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# Epithermal mineralization in Western Turkey: nature and origin of the fluids

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The Biga Peninsula in Western Turkey is part of the Tethys metallogenic belt. There are diverse styles of mineralization present in the peninsula, but the most important are the epithermal Au-Ag deposits, porphyry Au-Cu-Mo deposits and epithermal Pb-Zn-Cu-Au. This study focuses on five Pb-Zn-Cu deposits that share many features, but are hosted in different lithologies. The Bagirkacdere deposit is hosted by Palaeozoic metamorphic rocks, Arapucandere is hosted by Permo Triassic clastic and calcareous rocks and Koru, Balcilar and Kumarlar are hosted by Tertiary volcanic rocks. The mineralization is in veins containing galena, sphalerite, chalcopyrite, pyrite, marcasite, covellite, bornite and fahlore as ore minerals, with quartz, calcite, barite and specular hematite as gangue minerals (Bozkaya, et. al, 2008, Bozkaya, 2009, Bozkaya, 2011). The numerous deposits in the region have been well studied and the mineralogy, paragenesis, structure and alteration are reasonably constrained. What is less clear is the age of many of the deposits (although this is now being addressed) and the nature and source of the mineralizing fluids, especially the salinity and composition. Fluids have been suggested to be dominantly magmatic, dominantly meteoric or some mixture of the two. The purpose of this study is the identification of the source of the different components of the mineralizing fluids in order to better constrain a model of fluid circulation. Data were obtained from microthermometry, Raman spectroscopy, stable isotopes, LA-ICP-MS and crush leach. Numerous FIA's were identified in the different samples, but the inclusions were typically small ca. <20µm. Almost all were L+V and on freezing the vapour bubble frequently disappeared and did not return prior to final Ice melting, making the determination of salinity impossible in these circumstances. However, sufficient samples provided good salinity and homogenization temperatures. Only in the Arapucandere deposit was there clear evidence of V-dominated inclusions. The salinity and homogenization temperatures for the different deposits are as follows, Bagirkacdere: salinity (mass% NaCl) range 0.18 to 1.6, with an average of 0.49, $T_h$ range 180 to 301°C, with an average of 236 °C; Arapucandere: salinity range of 0.18 to 1.4 with an average of 0.63, $T_h$ range from 262 to 304.8 °C with an average of 277 °C; Koru: salinity range of 0.18 to 4.02 with an average of 1.43, $T_h$ range from 129.7 to 159.3 °C with an average of 147 °C; Balcilar: salinity range of 3.86 to 8.54 with an average of 4.42, $T_h$ range from 115.1 to 300 °C with an average of 155 °C; Kumarlar: salinity range from 3.54 to 8.81 with an average of 5.82, $T_h$ range 246 to 285.7 °C with an average of 283 °C. Raman spectroscopy did not detect any gases in the vapour bubble of the L-V and V-only inclusions. Stable isotope compositions ($\delta^{18}O$ and $\delta D$) of fluid inclusions, quartz and baryte associated with ore minerals were measured to determine the source of the water (Fig.1). Bagirkacedere plots on the MWL with Arapucandere, Balcilar and Koru showing a shift to more positive $\delta^{18}O$ values. Kumarlar partially plots in the magmatic box, but the majority of the data coincides with those from the other deposits. The data could suggest mixing between meteoric and magmatic water in varying amounts, but we suggest that there is little magmatic fluid involved and the $^{18}O$ shift to more positive values is the result of the intense WRI present at the deposits. Crush-leach analysis of the inclusions in quartz and baryte was used to determine Na, K, Cl and Br in the inclusions with the aim of using primarily Cl/Br as an indicator of the source of the salinity.

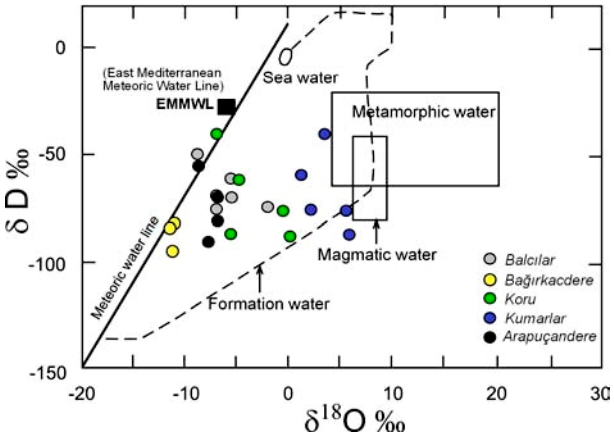


*Fig. 1. Summary diagram showing the variation in $\delta^{18}O$ and $\delta D$ isotopic compositions of the hydrothermal fluids in deposits from the Biga Peninsula, Turkey.*

Although this is a bulk technique, microthermometry showed there to be one dominant fluid in the samples. The main limitation on the analyses was the low yield of elements from the dilute fluids. Therefore the errors on the Cl/Br ratio may be as high as 50 %. Cl/Br for Balcilar averages 20,000, Koru averages 24,000, Arapucandere averages 10,000 and Bagirkacedre averages 450, much lower than the other deposits.

The Cl/Br of the deposits is extremely high and such ratios are a clear indication that the source of Cl was from dissolution of halite. The Cl/Br molar ratio of halite is c. 20,000 but can be higher if recrystallization of the salt has taken place. However the Cl/Br ratios normally found are between 3000 and 10 000, due to some of the Br-rich bittern fluid existing in inclusions or in pore spaces. The Cl/Br ratio does not indicate any significant magmatic source for the salinity as values for volcanic gases are typically less than 1500. LA-ICP-MS analysis was carried out using a Geolas Ar-F excimer laser system coupled to an Agilent 7500c Quadrupole mass spectrometer. The inclusions were analysed individually or as groups or a few small inclusions. The elements determined were Li, Na, Mg, K, Ca, Mn, Fe, Cu, Zn, Sr, Ag, Ba, Pb. The fluids in all deposits are dominated by Na with Mg, K and Ca being approximately the same. Figure 2. shows the variability of Na, K and Mg in inclusions from each deposit. The variability is exaggerated by using the Na value divided by a factor of 10 otherwise all samples would plot in the Na apex. However, there are slight differences apparent between each of the deposits which does not correlate with the local host rocks and may be more indicative of the composition of the source rocks that underwent extensive WRI.

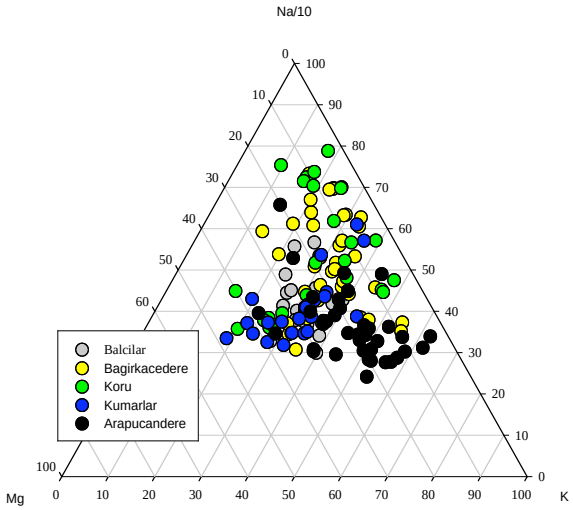


*Fig. 2. Ternary plot of LA-ICP-MS analyses of inclusions from the different deposits. Although the variability within a deposit seems large, individual samples are much less variable.*

The ratios of Mn, Fe Cu, Zn and Pb are similar in all the deposits. Despite the low salinity of the fluids their concentrations are still significant, reaching maximum values of approximately 100 ppm for Mn, Zn and Pb, 400 ppm for Fe, and 250 ppm for Cu. The data presented here support a common model for these deposits which although mineralogically similar are hosted in different lithologies. The salinity of the fluids is low, but the temperature is high and there is evidence of boiling in at least one deposit. Compositionally the fluids are very similar in both major and minor components with significant concentrations of ore metals despite the low salinity of the fluids. The source of the salinity is derived from dissolution of halite and the water is dominantly meteoric although the isotopic composition has been modified to different extents due to the varying intensity of WRI.

**REFERENCES**

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