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# Recognition of thermal convection in sedimentary basins: Coupled mineral dissolution-precipitation patterns integrated with reactive transport modeling

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While thermal convection is well manifested in geological records such as magmatic intrusions and mid-oceanic ridges, it is disputed whether thermal convection driven by thermal gradients actually occurred in sedimentary basins. As thermal convection may be related to the formation of mineral deposits, hydrocarbon and geothermal reservoirs, it is important to be able to recognize thermal convection from geologic records. There have been numerous theoretical and numerical studies modeling thermal convection in sedimentary basins in the literature, however, geological and geochemical studies directly pointing to evidence for thermal convection are rare.

This study demonstrates that thermal convection in sedimentary basins can be revealed by coupled mineral dissolution and precipitation patterns integrated with reactive transport modeling. Thermal convection, characterized by alternating upwelling and downwelling flow and associated positive and negative heat anomalies, may result in certain patterns of mineral precipitation and dissolution that cannot be produced by unidirectional fluid flow. This is particularly effective for quartz and calcite that are common diagenetic minerals. As quartz solubility increases with temperature, thermal convection leads to its dissolution at the bottom and precipitation at the top of an aquifer, whereas calcite solubility decreases with temperature, the opposite dissolution-precipitation pattern is produced. If the permeability is so low that there is no thermal convection, neither quartz nor calcite would show these dissolution-precipitation patterns. Additionally, thermal gradient and thickness are also important factors in determining whether or not thermal convection could occur. The mineral dissolution-precipitation patterns therefore can be used as direct evidence for thermal convection. This is demonstrated by a study of the Athabasca Basin (Saskatchewan, Canada), where several previous numerical studies have suggested that thermal convection occurred. However, these studies remained skeptical among geologists working in the basin. Our detailed petrographic studies documenting the quartz dissolution-precipitation pattern, integrated with reactive transport modeling, confirmed that large-scale thermal convection indeed happened and may be related to unconformity-related uranium mineralization.

[1] Wang, Y., Chi, G., Li, Z. & Bosman, S. (2021), Earth and Planetary Science Letters 574, 117168.