THE FUNCTION OF SALT FINGERS IN DEEP
BASIN EVAPORITE DEPOSITION

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$$\frac{\text{Scientific content}}{\text{Composition}} \quad \frac{A^-}{A} = 95$$

needs more reference support for the salt-finger section.

INTRODUCTION

When the phenomenon of salt fingers and their formation was brought to the attention of this student it occurred to me that they might play a role in the concentration of salts in deep ocean basins. If the salt fingers acted as a transport mechanism for hypersaline waters to the deep basins then such deep evaporite deposits as those seen in the Gulf of Mexico and the Mediterranean Sea might be more easily explained. A literature review was undertaken to support or destroy this hypothesis. Only the immediatly pertinent papers are discussed.

DISCUSSION

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Evaporite deposits have long been explained by the Salina model which is extensively explained in the paper by Schmaltz (1969). The model has four basic conditions which must be met for any evaporite deposition to occur. 1.) The climate must be hot and arid in order that the rate of evaporation will exceed the inflow of fresh water via precipitation or runoff. This condition must be met for the brine to form. 2.) The area must be in an enclosed embayment or a basin restricted in some manner. If the area were not restricted then mixing would destroy the effect of the first condition. 3.) There must be a source of salt (sea water inflow) for the basin waters to concentrate it into brine. 4.) There must be a place for the salt to be deposited. This last condition is most commonly dealt with by the supposition that the area (in the Salina model) is subsiding or the sea level is rising thereby lowering, **relatively**, the floor on which the salt is being deposited and making room for further deposition. This model is partly based on the observance of its occurrance (Phleyer, 1969) in several areas of the world. A shallow bay or tidal flat is periodically covered with sea water and then cutoff by falling tides or restricted so that the outflow of the brine is inhibited. The sea water is then evaporated leaving the salt bed. There follows a reflooding of the area and the cycle continues.

There are some problems with this model in explaining the occurrance of evaporites in areas that probably have never been close to the surface of the sea. The required arid climate is typically found between twenty and thirty degrees from the equator but deposits in Germany and Canada are inferred as climatological indicators of a varied climate in the past and therefore pose no real block to the acceptance of the Salina model. The supposition of subsidence is contradictory as observed deposition rates of 15 cm a year do not correspond to postulate subsidence rates (Schmaltz,1969). The thickness of the deposits can be as much as 600 meters or greater again in areas where a corresponding subsidence rate is doubtfull. Schmaltz also takes exception to the stratigraphy of the deep beds and those formed by the Salina model. The exposure of the Salina model incorporates wind blown sands and sediments not found in deep beds and does not exhibit the anoxic conditions necessary for the heavy organic layer found in deep beds. The most logical conclusion is that some evaporite deposits were formed beneath the sea and not by the total evapotation of the sea.

It was hypothesized that the salt fingers may play a role in transporting high slimity water formed at the surface of the sea to basins in the sea floor where their deposition was to occur.

Salt fingers form when warm saline water overlies cooler fresher water. The system is stable at first but ~~advective~~ diffusive cooling of the surface water tranforms the layers into saline water overlying fresher water of the same temperature. Thus the surface water becomes more dense than the underlying layer and at some point in time and space the surface water punches down into the lower layer by much the same mechanism as a salt diapir rising up from the sea floor. The "hole" acts as a drain allowing the denser water to flow beneath the underlying layer.

should discuss the fact that $D_t > D_s$ for molecular diffusion use reference since you haven't made the mechanism of salt-fingering clear

The hypothesis of this paper is that the upper layer of water could be concentrated and warmed by the evaporation typical of areas between twenty and thirty degrees from the equator. The area need not be restricted to river mouths. The evaporation of a normally stratified sea surface would then transform it into the required layers and, provided that mixing was not destructive, salt fingers would form. If the salinity in the surface water became great enough so that it bordered on precipitation then the cooling would trigger the fallout. The surface waters would approach forty degrees centigrade but when the finger reached the basin floor the temperature would be nearer to two or three degrees.

The CRC Handbook of Physical and Chemical Constants gives saturation points of 363 gm per Kg NaCl at 30 cent. and 357 gm per Kg. at 0 cent. These salinities are certainly beyond the realm of what is observed and therefore, unless an unknown mechanism for further concentration is active, the hypothesis must be rejected for present oceanic conditions. It may have applications in the deep basin model proposed by Scmalz (1969).

Schmaltz noted the inconsistances between deep deposits and the Salina model and proposed (1969) a deep basin model. All the conditions are met but whereas others inferred subsidence Schmaltz allowed a deep basin as the area for the deposition of the evaporite. He outlines a system that requires a deep basin with a shallow sill at the juncture of the oceanic waters. The evaporation removes water concentrating the solutes in brine. This heavy water then cycles to the floor of the basin where it is trapped by the sill. Since evaporation exceeds runoff and precipitaion there is a net inflow of oceanic water. As this water flows in it mixes with a portion of the trapped water increasing the salinity. Evaporation further increases salinity making it more dense than the water already trapped. This new water displaces the previously trapped water which mixes with the incoming water perpetuating the cycle. After the brine becomes so dense that it cannot be further displaced by the surface water the basin becomes anaerobic and reducing in chemical character. This allows the sediment layers not found in Salina formation which can not become anaerobic due to mixing of the very shallow waters. The surface layer now becomes more concentrated and gypsum begins to precipitate but dissolves as it enters the bottom water. Eventually the bottom water also becomes saturated whence deposition takes place. The same happens for halite and the other salts. The system continues until the basin is filled or climate changes or catastrophic teconics disrupt it.

In a model such as this the function of salt fingers in transporting hypersaline waters becomes much more plausible as mixing is minimal and the brine is becoming concentrated to the point where the cooling may trigger the precipitation.

In application to the problem of explaining the deposits of the Gulf of Mexico and the Mediterranean Sea Schmaltz's model is supported by other findings. The average depth of the Gulf of Mexico is approximately 2200 M. and the sills at the straights of Florida and the Yucatan are considerably less but cut by channels of 1000 and 2000 meters respectivly. Uchupi(1968) determined that these were shallower prior to the post Cretaceous period. His findings are based on fault-line scarps and the occurrence of reefs. The Gulf of Mexico would then have been much better isolated and more conducive to evaporite deposition prior to the post cretaceous period. Joides drilling operations in the Gulf confirmed that the Sigsbee Knolls are salt diapirs formed in the Jurassic or eary Cretaceous. Similarily the Mediterranean sill is now 320 meters and during low stands of seawater would have effectivly limited circulation. The area has been determined to have a negative water budget by Schott(1915,1928).

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