Ghost zones in sediment-hosted copper deposits

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It has been said that a mineral zonation in a sediment-hosted copper deposit appears as, from an upstream side, chalcocite - bornite - chalcopyrite - pyrite. However, the well-developed zonation has rarely been reported in the previous investigations in the deposits. In many deposits, wide monomineralic chalcocite and/or native copper zones have been observed, while chalcopyrite and/or bornite could be seen in narrow areas vicinity to pyrite zones.
Although several formation models of the deposits have been proposed, it is widely believed that the copper mineralization was caused by reducing copper bearing oxic fluids during their migration in sediments or sedimentary rocks. Therefore, the formation processes of the zonation may be investigated by analytical schemes for processes of reactive transport (infiltration metasomatism).
Let us suppose that mineral B is stable between minerals A and C, that is, the assemblage A + C is incompatible due to B. Minerals A, B and C are comparable with chalcocite, bornite and chalcopyrite, respectively, in the above deposits. Then, we may think the zoning as, for example, from the upstream side, A - B - C. However, we need to confirm if the velocity of the replacement front of C by B is surely faster than that of B by A. If not, the zone B becomes as a ghost zone, that is, C is directly replaced by A, while the solution at the front is in equilibrium with B and C, since C can not equilibrate with A. The practical meaning may be that C is replaced by B being replaced by A soon after its formation. Therefore, the zone B does not expand with time.
Analytical solutions of the velocities of the replacement fronts in the above mineral zonation in sediment-hosted copper deposits have been obtained by Mathematica (Wolfram Research), while the formation processes have been numerically simulated by MIX99 (Hoshino et al., 2000). The results are:
(1) Although primary reductants may be carbonaceous matters in sediment (rock), the front velocity of pyrite precipitation due to reducing fluids by carbonaceous matters is quite fast, so the direct reductant for the following fluids is pyrite.
(2) Chalcocite monomineralic zone is formed after (upstream side of) the pyrite dissolution front when the inlet fluid pH is low.
(3) Native copper zone and/or chalcocite zone are formed (in this sequence) after the pyrite dissolution front when the pH is high.
(4) Bornite and chalcopyrite do not form the zones in all analyzed conditions, but ghost ones vicinity to the pyrite dissolution front when they appear.
It can be concluded from the analytical results that bornite and chalcopyrite are transitional minerals even when they precipitate during mineralization, so that their well-developed zones have rarely be seen in the sediment-hosted copper deposits.

Keywords: sediment-hosted copper deposit, mineral zonation, ghost zone

