

## Phosphate geochemistry as a genetic indicator for gold deposits

Ryan D Taylor\*, Garth E Graham, and Kunfeng Qiu

U.S. Geological Survey, Denver, CO, USA, \*e-mail, rtaylor@usgs.gov

Controversy surrounds the genetic origins of many gold deposits, including those in the Jiaodong gold province of China and several gold deposits in Alaska, USA. Understanding formation mechanisms for these deposits is critical because ill-defined deposit models have adverse effects on exploration and production. Granites host many of these deposits, but questions remain as to whether these granites are the source of the gold and hydrothermal fluids.

Rare earth-bearing phosphate minerals such as monazite and xenotime are alteration products found in both orogenic and intrusion-related deposits and have proven important for geochronological investigations. Additionally, their trace element chemistry may be used to differentiate between metamorphic, magmatic, diagenetic, and hydrothermal origin.

*In situ* chemical characterization of monazite and xenotime has been carried out for various greenschist- and granite-hosted orogenic gold deposits in California, the alkaline-related Taurus, AK, and Cripple Creek, CO deposits, the calc-alkaline Pebble, AK, and Butte, MT porphyry deposits, the controversially classified Pogo deposit, AK, as well as deposits in the Jiaodong gold province. Chemical differences (including REE profiles, Pb, Th, Th/U, Nd, Sm, Ce/Pr, and Ce and Eu anomaly magnitudes) are noted among unequivocally primary magmatic, magmatic-hydrothermal, and metamorphic-hydrothermal phosphates from these deposits. Using these characteristics, we are able to infer details about the genetic origins of gold deposits of controversial origin in Alaska and the Jiaodong gold province.

The Pogo gold deposit is currently modeled by mine geologists and some researchers as an intrusion-related gold system. Regional calc-alkaline magmatism was contemporaneous with deposit formation, but a genetically related pluton is only inferred to exist at the mine site. Both monazite and xenotime from the Pogo deposit are chemically distinct (REE profiles, Th/U, Sm/Yb, Gd/Eu, Ce/Pr, Lu, and Pb) from magmatic-hydrothermal phases from calc-alkaline systems and closely resemble those related to orogenic gold deposits.

Monazite and xenotime chemistry from granite-hosted deposits in China, including magmatic monazite and hydrothermal monazite and xenotime from red potassic alteration in the Jurassic Linglong granite and from auriferous quartz-sericite-pyrite alteration in the Cretaceous Guojialing granite suggest contrasting geneses. The chemistry of magmatic and potassic alteration-related phosphates have similar chemistry, including trace element concentrations and REE profiles, although the latter have larger negative Eu anomalies. The phosphates associated with quartz-sericite-pyrite alteration are distinct with respect to Th, Th/U, Nd, Sm, and size of Eu anomaly. The chemistry of these phases suggest that the potassic alteration spatially associated with gold deposits in the Jurassic granites are a product of magmatic-hydrothermal fluids derived from the granite, whereas the phosphates associated with ore are more similar to those from orogenic gold deposits found in California.

Our study suggests that chemistry can be used to fingerprint phosphate origin and can be applied to genetic interpretations of controversially classified gold deposits. The correct model for gold mineralization in these regions determines whether exploration should be focused on structures or plutons, and this will have profound implications for effective exploration in these terranes.