

Environmentally hazardous trace elements of Eocene coal deposits in the north Anatolia, Turkey

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Amasya, Bolu and Kastamonu in Northern Anatolian Region in Turkey host high-calorie lignite coals of Eocene age with reserve more than 1 million tones. In this study, distribution of environmental elements in coals, enrichment factors of these elements and total organic material-element relations were investigated.

The lignite coals in Amasya are found in 4 different fields within the Eocene clastic deposits. In these fields, concentrations of Cu, Zn and Se are generally higher than that of the Turkish coals. Considering the enrichment factor calculations with respect to world coals, Mo, Pb, Cd and Sb are depleted while Cu, Ni, Co, Mn, V, Cr, Hg, Se, Th and As elements are enriched.

Mo, V, B, Se and S% values of the Bolu field coals are higher than the average value of Turkey. Enrichment factor calculations on these coals reveal that Pb, Cd, Sb and Th are depleted and Se, Cr, Co, Zn and Cu are enriched while Mo, Ni, Mn, As, V, B, Hg, U and S are considerably enriched.

Lignites in Kastamonu are found within the Eocene marl-limestone sequence. It was determined that Cu, Pb, Zn, Ni, Co and S concentrations of this field are higher than the average value of Turkish coals. Enrichment factor calculations on the Kastamonu coals reveal that Cd, Sb and Se are depleted and Mo, Cu, Pb, Zn, Co, Mn, As, V, B, U, Th and S are enriched while Ni, Cr, and Hg are considerably enriched.

Using the environmentally sensitive elements and total organic matter values of coals from all the fields, statistical evaluation was made.

In the Amasya-Kastamonu coals, Cr-V and As-S element pairs show positive correlations while B-TOC, Th-TOC, Cu-TOC and B-Cu element pairs display negative correlations.

Except for S-Cu element correlation resembling to the Amasya field, the Bolu field does not display any similarity to any of the fields.

Zeolite-calcite-silica formation in basalt during orogenic collapse, Washington Cascades

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Regional extension and collapse of the 96 to 45 Ma Cascade orogen during the Eocene is recorded by rapid basin subsidence, mafic to intermediate dike swarms, and exhumation of a partially migmatized gneiss complex (Miller *et al.*, 2007). Shallow hydrothermal systems developed as a response to high regional geothermal gradients ($35\text{--}40\text{ }^{\circ}\text{C km}^{-1}$) and local intrusions. The fossil hydrothermal system in the vicinity of the largest dike swarm (Teaway dikes) is recorded by calcite-gold veins in sandstone-shale and by zeolite-calcite-silica \pm Fe-oxy/hydroxide assemblages in distal and stratigraphically higher basalt lavas and pyroclastics. Silica in distal assemblages occurs as α -quartz, chalcedony, and moganite, forming agate. Zeolite phases are heulandite and stilbite.

Oxygen-isotope ($\delta^{18}\text{O}_{\text{SMOW}}$) values for silica phases range about $10\text{--}16\text{ }_{\text{‰}}$ and $10\text{--}15\text{ }_{\text{‰}}$ for calcite. Values of $\delta^{13}\text{C}_{\text{PDB}}$ for calcite range -9 to $-11\text{ }_{\text{‰}}$. Calculated temperatures of formation based on calcite-quartz pairs, calcite-water, and quartz-water thermometry indicate precipitation at $50\text{--}60\text{ }^{\circ}\text{C}$ in a meteoric water dominated system. Field-constrained 2D thermal models indicate that these temperatures are likely to have existed for about 10^4 years at subsurface depths of $50\text{--}100\text{ m}$.

Compositional modeling using PTAX and the Geochemists Workbench indicate that zeolite-calcite-silica formation occurred at $\log[a\text{Ca}^{2+}/a^2\text{H}^+] \approx 12\text{--}13$ and low $\log[a\text{Al}^{3+}/a^3\text{H}^+]$ values that evolved up to $3\text{--}4$ with time. Low Na activity in the fluid meant that mordenite or phillipsite were not stable zeolite phases in the CNKASH system. Based on phase relations in the albite-anorthite-quartz- H_2O system (Liou *et al.*, 1991), heulandite + stilbite may coexist at $50\text{--}100\text{ m}$ depth at temperatures less than about $105\text{ }^{\circ}\text{C}$ which is consistent with isotopic thermometry and inferences based on field observations.

Analytical and modeling results indicate that heated meteoric fluids reacted with basalt to produce an assemblage that at first was in equilibrium with basaltic glass, but later became more Al-rich indicating equilibrium with glass + plagioclase. It appears that as for the zeolite-calcite-silica occurrences of Iceland (Neuhoff *et al.*, 1999), porosity is an important factor in determining which zeolite precipitates during low-grade alteration-metamorphism of basalt.

References

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