Trisulfur anion helps explain gold deposits on Earth

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Native gold nugget. Credit: public domain

(Phys.org)—People have been excavating gold for thousands of years as a precious rare metal. Gold is in relatively low abundance in the Earth's crust likely coming from the metallic core and from meteorites. For reasons that are not entirely known, even though the average amount of gold throughout the Earth's crust is small, there are deposits containing gold in significantly greater concentrations than the crust's average abundance. These deposits tend to be in locations of geological activity and are likely due to the action of hydrothermal fluids. However, the concentration of gold in deposits is still higher than what would be expected from solutions carrying gold-chloride or gold-hydrogen sulfide.

A conglomerate of researchers hailing from the CNRS and several universities, and organizations in France has found a possible cause for the higher concentrations of gold. They propose that under hydrothermal conditions, the trisulfur ion (S_3^-) plays a key role in the deposition of gold. Their findings have implications for the way scientists predict the location of gold deposits and may lead to as-yet-discovered sites. Using x-ray absorption spectroscopy, hydrothermal reactor measurements coupled with first-principle molecular dynamics, and thermodynamic modeling, they provide quantitative data for the effect of the trisulfur ion in hydrothermal conditions. Their work appears in the *Proceedings of the National Academy of Sciences*.

According to Pokrovski et al., existing gold speciation studies ignore the trisulfur anion, S_3^-. Prior studies by this group and others have shown that the trisulfur ion exists in aqueous environments at high temperatures and pressures. For example, in previous research using in situ Raman spectroscopy, Pokrovski's group demonstrated that this form of sulfur is stable in aqueous solutions in a temperature range of at least 200°C to ~700°C and 30bar. Trisulfur had been difficult to identify because at cooler temperatures S_3^- breaks down to sufate and sulfide in aqueous solutions. Their prior work provided an impetus for considering more than hydrogen sulfide and chloride, the trisulfur anion in analyzing gold transport and deposition.

In an effort to quantify how S_3^- affects the concentration and precipitation of gold from aqueous hydrothermal fluids, Pokrovski et al. used model fluid systems comprised of gold metal and hydrogen sulfide, sulfate, and S_3^- and varied many of the system parameters such as temperature, pressure, redox potential, and acidity. Their data is from in situ X-ray absorption spectroscopy (XAS) and hydrothermal reactor measurements assisted by first-principles molecular dynamics (FPMD) and thermodynamic modeling.

Their study reveals that while $Au(HS)_2^-$ is the most stable species in aqueous solutions at moderate temperatures (250 °C) and pressures (>100 bar). These species enable extraction, transport, and focused precipitation of gold by sulfur-rich fluids 10–100 times more efficiently than sulfide and chloride only. As a result, S−3 exerts an important control on the source, concentration, and distribution of gold in its major economic deposits from magmatic, hydrothermal, and metamorphic settings. The growth and decay of S−3 during the fluid generation and evolution is one of the key factors that determine the fate of gold in the lithosphere.