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Clastic Pipes: Proxies of High Water Tables and Strong Ground Motion, Jurassic Carmel Formation, Southern Utah

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Multiple soft sediment deformation features from bed-scale to basin-scale are well preserved within the Jurassic Carmel Formation of Southern Utah. Field mapping reveals thousands of small-scale clastic injectite pipes (10 cm to 10 m diameter, up to 20 m tall) in extremely high densities (up to 500+ pipes per 0.075 square kilometers). The pipes weather out in positive relief from the surrounding host strata of massive sandstone (sabkha) and crossbedded sands with minor conglomerate and shale (fluvial) deposits. The host rock shows both brittle and ductile deformation. Reverse, normal, and antithetical faulting is common with increased frequency, including ring faults, surrounding the pipes.

The pipes formed from liquefaction and subsequent fluidization induced by strong ground motion. Down-dropped, graben blocks and ring faults surrounding pipes indicate initial sediment volume increase during pipe emplacement followed by sediment volume decrease during dewatering. Complex crosscutting relationships indicate several injection events where some pipe events reached the surface as sand blows. Multiple ash layers provide excellent stratigraphic and temporal constraints for the pipe system with the host strata deposited between 166 and 164 Ma. Common volcanic fragments and rounded volcanic cobbles occur within sandstone and conglomerate beds, and pipes. Isolated volcanic clasts in massive sandstone indicate explosive volcanic events that could have been the exogenic trigger for earthquakes.

The distribution of pipes are roughly parallel to the Middle Jurassic paleoshoreline located in marginal environments between the shallow epicontinental Sundance Sea and continental dryland. At the vertical stratigraphic facies change from dominantly fluvial sediments to dominantly massive sabkha sediments, there is a 1-2 m-thick floodplain mudstone that was a likely seal for underlying, overpressurized sediments. The combination of loose porous sediment at a critical depth of water saturation made the system extremely susceptible to liquefaction. Fluid inclusions of carbonate nodules present on the pipe margins indicate salinity, temperature, and character of possible early diagenetic fluids before significant burial. These inclusions can reveal information about brines from point sources or fed via groundwater.

Overall, the combination of clastic pipes and their related soft deformation structures in the host rock provide proxies for the existence of high water table conditions within arid climate regimes and transitional paleoenvironments previously assumed to be devoid of significant amounts of water. The pipe distribution and evidence of multiple injectite events paralleling an ancient paleoshoreline provides basin-scale insights on repeated paleoseismicity and volcanism along the convergent boundary of the Cordilleran.