Pedogenic and Groundwater Silcretes in Paleovalley Filling J3 & J2 Sandstones, Medicine River Area, West Central Alberta, Canada

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Summary

J3 & J2 sandstones in the subsurface of the Medicine River and Gilby areas of west-central Alberta are paleovalley-filling siliciclastic deposits that are overprinted by siliceous pedogenesis. Overprinting of the J3 sandstones typically spans their vertical extent, whereas overprinting of the J2 sandstones is localized to the stratigraphic interval subjacent to the J3 sandstones. Silica was introduced during extended periods of subaerial exposure and prior to deposition of the Lower Cretaceous, Ellerslie Member, and has resulted in a complexly aggregated duripan. Previous studies have highlighted the fact that J3 sandstones are immature and submature, have mud-sized and cryptocrystalline matrices, and have grain- and mud-supported fabrics with quartz and chert grains and kaolinite clay (Hopkins, 1981; Folk, 1974). Our study confirms these observations and extends them to J2 sandstones in close proximity to J3 sandstones. We note as well, that the muddy and cryptocrystalline matrix materials in addition to kaolinite include abundant opal, poorly crystalline silica, chert, micro and megaquartz, neoformed clay and iron sulfides. Sand-sized quartz and chert framework grains frequently are corroded and grain outlines are irregular. Grains and matrices are disposed in Terrazo (T)/Floating (F), Grain Supported (GS), and Matrix (M) fabrics; all fabrics that are common in silcretes (Smale, 1973; Langford-Smith (Editor), 1978; Summerfield, 1983; Thiry, 1999; Ullyot et al., 2004; Mellor, 2006). The rocks also contain a number of different pedogenetic remains that include illuvial clay deposits in soil channels, peds and microfracture sets, cutanic deposits (ferrans, argillans and silans), root structures and animal burrows, and abundant nodular and disseminated iron sulfides. In summary, the fine grained and cryptocrystalline matrix material in J3 and J2 sandstones is silica- and clay-rich, sulfidized soil plasma that accumulated in response to pedogenic vadose and soil groundwater processes. As a consequence, the original J3 and J2 paleovalley filling sandstones were extensively modified and cemented by early clay, silica and sulfides.

We have characterized the J3 and J2 silcretes with 9 pedofacies (PF) that reflect pedogenic (vadose) and soil groundwater (phreatic) processes and illustrate them with the 08-28-39-03W5 core that spans the J3 and upper J2 intervals. The pedogenic profile and accompanying pedofacies, near the axes of central and side paleovalleys, encompass stratigraphic intervals that are greater than 40 metres thick. Pedofacies 1-4 (PF 1-4) correspond to gleyed, silicified and sulfidized E, B and E/B soil horizons disposed in sequa (Fanning & Fanning, 1989). These particular horizons and sequa occur repeatedly in the upper half of the duripan and can attain a

combined thickness greater than 25 m. Similarly the lower paleosol interval is represented by PF 5-9. These pedofacies are variably silicified, gleyed and sulfidized B, BC, C and CR soil horizons that commonly and to varying degrees preserve parent depositional features. Medicine River area duripan/silcretes also preserve evidence of cumulative soil profile development and multistory stacking which has been observed elsewhere in ancient and modern floodplains (Kraus, 1999; Kraus & Aslan, 1999). Multistory stacking would have been a response to periodic flooding of the fluvioestuarine paleovalley when sand-sized sediment would have been unloaded into the valley's flood basins and point bars during inundation events. Following the sedimentation events, silica-, clay- and sulfide-saturated fresh and saline groundwater mixtures would have precipitated clay, silica and iron sulfides minerals and mineraloids that cemented the paleovalley deposits as fluids permeated through them. Over time repeated sedimentation and pedogenic vadose and soil groundawter events would have contributed to the development of a well-cemented and cumulative pedogenic and groundwater silcrete profile.

Previous Studies

Multiple Jurassic sandstone bodies separated by unconformities were first reported by Ter Berg (1967, p.70). This author identified the sandstone bodies as channel deposits and segregated them with alphanumeric names, JI, JII & JIII, where the larger numbers represented stratigraphically younger units. Subsequently, Rall (1980) studied the area and also noted the channel-filling character of the sandstones and, in addition, noted the abundant silicification that was present in these rocks. However, it was the detailed study of these sandstones bodies by Hopkins (1981) that brought to light the important mineral composition differences that distinguish these sandstones. He also subdivided them into alphanumeric units and identified the valley filling stratigraphic intervals as follows: J1/Detrital "formation", Poker Chip Shale, J2 and J3 sandstones and Ellerslie Member. Hopkins (1981) further advanced the notion that the multiple Jurassic sandstone bodies were valley-filling deposits and that the unconformities separating them were incision surfaces that resulted from excavation events during the long evolution of the paleovalley. Following these earlier observations, Hopkins et al. (1998) revisited the area and illustrated the paleovalley present in the Mississippian substrate with a three dimensional seismic interpretation that not only depicts the shape of the valley, but also highlights the steep nature of the valley walls. In this study Hopkins et al. (1998) proposed that J2 sandstones were estuarine deposits that accumulated within reaches of drowned valleys, that J3 sandstones were largely fluvial flood basin deposits with minor channel sandstone bodies and that these sandstones had been overprinted by pedogenesis.

Conclusions

We have reexamined the valley filling rocks in the Medicine River area and focused our attention on the enigmatic J3 sandstone interval because these sandstones provide the seal for the Medicine River Jurassic "D" Pool as was already noted by Hopkins et al. (1998, p.39). We concur with the studies of Hopkins (1981) and Hopkins et al. (1998) in that these deposits are continental and marginal marine in nature, but in addition we provide evidence that paleosoils are indeed present in the J3 and to a lesser extent in the J2 sandstones as extensive siliceous and sulfidic pedogenetic processes modified them.

The response from these paleosolic processes is a multistory and sequal duripan that is widespread throughout the subsurface of the Medicine River area. It is this seemingly atypical, early diagenetic, modification of sandstone by silica that is embossed in these rocks and that is of economic import. Even though the sandstones are porous, pedogenesis has changed them into very poorly permeable units that act as an effective coarse-grained siliciclastic reservoir seal. As hydrocarbon exploration pursues much deeper petroleum accumulations the notion of early silica cementation of sandstones attains additional economic import. Significantly, early mineraloid silica accumulations are altered to crystalline forms with burial, leaving behind quartz-cemented sandstones that are poorly permeable. Thus, geoscientists and engineers engaged in the search for additional hydrocarbn resources should consider the working hypothesis that silica in Jurassic “tight” or “unconventional” sandstone reservoirs elsewhere in the Western Canada Sedimentary Basin may have been sourced early in their history, during and shortly after deposition.

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