Epithermal systems of the Seongsan district, South Korea

an investigation on the

geological setting and spatial and temporal relationships between

high and low sulfidation systems

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ABSTRACT

Two distinct styles of epithermal Au-Ag deposits have been recognised globally for the past 25 years or so, low-sulfidation or adularia-sericite systems and high-sulfidation or acid-sulfate systems. Both types of epithermal systems occur in a volcanic arc setting at regional scale, but generally they are not found together at the district scale and the extent to which they are genetically related is often not clear. The Seongsan district of South Korea however, does host high-sulfidation style clay-sulfate-silica deposits that are exploited as commercial sources of kaolinite and dickite. The district also hosts several low-sulfidation Au-Ag mineralised epithermal systems that have only been recognised recently. Little is known about their geological setting, any structural controls on their location, or their relationship, if any, to the nearby clay-sulfate-silica deposits.

Advanced argillic alteration in the Seongsan district has been mined as a source of clay rather than Au and Ag. The region therefore also offers as opportunity to assess the controls on clay ore as well as Au-Ag ore development in a high-sulfidation/acid-sulfate environment.

The primary objective of this project is to investigate the geological setting and the spatial and temporal relationships between the high and low-sulfidation epithermal systems in the Seongsan district of South Korea. The Seongsan district provides the opportunity to examine if the two distinctly different types of epithermal systems are coeval parts of a single hydrothermal event, or separate events formed by different fluids at different times.

The Cretaceous Yuchon Group that hosts the epithermal systems of the Seongsan district comprises a sequence of pyroclastic ignimbrite flows and subplinian, plinian and phreatoplinian fall and surge deposits. Sub-volcanic intrusive domes, flows and proximal to distal pyroclastic and volcaniclastic deposits formed during later stages in the magmatic history. These are all intercalated with epiclastic fluvial, alluvial fan, and lacustrine sediments. The volcanic rocks in the Seongsan district represent an ancient continental silicic volcanic succession. No evidence of a caldera setting was seen in the Seongsan district despite previous workers assumptions to the contrary.

Both low- and high-sulfidation systems are often localised along faults that comprise zones of brittle fractured rock a few cm to 10s of metre wide. Two phases of fault movement and alteration have affected the Seongsan district. Advanced argillic alteration is localised along a network of brittle faults whose internal geometry and slickenlines indicate that high-sulfidation

hydrothermal activity occurred during sinistral strike-slip movement. Quartz-Au-Ag veins and associated adularia alteration are localised along younger normal faults. Synchronous reactivation of some strike-slip faults resulted in deformation of the advanced argillic alteration. The structural framework of the Seongsan district was determined to have developed under two distinctly different stress regimes, characterised initially by wrenching (district-scale stress regime 1; $\sigma1$ north-northeast – south-southwest) followed by extension (district-scale stress regime 2; $\sigma3$ north-northwest – south-southeast).

$^{40}Ar/^{39}Ar$ stepwise heating age data indicate adularia in the low-sulfidation systems crystallised between 77.4±0.5Ma and 78.1±0.3Ma. When coupled with published age data on the high-sulfidation deposits, this new data shows that the advanced argillic and adularia-phyllic alteration occurred between 1.3Ma and 5.5Ma apart. Epithermal systems of the district formed during two discrete hydrothermal events, although they could be considered as two parts of a long-lived cycle of crustal convergence, subduction, volcanism and associated hydrothermal activity.

A lack of workable primary fluid inclusions resulted in negligible information being obtained from microthermometric fluid inclusion analyses. Mineral phase relations show that the high-sulfidation systems formed under oxidised, acidic, SO_4-dominant conditions, whereas the low-sulfidation systems formed under reduced, near-neutral pH, H_2S-dominant conditions. Fluids associated with the Au-Ag-bearing paragenetic stages were of intermediate- to low-sulfidation-state, regardless of which epithermal system they formed in. Oxygen and hydrogen isotopic ratios show that a meteoric-derived fluid characterised by a $\delta^{18}O$ range of -8 to 1‰ and δD of -65 to -100‰ formed the low-sulfidation Au-Ag vein systems, whereas a magmatic fluid characterised by a $\delta^{18}O$ range of 2 to 7‰ and δD of -145 to -40‰ formed the high-sulfidation systems. Sulfur isotopic ratios of pyrite (-9 to 0‰ $\delta^{34}S$) and alunite (5 to 7‰ $\delta^{34}S$) from the high-sulfidation systems show marked fractionation, and imply a SO_4-dominant, magmatic-steam origin for fluids that formed the advanced argillic alteration. The relatively narrow range of $\delta^{34}S_{sulfide}$ from the low-sulfidation systems implies that the associated phyllic-argillic alteration formed from fluids in which H_2S was the dominant sulfur species.

Epithermal systems in the Seongsan district shares many similarities with those in the Comstock district of Nevada, Mt Skukum in Canada, southern Kyushu in Japan and the Mankayan district in the Philippines. All districts show a superimposition of low- on high-sulfidation style alteration (±mineralisation) coupled to a change in structural setting from compression/ wrenching to extension, typically over a period of ca. 1 to 2Ma. This suggests that, although rare, districts that host both high- and low-sulfidation systems share a common structural and hydrothermal evolution.

Rhyolitic to dacitic host rocks and SO_4-dominant conditions play critical roles in the development of clay deposits. Metalliferous mineralisation requires sulfur speciation to be H_2S-dominant, whereas host rock composition is less critical.

The Seongsan district is possibly the first documented area in Korea, if not globally, that hosts both high- and low-sulfidation epithermal systems that produce economic clay/sulfate and Au-Ag from the same district.

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