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Coupled fault-valve (deep) and suction-pump (shallow) model for structure-controlled, world-class mineralization in sedimentary basins – evidence from fluid inclusions and numerical modeling

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Many world-class mineral deposits are hosted in sedimentary basins and spatially associated with structures. The controlling factors for the formation and localization of such deposits may include those within the basins and those at depth in the basement. Various studies have emphasized either intrabasinal factors such as sedimentary facies and development of basinal brines, or deep-seated processes such as heat sources, but few examined the linkage between them, which may be the key factor determining whether or not and where economic mineralization may take place, as demonstrated by the giant Jinding Zn-Pb deposit in the Meso-Cenozoic Lanping Basin (China) and unconformity-related uranium deposits in the Proterozoic Athabasca Basin. The fault-valve and suction-pump mechanisms have been proposed as major driving forces of structure-controlled fluid flow at deep (ductile-brittle transitional) and shallow (brittle) environments, respectively. It is shown here that the linkage between the two mechanisms is critical for large-scale mineralization. In the case of the Jinding Zn-Pb deposit, the orebodies are hosted in a structural dome adjacent to a regional, trans-crustal fault. Fluid inclusion studies indicate that the deposit formed from overpressured, metal-rich brines injecting into an oil-gas reservoir, whereas numerical modeling indicates that fluid overpressure could not be generated within the basin. The episodic reactivation of the regional fault by the fault-valve mechanism at depth is postulated to have controlled pulsed fluid flow within the basin, feeding ore fluids to the H_2S-rich oil-gas reservoir (trap) and formed the deposit. In the case of the Athabasca Basin U deposits, the mineralization is associated with reactivated basement faults. Numerical modeling indicates a hydrostatic pressure regime in the basin, and fluid inclusion studies indicate fluid boiling and sub-hydrostatic pressure, as is expected in a suction pump model. The reactivation of the basement faults was controlled by the fault-valve mechanism deep in the basement, whereas the fluid flow directly related to mineralization was driven by the suction pump mechanism near the unconformity, followed by fluid convection driven by elevated geothermal gradient. In both cases, the combination of the fault-valve model at depth and suction-pump model at the site of mineralization controlled the mineralization.