Clay Laminations in Halite: Their Cause and Effect

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ABSTRACT

Flash floods entering hypersaline brine pools produce a stable density stratification, which prevents clays from forming turbidity currents. Instead, they spread out along interfaces in a thin blanket and settle slowly over wide areas, the settling velocity being a function of original pore spaces.

INTRODUCTION

Flash floods develop substantial force in semi-arid and arid terrains with discontinuous vegetation cover. They pick up an enormous amount of loose weathering products and deliver them to the lowest point in the topographic profile. If that lowest point is a body of water, a lake, a lagoon or a marginal sea, a mudflow is released into the water and cascades down the floor of that water body in the form of a turbidity current. Turbidity currents can develop only in freshwater bodies and in bodies of normal ocean water. In hypersaline brine pools the mud particles are prevented from directly falling through the water column by the density stratification in the brine.

The same rains that caused the flash floods also produced a low salinity layer on top of the brine surface. The low-salinity layer is separated from the brine by a sharp interface. Further microstratifications develop within the hypersaline brine either as advancing mixing fronts of previous dilutions of surface waters or as gravity separation of hydrated metal-chloride complexes.

Solar radiation crossing the interface is in part absorbed by the brine and, if reflected by the bottom, prevented from leaving the brine by strong refraction (Hudec and Sonnenfeld, 1974). Figure 1 simulates the bending and consequent entrapment of a solar ray reflected from bottom sediments by the stratification within the brine. The stratification is reasonably stable, if the density difference across the interface exceeds 15 g/liter in a brine with sulfate as the predominant anion and 11 g/liter in a chloride brine.

When the flash flood delivers its heterogeneous mixture of terrigenous materials, the coarser fraction falls through to the bottom and cannot be moved by bottom currents of relatively low energy. The flood waters spread out on the surface and the finer terrigenous fraction, composed mainly of clay minerals, sinks through the surface layer to the interface, where it spreads out in the fashion of a delta. Figure 2 shows the spearheading advance of a cloud of clay particles along the surface water/brine interface.

CLAY FLOCCULATION

When the clay minerals have exchanged a sufficient quantity of their hydrogen atoms for sodium and other alkali or alkali earth ions, they begin to flocculate and commence to descend through the hypersaline brine, being slowed at every level of microstratification (Figure 3). The process is slow and there is then enough time available for the clay particles to spread out either over the complete interface, or a very large portion of it, before commencing their descent. The descent is further delayed by any currents existing at the interface(s). In a lagoon on the island of Los Roques, Venezuelan Antilles, the authors observed an interface current of 2 to 3 cm/sec. The ability to stay in suspension for long periods of time gives rise to paper-thin clay laminations intercalated with evaporites, which can be basin-wide in extent.

The horizontal motion of the clay suspension forms concentric convection cells in the horizontal plane (Figure 4), as originally described by Benard (1901) and Dauzere (1912). These convection cells are a temporary phenomenon. After all clays have settled through the brine, the density stratification reestablishes itself, as was proven by laser experiments and by density measurements.

The rate of descent of the clay minerals depends on the concentration of the brine and on the composition of the clay mixture. Clays descend faster in a moderately concentrated brine than in residual bitterns enriched in potas-

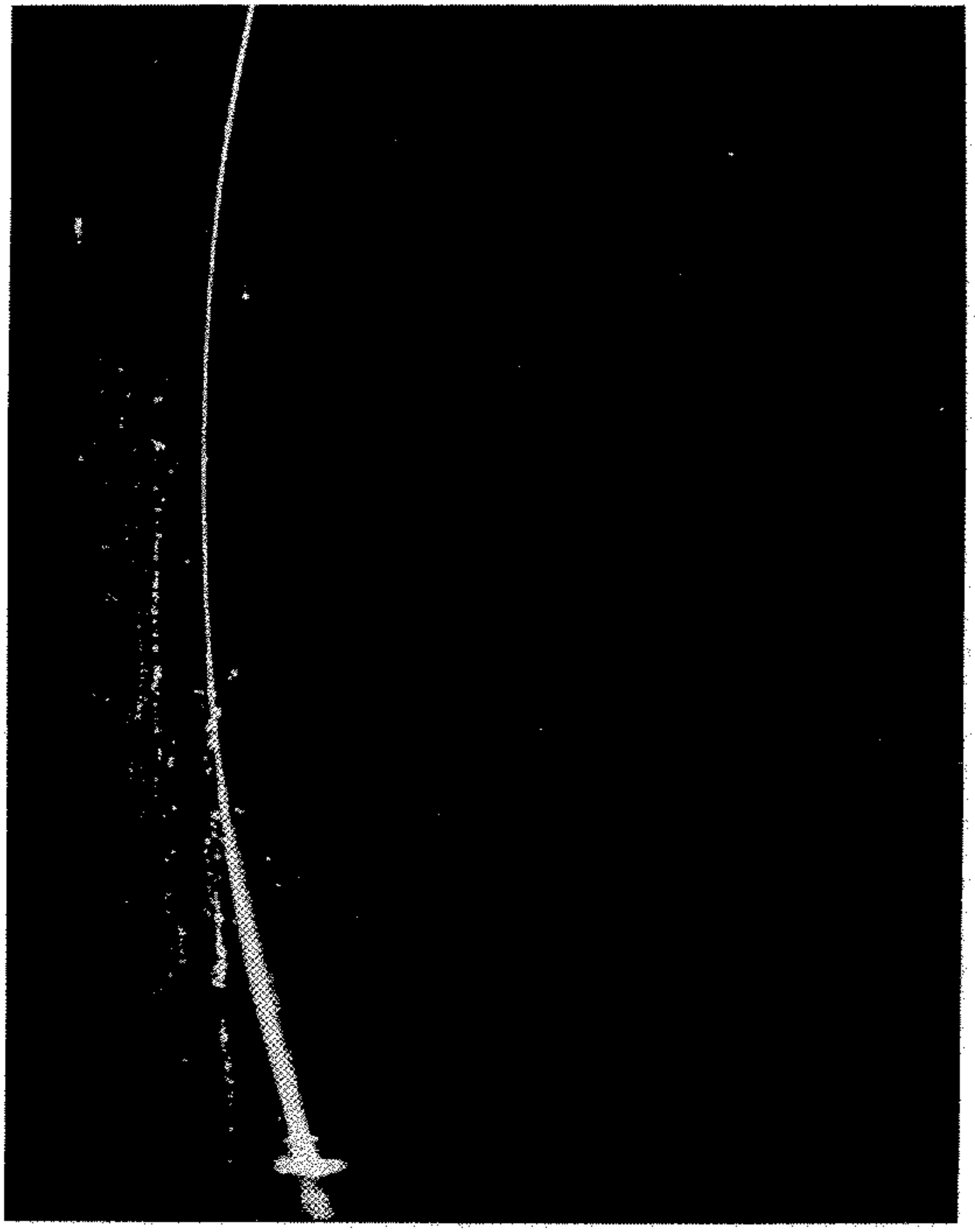

Figure 1. Path of a laser beam through a density stratified hypersaline brine simulating the bending and consequent entrapment of a solar ray reflected from bottom sediments.

Figure 2. Advancing clay slurry along the brine/surface water interface.

Figure 3. Clay descending through a density stratified brine is slowed at every microstratification surface.

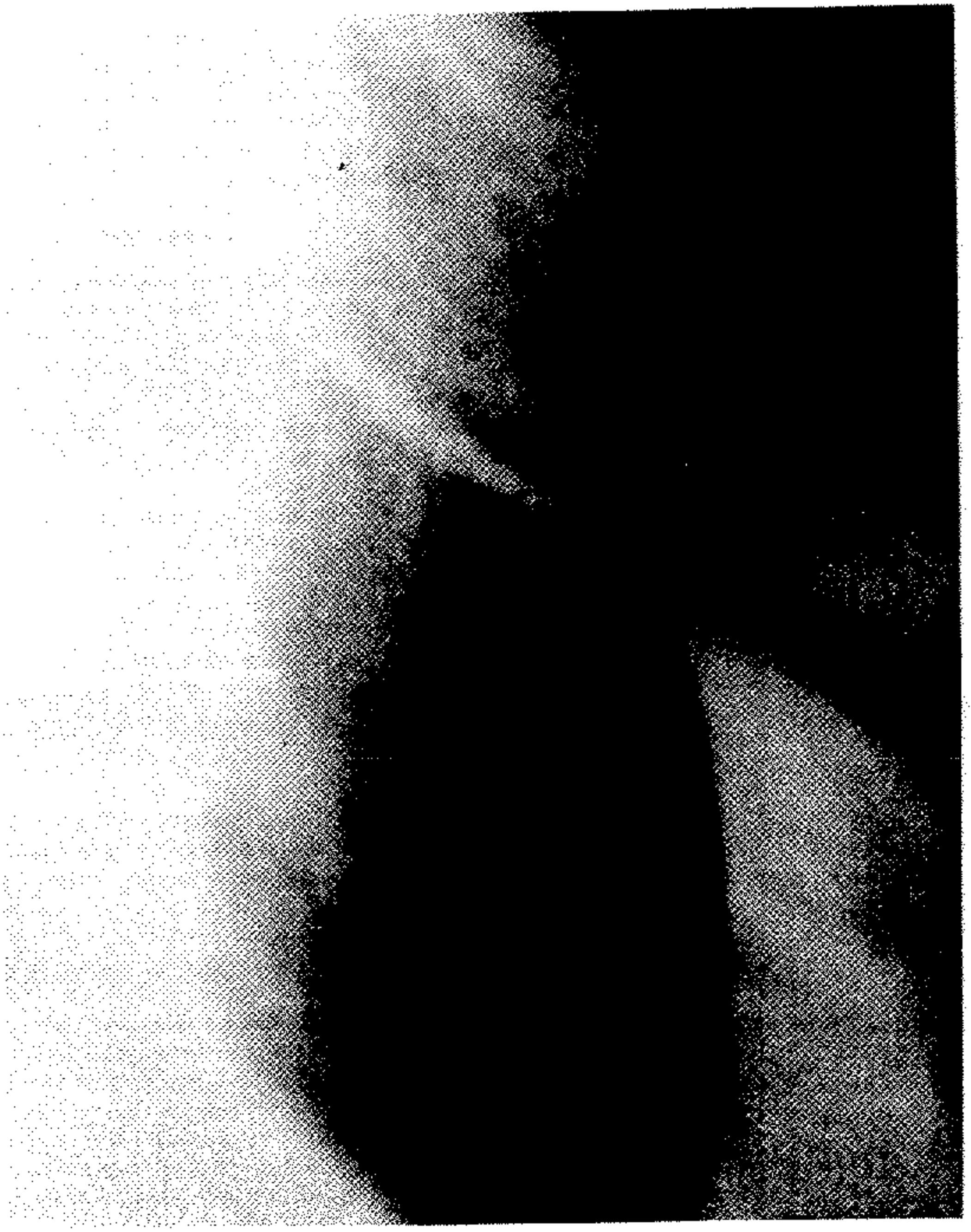

Figure 4. Horizontal Benard cells formed within the clay slurry.

sium and magnesium (Ramsay, 1876). That is because floccule size increases with rising solute content of the brine (Little-Gadow, 1974). The clay front spreads laterally, continually flocculating the clay. The floccules pass through the mixing zone into the hypersaline brines below. This explains why the settling of clays may proceed without any noticeable reduction in salinity of bottom brines. The clay sediment may even incorporate euhedral crystals derived from salting out due to clay/brine ion exchanges.

Members of the kaolin group descend faster than illite minerals, while montmorillonitic clays remain suspended at the interface for the longest period of time. They form the largest floccules, because originally they contained the largest inter-lamellar spacing. Mixtures of clay types produce settling patterns more closely resembling the faster flocculating member of the group. When the clay eventually settles on the bottom, it at first assumes a cardhouse pattern of high permeability that depends in its configuration on the available cations in the brine. This cardhouse pattern produced by flocculated clay wafers is particularly resistant to compaction in an evaporite sequence (Kulke, 1979), because the precipitated salt is dewatered and becomes impermeable before the brine can escape the pore spaces in the clay.

CONCLUSION

It can be concluded that flash floods do not produce turbidity currents of terrigenous material in hypersaline brines. The flood waters spread out along the brine surface; the clay particle suspension flows out as a delta at the interface between brine and low salinity water. Only the coarse clastics fall immediately to the bottom of the brine body, forming normal coarse clastic deltas. The feeble bottom currents in hypersaline brines are then not strong enough to move the coarser clastics out of the near-shore environment. The clays descend through the brine only after having spread out, producing a lamina of uniform thickness and wide areal correlatability. Turbidites composed of gypsarenites, and more rarely halite fragments, are known from many localities and represent submarine gravity flows from shelves to basin centre. These, however, have either no clay content, or only minor, pre-flocculated clay.

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