Controls on the transport and deposition of metals in ore-forming hydrothermal systems

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Hydrothermal fluids transport metals in concentrations sufficient to form ore deposits, mainly because H_2O is a polar molecule and many ore metals form strong aqueous complexes with ligands found commonly in nature. Here, the properties of hydrothermal liquids and vapours are summarised, and it is shown how the hard-soft-acid-base principle can be used to predict why certain metals form strong complexes with particular ligands. For example, it is predicted that monovalent gold, a soft metal, forms strong complexes with bisulphide ions (soft) but not fluoride ions (hard), whereas the REE (hard) form strong complexes with fluoride ions. Experimental studies of aqueous metal speciation support these predictions, and show in addition, that copper, zinc and to a lesser extent silver, are transported mainly as chloride species, and molybdenum as oxyacids. In vapours and vapour-like supercritical fluids, and in contrast to aqueous liquids, the partial pressure of H_2O is the principal control on metal solubility, which increases with the hydration number of the species and exponentially with pressure. Data on the speciation of a selection of base, precious and critical metals in aqueous liquids and vapours are used in conjunction with stability data for the corresponding ore minerals to address a number of observations of ore-forming systems. For example, they are used to explain why the ore in porphyry Cu-Mo deposits commonly comprises a deep molybdenite-rich zone and a shallower chalcopyrite zone, both associated with potassic alteration. They are used also to test the hypothesis that Mississippi Valley Type (MVT) deposits are the products of hydrothermal zinc and reduced sulphur from separate fluids. In a third example, they are used to evaluate the common assumption, based on the association of REE minerals with fluorite, and the high stability of REE-fluoride complexes, that the latter species dominate REE transport. In a final example, they are used to support the hypothesis that high sulphidation epithermal gold deposits can be the products of auriferous vapours. These examples underline the importance of understanding metal speciation when evaluating depositional mechanisms (e.g., fluid mixing, boiling, fluid-rock interaction) in ore-forming hydrothermal systems.