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Gold Accumulation Driven by Earthquake-Induced Piezoelectricity

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For thousands of years people have observed that coarse gold occurs almost exclusively in quartz veins, as either large nuggets or as highly interconnected fracture networks. The current understanding is that gold is precipitated together with quartz from hydrothermal fluids in response to changes in temperature, pressure, and/or fluid chemistry. The overall mechanisms that are responsible for the transport and deposition of gold are relatively well understood, resulting from an interplay between these geochemical and structural factors. However, no widely accepted mechanism can explain the extreme localisation of gold needed to form large nuggets that occur in orogenic quartz veins. They represent a long-unsolved paradox: the solubility of gold in fluids is up to ~1 ppm, whereas the local concentration of gold in quartz can even exceed 50%. Here, we investigate whether piezoelectric discharge from quartz crystals during earthquakes can provide a suitable explanation for extreme gold localisation in orogenic quartz veins. Quartz is the only abundant piezoelectric mineral on Earth, meaning that when distorted under stress the crystals produce an electrical potential proportional to the applied force. Seismic activity that drives orogenic gold deposit formation means that quartz crystals in veins will experience thousands of episodes of deviatoric stress. The elastic rattling of quartz during this activity creates an oscillating piezoelectric voltage that induces alternating oxidation-reduction reaction fronts on crystal surfaces. When this voltage shifts the energy of the quartz valence band above the redox potential of Au-bearing ligands, gold will be electrochemically deposited. Additionally, because gold nanoparticles migrate under electric fields to attach to electrodes, these will also accumulate on instantaneously charged crystal faces. Both effects were confirmed experimentally. The nucleation of gold via piezo-driven reactions is rate-limiting because quartz is an insulator. However, gold is an outstanding conductor, meaning that existing gold grains will adopt the voltage from adjacent quartz and become the focus of ongoing growth - allowing the creation of large nuggets. Since piezoelectric voltages are coupled with stress, the largest potentials are achieved during brittle failure, possibly explaining an origin for highly interconnected networks of gold fractures in quartz veins.