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Direct Effects of the Emplacement of Basaltic Lava Onto Sand, Considering Diagenesis of Potential Intra- and Sub-Lava Petroleum Reservoirs

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ABSTRACT

This work qualifies the amount of reservoir destruction caused during early diagenesis by the emplacement of basaltic lava flows onto unconsolidated sand (lava drowning). The effects described are direct in that they are caused by the emplacement of the lava flow rather than subsequently during burial by later sediments/lava, although by no means does diagenesis of such sediments cease after initial burial by lava. We use datasets from field outcrops where lava flows have drowned sedimentary systems: (1) The aeolian Twyfelfontein Formation sandstone drowned by the Lower Cretaceous Etendeka Flood Basalts, Namibia; (2) Miocene fluvial sediments drowned by the Miocene Columbia River Flood Basalts, USA and (3) Recent paralic sediments drowned by recent basaltic lava flows, Iceland. The study uses petrographic techniques, geochemistry, stable isotope geochemistry and XRD to reveal the diagenetic history of the rocks/sediment. In order to compare these different case studies a method was developed to determine the distance below the lava at which 'background porosity' had been regained.

Results show that porosity is normally reduced in sediment under lava flows, with porosity increasing downwards, away from the lava flow base. This reduction of porosity is usually linear out to the background porosity, where no lava-related effects are recognised. Porosity is rarely as low as 0 % at lava-sediment contacts and background porosity was always found to return by 4 m below even the thickest (~40 m) individual lava units. The nature of the diagenesis was found to be controlled by substrate sediment composition and palaeoenvironment (water availability); with increased compaction immediately below lava flows being common across all palaeoenvironments and substrate compositions. Petrographic relationships and stable isotopic data suggest the observed diagenesis here is early, and during the emplacement of the overlying lava flows. Increased compaction below lava flows was also found to be the single largest porosity reducing mechanism. The distance below a lava flow at which background sediment porosity returns was found to be proportional to lava flow thickness following a logarithmic relationship.

This work provides a useful tool during petroleum exploration for estimating the amount of sandstone porosity loss expected for a given lava flow thickness, as below each lava flow, porosity loss is linear out to the background porosity (background porosity being determined from regional databases during exploration). Overall the amount of porosity reduction is volumetrically minor and certainly orders of magnitude less than the other errors associated with prospect definition (e.g. GRV determination, OWC estimation). Hence during routine exploration, the direct porosity reducing effects of lava emplacement onto potential reservoir sediment can be encompassed within normal porosity ranges used for probabilistic volume assessments and do not pose a significant risk except where thin sands are prognosed.