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Hydrothermal Fluid Origins in Mississippi Valley-Type Ore Districts: Combined Noble Gas (He, Ar, Kr) and Halogen (Cl, Br, I) Analysis of Fluid Inclusions from the Illinois-Kentucky Fluorspar District, Viburnum Trend, and Tri-State Districts, Midcontinent United States

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Abstract

Samples were selected from three of the classic Mississippi Valley-type districts in the midcontinent area of North America. The Illinois-Kentucky fluorspar district belongs to the fluoritic subtype of Mississippi Valley-type districts, and the Ozark districts of the Viburnum Trend and Tri-State are representative of the Pb-rich and more typical Zn-rich subtypes of Mississippi Valley-type mineralization, respectively. Noble gas (Ar, Kr) and halogen (Cl, Br, I) data have been obtained simultaneously by noble gas mass spectrometry of inclusion fluids released by in vacuo crushing of irradiated fluorite, quartz, carbonate, and sphalerite samples. Additionally, He analyses have been obtained from nonirradiated fluorite from the Illinois-Kentucky fluorspar district.

Fluorite from the Illinois-Kentucky fluorspar district has a maximum $^{3}He/^{4}He$ ratio of 0.35 Ra (where Ra = atmospheric $^{3}He/^{4}He$ ratio of 1.4×10^{-6}), higher than values typical of crustal fluids and confirming the presence of a minor mantle component, equal to less than 6 percent of the total He in the fluids of the Illinois-Kentucky fluorspar district.

The Br/Cl mol ratios of all the deposits are, with one exception, higher than the value of seawater (1.54×10^{-3}), ranging from 1.69 to 3.70×10^{-3}, and indicating acquisition of salinity by the evaporation of seawater beyond the point of halite saturation. Late quartz from the Tri-State district contains a very minor component of halite dissolution water and has a Br/Cl mol ratio of 1.46×10^{-3}. The I/Cl mol ratios are typical of oil field brines and are ubiquitously higher than what is attainable by the evaporation of seawater alone. I/Cl mol ratios are in the range of 6 to 270×10^{-6}, indicating that the fluids have interacted with I-rich organic matter present in sedimentary rocks.

In the Ozark districts, $^{40}Ar/^{36}Ar$ ratios vary between 320 and 345 in the Tri-State and between 350 and 420 in the Viburnum Trend. In the Illinois-Kentucky fluorspar district $^{40}Ar/^{36}Ar$ ratios reach values of 1,200. The corresponding concentrations of $^{40}Ar_{excess}$ (^{40}Ar not attributable to radiogenic decay of ^{40}K or an atmospheric source) are similarly elevated in the main-stage fluorite mineralization of the Illinois-Kentucky fluorspar district ($6.8–18.2 \times 10^{-4}$ $cm^3cm^{-3}H_2O$) relative to the Viburnum Trend and Tri-State districts (mostly $1.3–3.3 \times 10^{-4}cm^3cm^{-3}H_2O$ and $0.3–1.4 \times 10^{-4}$ $cm^3cm^{-3}H_2O$, respectively).

Together the noble gas and halogen data indicate the existence of three brine provinces, (1) a regional Tri-State brine present throughout the Ozark region, (2) a Viburnum Trend brine, and (3) an Illinois-Kentucky brine. Furthermore, in the Viburnum Trend the halogen composition of main-stage dolomite is distinct from that of the main-stage sphalerite but identical to the regional hydrothermal dolomite seen in the Tri-State district. The data imply that mixing relationships in the Viburnum Trend are highly complex but are compatible with regional models in which the Tri-State brine, present throughout the Ozark region, was sourced in the Arkoma basin.