

## Using Uranium Isotopes to Determine Salinity Sources in Rio Grande Waters

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### Abstract

The Rio Grande flows from Southern Colorado through New Mexico and West Texas down to the Gulf of Mexico. It serves as an important water supply for agricultural and municipal needs. In Rio Grande waters, total dissolved solids (TDS) increase from ~40 mg/L at the headwaters to 500-1500 mg/L at El Paso, Texas. The elevated TDS values in downstream water cause various problems such as reduction in crop productivity and deterioration of soil quality due to salt loading. A number of natural and anthropogenic factors may lead to increased salinity, so the exact sources and their relative contributions to the salt load remain unclear. U isotopes (e.g., <sup>234</sup>U and <sup>238</sup>U) fractionate naturally when released from rocks to waters during chemical weathering processes at Earth's surface. It has been suggested that the degree of U isotope fractionation depends largely on local lithology and climate conditions, which affect chemical weathering and U release rates. U isotopes in natural waters thus have great potential to serve as natural tracers for chemical weathering processes, which in turn can help to determine the origins of dissolved solids (i.e., salts) and their history.

Here, we measured the U concentrations and isotope ratios for water samples collected along a ~ 1000 km stretch of Rio Grande (from the headwaters in Colorado to El Paso, Texas), as well as from streams and springs in the Jemez Mountains, a small drainage basin that recharges to Rio Grande in northern New Mexico. The comparison of these two case studies reveals different evolution histories for U in surface waters. In the Jemez Mountain region where human impacts are minimal, U isotope ratios in surface waters are largely controlled by rhyolite weathering, and both U concentrations (0.01-0.19 ppb) and (<sup>234</sup>U/<sup>238</sup>U) activity ratios (1.5-3.0) vary systematically with elevation (2600-2900 m). Here, solutes in streams largely represent mixing of two sources: young surface water (e.g., several months old) with low U concentrations and high (<sup>234</sup>U/<sup>238</sup>U) ratios and relatively old shallow groundwater that has higher U concentrations and lower (<sup>234</sup>U/<sup>238</sup>U) ratios. Similar ranges of U concentrations and (<sup>234</sup>U/<sup>238</sup>U) ratios are observed for the headwater regions of the Rio Grande. U concentrations in the Rio Grande increase significantly downstream (0.12 to 5.97 ppb) and correlate well with Ca<sup>2+</sup>, Mg<sup>2+</sup>, and HCO<sub>3</sub><sup>-</sup> ions, revealing a control of carbonate dissolution/precipitation on river water chemistry. This is probably due to a change of lithology. In addition, both (<sup>234</sup>U/<sup>238</sup>U) ratios (1.6-2.1) and U concentrations in the Rio Grande waters show strong seasonal patterns, reflecting the human impacts on river chemistry, such as the regulation of river flows by reservoirs and dams, agricultural irrigation return flows, and pumping of cold/geothermal aquifer waters.

## Petrogenesis of the Aolunhua igneous complex, eastern Central Asian Orogenic Belt: Geochemical, and Sr–Nd–Hf isotopic constraints

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A large-scale Early Cretaceous magmatic-metallogenic belt (known as the Xar moron belt) has recently been recognized in the eastern Central Asian Orogenic Belt (CAOB), but the process and mechanism for the formation of this belt are controversial. Here we report geochemical and Sr–Nd–Hf isotopic data for the Aolunhua igneous complex (genetically related to a porphyry-type Mo deposit), to reveal its petrogenesis, source nature, and implications for the Mesozoic tectonic evolution of eastern CAOB.

The complex consists of a batholith (monzogranite-porphyry) and late-stage bimodal dyke swarms (quartz-porphyry and diorite dykes). Geochemically, the monzogranite-porphyry exhibits features of arc rocks such as conspicuous Nb, Ta negative anomalies and LILE enrichment (e.g., Sr and Ba). It has low *I*<sub>Sr</sub>, positive ε<sub>Nd</sub>(*t*) values of +0.5 to +1.4 and ε<sub>Hf</sub>(*t*) values of +3.5 to +9.8. These features, together with young inherited zircons (< 360 Ma) from the source region, suggest a juvenile basement dominated by the late Paleozoic island-arc series. The mafic enclaves hosted in the monzogranite-porphyry are characterized by containing H<sub>2</sub>O-bearing minerals (e.g., Hb and Bi) and more calcic plagioclases, variable elements compositions, high Mg<sup>#</sup>, enrichment of Sr and LREE, and radiogenic Nd–Hf isotopic compositions (ε<sub>Nd</sub>(*t*) = +0.7 to +1.6 and ε<sub>Hf</sub>(*t*) = +3.3 to +10.9), indicating that they originated from a subduction-modified mantle, followed by a significant fractionation of ferromagnesian phases such as pyroxene and hornblende. Petrological and geochemical evidences including hornblende-rimmed quartz ocelli, pervasive acicular apatites in mafic enclaves, compositional disequilibrium in plagioclases and high Mg<sup>#</sup> features of the host rocks, demonstrate that mixing between mantle magma and crustal melts have played an important role in the formation of monzogranite-porphyry. The quartz-porphyry dykes show high SiO<sub>2</sub> concentrations, low Mg<sup>#</sup>, conspicuous negative Eu anomalies and relatively flat REE patterns. The contemporaneous diorite dykes, however, show geochemical and isotopic characteristics similar to the mafic enclaves. The two kinds of dykes probably have been originated from melting of lower crust and mantle source, respectively, in a late stage when the monzogranite-porphyry batholiths was solidified.

In summary, the Aolunhua igneous complex formed due to the reactivation of the juvenile CAOB in the Early Cretaceous when the Paleo-Pacific oceanic slab subducted beneath eastern China, and triggered the upwelling of asthenosphere, which resulted in lithospheric thinning and extensive magmatism in the eastern CAOB.