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Salt Dissolution Collapse-Induced Breccia Pipe-Sinkhole Complexes and Linked Debris Flows in the Northern Athabasca Oil Sands Deposit: Insights on the Origin of Overly Thick Mudstone Clast Breccia Deposits

Dr. Paul Broughton, Broughton and Associates

Abstract

The vertical gravity drives of Upper Devonian-McMurray fault blocks overlying collapsed roofs of salt dissolution chimneys were modified by oblique trajectories during their rapid, often cataclysmic, descent. Breccia pipes were impinged along the deeper reaches of the block-to-block fault planes as they differentially rotated apart and towards each other. This resulted in a collision zone having both compressional and extensional bed deformations along the fault plane. The breccia pipes pass upward along fault planes into zones with twisted beds and zigzag suture welding between adjacent blocks. Upper reaches of the collision zone between adjacent fault blocks were dominated by compressional deformation that resulted in a sinkhole bounded on one side by a fault plane. Further compression of a sinkholes between colliding blocks deformed and fragmented many into splintered and compartmentalized zones having mixed tectonic breccia and reconfigured beds with vertical alignments. These fault block collapse-induced collisions were often sufficiently cataclysmic to seismically trigger fluidization of the upper breccia pipe intervals and mobilize debris flows that spread across adjacent fault block surfaces. This model for mobilization of tectonic breccia is useful to interpret the morphogenesis of anomalously thick (>10 m) sedimentary breccia as a variation of debris flow dynamics across differentially subsided-collapsed fault blocks. It has been widely accepted that multiple parallel layers of 1-2 m thick sedimentary mudstone clast breccia resulted from reworked muddy inclined accretion surfaces on point bars and as 1-3 m thick channel lags in the fluvio-estuarine middle McMurray strata. Breccia deposits are also interpreted as channel bank collapses that disaggregated with down-channel transport. However, these origins are not adequate to explain overly thick breccia intervals up to 30 m accumulated within vertical zones less than 100 m across such that the breccia is not continuous laterally into beds penetrated by adjacent wells. Such vertically constrained aggradations are interpreted as a result of cataclysmic salt collapse-induced fault block rotations that mobilized upper intervals of the impinged breccia pipe complexes. In other areas, continuous erosion of exposed fault block surfaces sustained supplies of breccia transported into a narrow subsiding depocenters as over-thickened mudstone clast aggradations with restricted lateral continuity.