COMMENT

GENESIS OF STRATABOUND ORE DEPOSITS IN THE MIDCONTINENT BASINS OF NORTH AMERICA. 1. THE ROLE OF REGIONAL GROUNDWATER FLOW

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Garven and others (1993) claim that the hydrogeologic modeling they present provides a clearer picture regarding the paleohydrology of MVT ore formation at a regional scale. I disagree with this presumption. If a study is to explore more specific and direct hydrologic evolution of the nature of regional groundwater flow, it seems illogical to cite mistakes of others, simplify stratigraphic relations, and disregard particular fault systems.

Citing the mistakes of others undermines the credibility of their study. For example, Garven and others (1993) cite Leach and Rowan (1991) and state that there is little field evidence linking ore mineralization to faulting in the Ozark region. Faulting as an ore control in southeast Missouri was initially recognized by Tarr (1936). Snyder (1967), Brown (1967), Snyder and Gerdemann (1968), Pettus and Dunn (1986), and Clendenin (1993) provide specific field evidence of relations between faulting and mineralization in both the Old Lead Belt and Viburnum Trend. Snyder and Gerdemann (1968, p. 343, 347, 349) clearly define these relations: "The most important role played by faulting is ground preparation, intense fracturing that permitted easy movement of solutions through the host rock structures and provided access to lithologic types not normally mineralized. In reef, slide breccia, (or) the boulder bed, the fractures cut across primary features, providing easy access for mineralizing solutions. Again, the result is a greater than usual height of mineralization and higher-grade-ore. Equally apparent is an inconsistency of the mineralization with sedimentary features." Snyder and Gerdemann (1968, p. 345) also provide a map that shows relationships between intensity of mineralization and faulting in the Old Lead Belt. Pettus and Dunn (1986, p. 71) state the following about the Conway fault in the Viburnum Trend: "A large, complex fault zone, the Conway fault, that strikes north-northeast across the southern third of the (#28) mine has caused difficult mining conditions, due to bad ground conditions and a large inflow of water to the mine. Some areas adjacent to the fault have produced abnormally rich ore that may be related to ground preparation and/or movement of ore fluids along the fault." Kaiser and others (1987) show that in the Southeast Missouri Barite district barite-galena-sphalerite- and chalcopyrite-zonation patterns outline fault-controlled ore runs developed by fluids dispersed from subvertical faults and support this mapping with fluid inclusion, sulfur- and oxygen-isotope studies. Viets and Leach (1990) also point out that in the Central

Missouri, Northern Arkansas, and Tri-State districts ore in zones of higher permeability is associated with faulting, minor folding, and solution collapse.

Discussing ore controls may seem to be a minor point; but in this instance, differences of opinion stem directly from how faults are treated in flow models. Few will argue against Garven and others (1993) basic premise that basin-scale brine migration was stimulated by orogenic events. Clendenin and Duane (1990) agreed with this premise and indicated that Ouachita deformation was the regional drive for northward fluid migration. However, we were mistaken when we indicated that it was not necessary to model gravity-driven flow. Be that as it may, the only real modification Clendenin and Duane (1990) proposed to the regional model was that distal fluid movement was focused by secondary faults in compartments bound by larger barren regional faults. Tobin and others (1993) have demonstrated that fluid expulsion from the deforming sediments at the toe of the Oregon accretionary prism is preferentially concentrated along fault traces. They also state that the discovery of strike-slip faults acting as efficient fluid conduits emphasizes the generally unappreciated importance of strike-slip and normal faults in dewatering accretionary prisms. A major leap in logic is not required to apply these relations to faults in the Ozark region north of the Ouachita front.

If we set differences of opinion aside, the point remains that Garven and others (1993) have compromised their simulations by ignoring particular fault systems while treating others as barriers to flow. Bredehoeft, Belitz, and Sharp-Hansen (1992) recently showed that differing interpretations are possible depending on whether faults are ignored or treated as barriers to horizontal flow. However, if particular fault systems are not considered in the modeling, then the models cannot be claimed to be internally consistent nor geologically realistic.

The hydrogeologic model for section A-A′ ignores the Bolivar-Mansfield fault system which divides the Ozark region into two distinct metallogenic provinces. A continuous aquifer (Lamotte Sandstone-Bonneterre Formation) interpretation suffers if the fault system is acknowledged. Antonellini, Ayden, and Polland (1992) have demonstrated that faults in porous sandstones make highly effective barriers against fluid flow. It might be argued, as Viets and Leach (1990) have, that restricted flow through the Lamotte Sandstone resulted in much of the subsequent flow traversing the Bonneterre Formation. Regardless of how broad a brush is used to paint the regional picture, a continuous Bonneterre Formation aquifer is questionable because (1) sandstones and carbonates do not have the same permeability characteristics in the Midcontinent region unless the carbonates are pervasively fractured, and (2) facies patterns within the Bonneterre Formation, which control aquifer transmissivity, were complexly modified by Dresbachian syndepositional tectonics. Calling on the so-called "Knox" aquifer to move the fluids northward is also suspect for a number of reasons: (1) The Davis

Shale is greater than 40 m thick in south-central Missouri, and movement of fluids from the "Knox" aquifer into the underlying Bonneterre Formation would require *major* structural juxtaposition of the two stratigraphic units. (2) Devonian and post-Mississippian uplift of the Ozark dome resulted in extensive erosion over the region, and fluids driven northward in the "Knox" aquifer were probably expelled at the surface or diluted by fluids from a recharge area related to uplift of the Ozark dome. (3) Fluid inclusion studies of dolomite cement associated with MVT ores in southeast Missouri by Shelton, Bauer, and Gregg (1992) also indicate that data do not support a regional thermal gradient extending northward in the Ozark region from the Ouachita front. In the absence of such a gradient and regardless if faults are acknowledged or not, models of northward linear flow are suspect, and vocabulary such as "well established" should be modified to "presumed."

The models for sections B-B′, F-F′, and C-C′ treat faults as barriers to lateral flow. Bredehoeft, Belitz, and Sharp-Hansen (1992) point out that in the case where faults are lateral barriers, the basin is broken into compartments. The suggestion of compartmentalized basins also argues against presumptions of the existence of a continuous aquifer system in the Midcontinent region. However, as Garven and others (1993) imply, the basic observation is that throughgoing faults have the capability to influence strongly basin-scale fluid flow and the subsurface thermal regime (Smith, Forster, and Evans, 1990). A second point is that a basin-scale flow system is more sensitive to changes occurring within fault zones than in the surrounding protolith (Smith, Forster, and Evans, 1990). Recent field studies have shown that the regional faults were being reactivated by a number of the same events that Garven and others (1993) suggest as stimulating regional flow (Clendenin and others, 1993).

If faults are considered as lateral barriers in the models, inferences based on sections F-F′, C-C′, and E-E′ are questionable. The model based on F-F′ does not depict flow paths to the Old Lead Belt. The surface expression of the Ste. Genevieve fault system is approx 50 km east of the Old Lead Belt and would have disrupted, as the model suggests, east to west flow. Suggestions of east to west flow are also suspect because to date no major deposits have been discovered associated with or in close proximity to the Ste. Genevieve fault system. This relation clearly indicates that fluids were not discharged near the western margin of the Illinois basin. The model based on section E-E′ does not discuss what effects the Simms Mountain and Black fault systems would have had on lateral flow. If the faults are considered, it is difficult to envision any brine migration over the St. Francois high. Arguments used for the Ste. Genevieve fault system could be applied to the Simms Mountain fault system juxtaposed to the Old Lead Belt, that is, vertical brine flow was induced by a rapid rise in basement elevation. I presume that the vertical fault on the right margin of section C-C′ is the Greenville fault. The Greenville fault lies to the northwest of the English Hill fault system which marks the northwest margin of the Reelfoot rift. If the English Hill fault system is ignored, an interpretation of a continuous aquifer system still suffers because both the Lamotte Sandstone and Bonneterre Formation are discontinuous over the right third of the section. A series of horsts and grabens are present in this area which complicate facies patterns and thicknesses in both formations (Clendenin, Lowell, and Niewendorp, 1993).

I agree with Garven and others (1993) that (1) extensive fault systems were not a prerequisite for fluid migration, (2) exotic hydrologic theories (seismic pumping) need not be imposed for the evolution of MVT deposits in the Midcontinent region, and (3) gravity driven flow was stimulated by orogenic events. However, as I have pointed out, stratigraphy may not have provided the best framework for continuity of regional flow. If presumptions are replaced with known geologic relations, a pattern of flow may eventually be interpreted and modeled on the spatial distribution of permeability. Modeling of this spatial distribution would identify which faults act as either barriers or nonbarriers to flow, depending upon whether the fault zones are more permeable or less permeable than the adjoining aquifers (Bredehoeft, Belitz and Sharp-Hansen, 1992). Once this modeling is conducted, we might then be able to place most of the pieces in the puzzle of MVT ore genesis in their correct positions and have a clearer picture regarding the paleohydrology at a regional scale.

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