

Island arc origin of the "El Arco" porphyry copper deposit, Baja California: evidence from ^{40}Ar - ^{39}Ar dating and radiogenic isotopes

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The El Arco porphyry copper deposit (EAPC) is located in Baja California at the border between the states of Baja California and Baja California Sur, NW Mexico. Its geographic position makes the EAPC different from other porphyry copper deposits known from mainland Mexico, Arizona, and New Mexico, which are mostly associated with the emplacement of Laramide batholiths (~80-50 Ma, Damon et al., 1983). The EAPC, in contrast, is embedded in meta-volcanic rocks of an Early Cretaceous volcanic arc that was intruded by the Peninsular Ranges batholith (PRB). Primitive island arc-related intrusions to the west are older (140-105 Ma) than more evolved igneous rocks from the eastern zone of the PRB (105-80 Ma). Both are separated by the magnetite-ilmenite line that marks the internal limit of the Yuma composite terrane (Sedlock et al., 1993). Previously reported K-Ar ages from the EAPC (~93-107 Ma) have indicated a relation to the eastern PRB.

We present geochemical and Sr-Nd-Pd isotope data together with ^{40}Ar - ^{39}Ar laser dating of single grains from EAPC drill cores. Cu mineralisation is concentrated in a core of potassic alteration mainly in shallow plutonic rocks surrounded by propylitic alteration chiefly in andesitic lavas. Argillic alteration is absent. Mafic dikes that intruded the EAPC are not mineralised but they are affected by low-grade metamorphism. The dikes are the most primitive in trace element composition, while andesites and intrusives display typical volcanic arc-like trace element patterns. Sr and Nd isotopes indicate that the magmas evolved from a depleted mantle reservoir. The Pb isotope data (whole rock, quartz, feldspar, sulfides) indicate: (1) the intrusive body and the surrounding andesites evolved from a similar source with an average μ -value of 9.4; (2) no external lead was added during Cu mineralisation; (3) Pb isotope compositions were slightly disturbed by later low grade metamorphism. ^{40}Ar - ^{39}Ar dating of single pyrite crystals yielded an isochron at 137.3 ± 1.4 Ma (1σ). This age is in agreement with a Rb-Sr whole rock isochron age of 134 ± 10 Ma (95% c.l.). A non-mineralised dike gives an ^{40}Ar - ^{39}Ar age (WR) of 95.2 ± 0.8 Ma (1σ).

Our data favour a model in which the EAPC developed during the Early Cretaceous within an outboard island arc terrane that was accreted in the late Early Cretaceous, forming the Yuma composite terrane.

References

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The exsolution of magmatic brine

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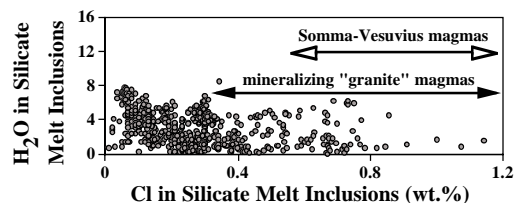
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Chlorine-rich fluid and silicate melt inclusions from numerous igneous systems imply that magmas exsolve brines (equivalent to hydrosaline liquids), even though other textural evidence of magmatic brines is rarely preserved. Brine may form by subcritical phase separation of a magmatic fluid to vapor plus brine or brine may exsolve directly from magma. Knowledge of magmatic brines (and Cl-bearing aqueous vapors and fluids) is crucial for understanding the generation of many magmatic-hydrothermal mineral deposits and because brines may exsolve "early" in magmatic systems.

Abundances and solubilities of Cl in melts

Investigating the exsolution of brine from silicate melt requires accurate constraints on the abundances of Cl and H_2O in magmas. The Cl contents of more than 600 silicate melt inclusions from 22 felsic to mafic igneous rocks (including some alkaline varieties) range from hundreds of ppm to more than 1 wt.% and indicate that some magmas are strongly enriched in Cl.

Predicting the exsolution of brine from silicate melts requires knowledge of the solubility of Cl in melt. Using a newly developed model for computing Cl solubility in melts containing low to moderate H_2O contents, the Cl concentrations of melt can be computed and compared with typical abundances of Cl in magma. In the figure below, the arrows show predicted Cl concentrations in melts that are brine saturated.



Magmatic brine exsolution

The modeled Cl solubilities, coupled with the presence of moderate to high Cl and low to moderate H_2O concentrations of melt inclusions, indicate that many granites and rhyolites - including those that generate Sn greisens and porphyry Cu and porphyry Mo deposits - can exsolve magmatic brine directly. Thus, the presence of brine in such magmas is not solely due to subcritical immiscibility of vapor plus brine. The presence of magmatic, Cl-enriched brines has undoubtedly influenced the generation of numerous metal-laden ore fluids and has affected magmatic degassing in subduction-related alkaline volcanism like that at Mt. Somma-Vesuvius.