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New Insights into the Genesis of Apatite of the Sorkhe-Dizaj Magnetite Deposit (Tarom, NW Iran) Constrained by Fluid Inclusion Investigation

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The Sorkheh-Dizaj magnetite-apatite deposits are situated in the Alborz-Azarbaijan magmatic belt (NW Iran). Eocene calc-alkaline volcanic rocks (Karaj Formation) are intruded, shortly after their emplacement, by felsic (granodiorite, monzonite, granite) plutons, over the subduction zone of the Neo-Tethys. They are of "type I" metaluminous, amphibole calc-alkaline (ACG) to potassic calc-alkaline (KCG) granitoid, of K-rich calc-alkaline affinity.

The magnetite-apatite mineralization is of iron oxide-apatite Kiruna type and occurs in massive vein types, irregular veinlets, or stockworks. They were formed under high oxygen fugacity, over the magnetite-hematite buffer. They have a high concentration of REEs (up to 8,000 times the chondritic value) and show a strong LREE/HREE ratio with a negative Eu anomaly.

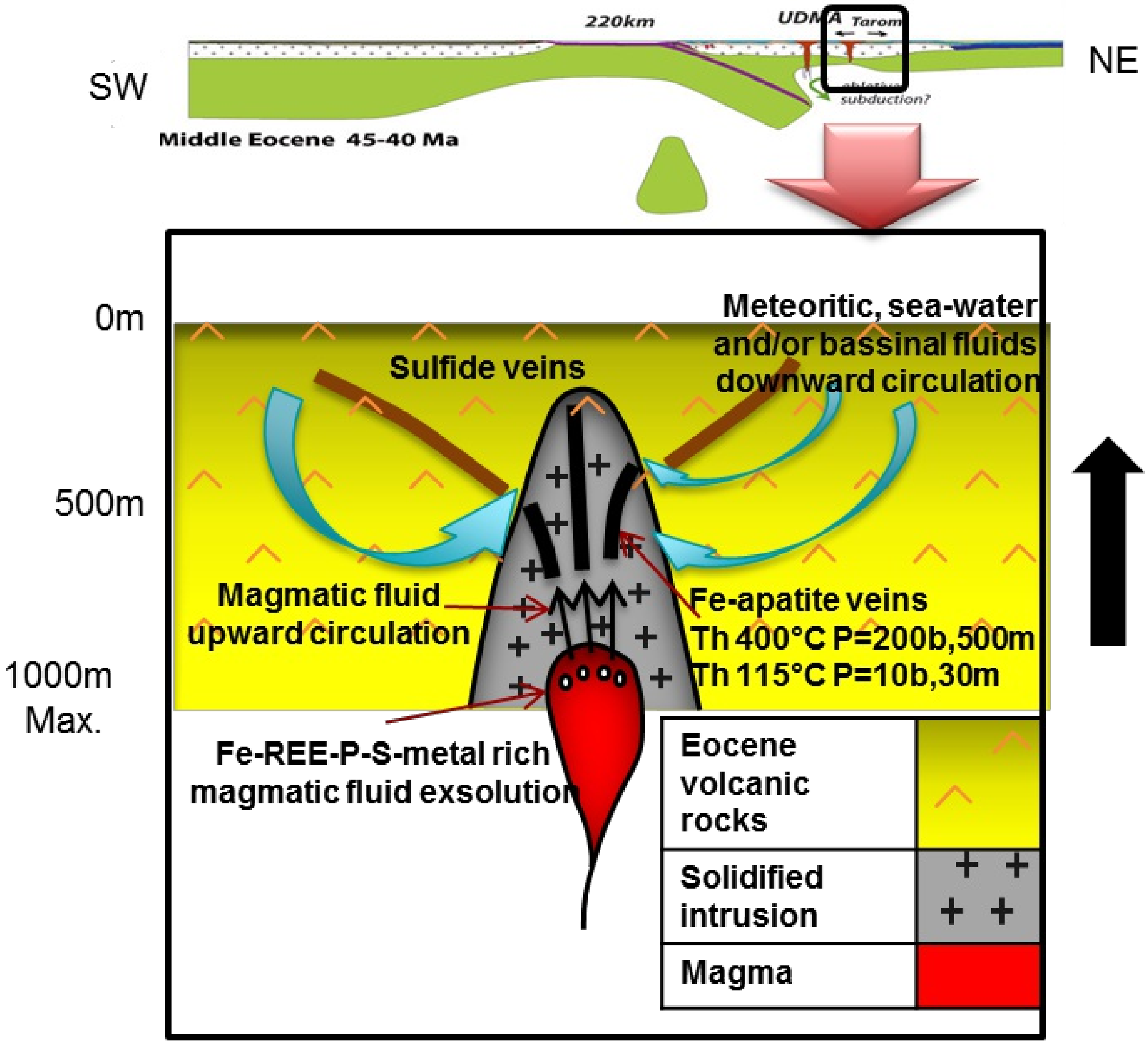
Petrography and microthermometry of ~120 apatite fluid inclusions indicate entrapment of primary and secondary generations of inclusions. The variable volumes of vapor in the primary inclusions suggest that the fluids were boiling at the time of growth of apatite.

Low first-melting temperature (-50° to -28°C) suggests mixing of H_2O-NaCl-$CaCl_2$ in the fluids. Primary inclusions have homogenization temperatures ($T_{h\ LV\text{-}L}$) with an apparent bimodal repartition (~360°-380°C and ~180°-200°C). The salt content is in the range 1-40 wt % NaCl and 0-10.4 wt % $CaCl_2$. The homogenization temperatures of secondary fluid inclusions range between 115° and 234°C. The secondary inclusions have a salinity ranging between 3 and 22 wt % NaCl equiv, and in the H_2O-NaCl-$CaCl_2$ system, between 4.5 and 8.8 wt % NaCl and between 2.6 and 14.7 wt % $CaCl_2$, slightly richer in $CaCl_2$ than the primary inclusions. The calculated pressure at entrapment conditions is less than 200 bar.

Raman spectrometry reveals that the gas phase is composed of pure H_2O without any trace of CO_2, CH_4, N_2, H_2, and H_2S. The compositions of microsolids detected in the primary inclusions reveal the presence of magnetite, apatite, chalcopyrite, xenotime, calcite, celestite, goethite, and hematite in different proportions. This suggests that the fluids circulating around the apatites were oversaturated in the elements constituting these solids.

These observations suggest that high temperatures and high-salinity magmatic fluids, observed in the primary inclusions, rich in Fe-REE-P-S and metals, exsolved from felsic magmas. Moving upward in the already solidified pluton at low depth, they encountered other fluids of lower salinity and temperature coming from the surface (meteoritic, seawater, and/or basinal fluids). These fluids do not mix completely, as pure water has been detected in some primary inclusions besides primary fluid inclusions with the highest salinity.

Over the intrusion and laterally, sulfide veins filled fractures at lower temperatures. These fluids correspond in salinity and homogenization temperature to the secondary fluids in the apatite and those filling the quartz-sulfide veinlets crosscutting the Fe apatite deposits.



220km
UDMA
Tarom
subduction?
SW
NE
Middle Eocene 45-40 Ma
0m
500m
1000m
Max.
Sulfide veins
Meteoritic, sea-water
and/or bassinal fluids
downward circulation
Magmatic fluid
upward circulation
Fe-apatite veins
Th 400°C P=200b,500m
Th 115°C P=10b,30m
Fe-REE-P-S-metal rich
magmatic fluid exsolution
Eocene
volcanic
rocks
Solidified
intrusion
Magma