Fluid Flow and Reaction Kinetics in the Formation of MVT Deposits

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A continuing problem in theories of MVT ore genesis is the origin of the sulfur in the ore minerals, mostly sphalerite and galena. Reduction of seawater sulfate to H_2S is commonly called upon, but ore formation temperatures are too high for bacterial reduction, and thermochemical sulfate reduction (TSR) is known to be very slow. For these reasons sulfate reduction is generally held to occur *before* ore deposition, with the H_2S held in a trap later intersected by a metal-bearing solution. Such mixing (the "mixing hypothesis") should result in a high degree of supersaturation and hence fine-grained (e.g. colloform) textures, but the kinetics of the sulfate reduction reaction is not a genetic factor, and there are theoretically few limits to the amount of ore produced. Compilation of all available data, including some recent data of our own, shows that at a typical MVT ore formation temperature of 150°C, the first order rate constant for the overall TSR reaction lies between 10^0 and 10^{-4} y^{-1}, depending on the reductant and other factors. To what extent these measured rate constants apply to natural conditions remains problematic.

An alternative to sulfate reduction is the release of H_2S from natural organics such as petroleum or organic-rich shale. Our preliminary data on the rate constant for the release of H_2S from the New Albany shale lies in the same range. Reactions with these rate constants are very slow, and crystal growth controlled by these rates would presumably be relatively large and well formed, but the question is rather whether these rates could result in enough precipitation to form an ore body in a reasonable length of time.

A simple "continous stirred tank reactor" flow model used by chemical engineers shows that rate constants in the upper part of this range could form 20 million tonnes of 5% zinc ore in less than 10^5 y, but only a smaller deposit in 10^4 y. With a rate constant of 10^{-4}, such a deposit would not form in 10^6 y. However, a 1D reactive transport model shows that with the larger rate constants and low fluid velocities all the zinc will precipitate as sphalerite within a few meters in the flow path. This is not considered reasonable, so that in this sense the larger rate constants may be too fast.

So although very slow, flow models show that reaction rates for both processes are fast enough to generate small ore bodies, with H_2S generation taking place during ore formation. The ore deposits of Central Tennessee have several features such as large, well formed sphalerites in relatively small deposits, which suggest that one (or both) of these processes may be responsible.