

Chemical zoning in pyrite with implications for ore-forming processes

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Oscillatory and sector zoning occur in over 75 different mineral species, yet there is still debate over the mechanisms that control this chemical zoning. Two models in particular are generally invoked for these processes: (1) the fluid-pulse model; and (2) the crystal-growth disequilibrium model. The fluid-pulse model involves bulk chemical changes of a mineralizing fluid through repeated pulses, introducing new elements that are incorporated into distinct zones within minerals as they grow. The crystal-growth disequilibrium model invokes local, chemical disequilibrium at the fluid-mineral growth interface as a result of rapid growth rate with commensurate substitution of trace elements for elements normally incorporated. Importantly, this second model does not require a change in the bulk fluid chemistry. The recognition of chemical zonation in arsenian pyrite has led to updated hypotheses for these models, particularly for Au deposits. Recent advocates of the fluid-pulse model have used zoned textures in arsenian pyrite combined with in-situ analyses of S isotopes ($\delta^{34}\text{S} +0.34\text{‰}$ in barren vs. -11.98‰ in Au-rich zones) to suggest that Au-rich zones are a result of fluctuating bulk fluid chemistry caused by seismic-induced pulses (fault-valve dynamics). In contrast, recent evidence from atom probe analyses of arsenian pyrite supports the crystal-growth disequilibrium model, by demonstrating that As- and Au-rich zones are dependent upon the growth rate of pyrite. Investigation of chemical zoning in Au-bearing, arsenian pyrite at the Jerome deposit, Swayze greenstone belt, revealed two key lines of evidence to dispute the fluid-pulse model: (1) in-situ S isotope analysis of chemically zoned, arsenian pyrite by Secondary Ion Mass Spectrometry (SIMS) indicates the S source remains constant between adjacent oscillatory zones, and only varies slightly from core to rim ($\delta^{34}\text{S} = -14$ to -19‰), rather than fluctuating during pyrite growth; and (2) the presence of sector zoning in the same generation of arsenian pyrite suggests separate chemical zones were present contemporaneously with an identical chemistry to oscillatory zones. The latter suggests these zones are best explained by local chemical changes during mineral growth, rather than fluctuating bulk fluid chemistry. These observations have significant implications for Au deposit formation as well as broad implications for mechanisms controlling chemical zonation of many other mineral species, since it is likely that these similar textures indicate that similar processes are operating in different geological environments.