite with abundant fluid inclusions. The spectrum shows diagnostic features C-H and H-H bonds (methane) and C=O bond (associated calcite). The typical infrared spectrum of pure methane is presented as a green shaded area, after the National Institute of Standards and Technology (<https://www.nist.gov/>)