

# Salt Mirror and Petroleum Formation

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## ABSTRACT

*The genesis of mineral oil is described as a process in which a salt diapir is dissolved by surface water forming a brackish lake with the salt mirror of the salt diapir as the bottom. During the dissolution of the salt mirror, algae and other organisms are continuously living (assimilating solar energy) and dying near the surface of the brackish water lake. They sink as debris to the bottom of the lake where they are decomposed by anaerobic microbes to soluble organic compounds and  $H_2S$  originating from the gypsum in the diapir. The resulting solution sinks along the flanks of the diapir to great depths where by geothermal heating the organic compounds are decarboxylated and hydrogenated with the help of  $H_2S$ . The hydrocarbons formed collect in droplets which are lighter than the water of the aquifer. They rise in the supernatant aquifer and are trapped in suitable "structures" as "mineral oil." The carbon dioxides formed simultaneously facilitates the migration of the oil drops through karst formation in the "source rock."*

## INTRODUCTION

### Stratified saline aquifers

The peculiar flow patterns in saline aquifers have not been studied extensively by hydrologists. These aquifers occur frequently in arid zones and usually arise from evaporative concentration of the salts contained in rain-water. These salts originate from ocean water spray and do not have the same ion ratios as ocean water; surface tension impoverishes the salts differently when air bubbles burst on the ocean surface (Sugawara 1958, Bloch, *et al.* 1966, Bloch and Luecke, 1972 and Loewengart, 1962). Of quite another origin are the saline aquifers which contain salts leached by surface or groundwater from evaporite deposits. These evaporites originally crystallized from ocean water at different geological periods (Preul, 1968).

Both of these types of saline groundwater are of great interest. However we are dealing here only with those which originate from the dissolution of massive evaporite deposits which were forced up isostatically from a great depth in the form of salt diapirs perforating overlying rock. When these rising salt bodies are eventually covered by free or vadose fresh water bodies, they are dissolved from above, forming the so-called "salt mirrors." The mechanism of this dissolution from the top has been described and investigated in some detail, and M. Reiner demonstrated its very distinctive way of working which he called the "teapot effect." (Farkas, Litman and Bloch, 1951; Bloch *et al.*, 1952; Reiner, 1952).

When a salt body projects into fresh water or into a diluted salt solution, a saline stream is induced which runs down the flanks of the salt body. The stream curtains the surface against attack by adjacent fresh water as long as the flanks remain off the horizontal (Fig. 1). The saline streams emanating from the horizontal surfaces of the salt-body, the salt mirror, overflows its edge saturated with salt. The volume velocity is proportional to the length of the edge and to the difference of the specific weight of the stream and the specific weight of the dissolv-

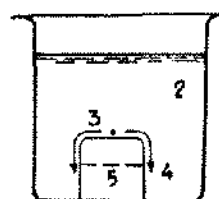


FIG 1a

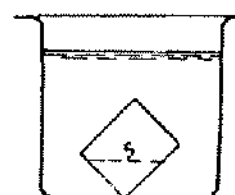


FIG 1b

**Figure 1.** Illustrates how a NaCl-crystal starts to dissolve in  $H_2O$  (2). A permanganate fragment (3) colours the path (4) of the saturated salt solution which protects the vertical faces of the NaCl-crystal. After several hours the crystal has been reduced to the height of the dotted line (5).



Figure 2.

ing solution. Essentially only horizontal surfaces are dissolved and are lowered parallel to themselves with a speed which depends on the length of their circumference and on the supply of dissolving water. In Figure 2 a piece of salt partly dissolved by water is shown after dissolution has practically stopped owing to the saturated brine level having reached the height of the "salt mirror" which it had formed.

The interface between the saturated salt solution is clearly visible and is seen to coincide with the height of the salt mirror. To demonstrate and determine the nature of the saline streams around dissolving salt bodies the experiment shown in Figure 3 was established.

The reservoir (1) is filled with sand (3) in which a salt block (2) is imbedded. A pipe (6) connects the reservoir (1) with the bottle (4) through stopper (5) that ends near the bottom of bottle (4). Reservoir (1) and bottle (4) are then filled with fresh water through an inlet (7). The salt block (3) now starts dissolving and the salt solution formed sinks into the bottle (4) where it accumulates as a concentrated salt solution layer (9). The fresh water stratum overlaying this brine layer (9) is slowly forced up through another pipe (8) back into reservoir (1) where it further dissolves the remainder of the salt block (2).

During this experiment the stratified brine (9) in the bottle (4) was heated artificially by a bunsen flame (10). Despite this heating of the stratified brine, even about 100°C, the fresh water or the brackish water overlaying the heated brine did not mix with the brine and remained cold.

#### Formation of mineral oil in a geothermal saline pool

This experiment was used to develop a hypothesis for the genesis of the Dead Sea as a sinkhole (Bloch and Picard, 1970). This publication describes the earlier experiments with dissolving salt; and geological data combined with the results of these experiments show how the salts

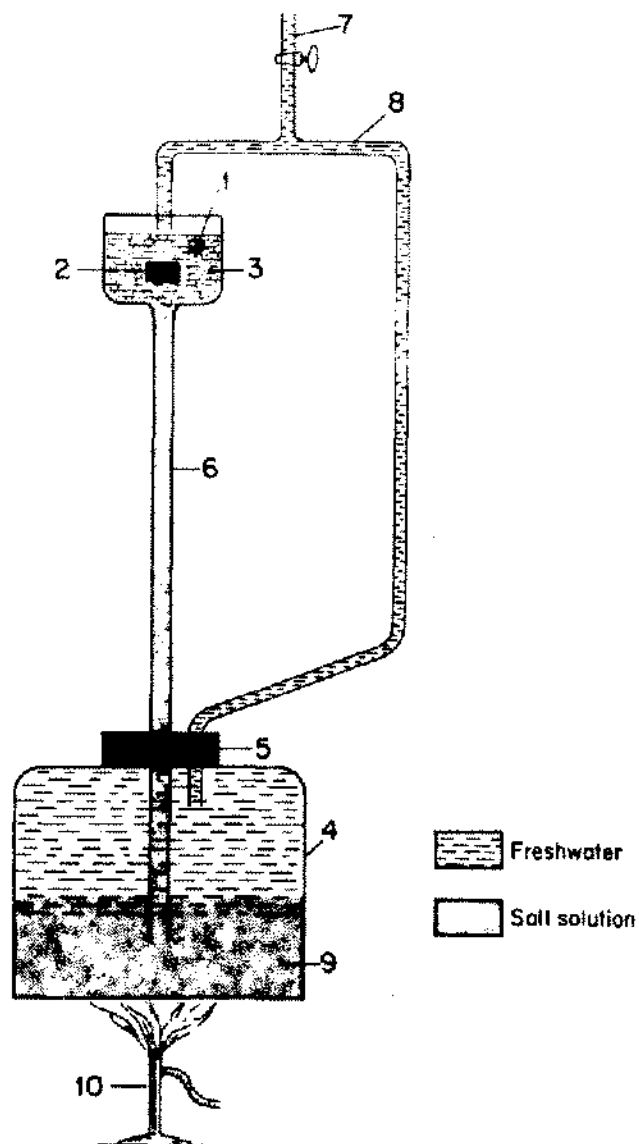


Figure 3.

of a diapir are carried to a great depth by the sinking of saturated salt brine along the flanks of the diapir, thus protecting its flanks against the attack of adjacent fresh water aquifers (Fig. 4). According to this hypothesis the bottom of the present Dead Sea is a salt mirror.

In the same paper (Bloch and Picard, 1970) it was suggested that the salt mirror formation might be connected with the formation of mineral oil. Such oil is formed under the set circumstances from brackish water flora and fauna living in the fresh or brackish water body (lake) above a dissolving salt mirror. (Engler, 1906; Radziszewski, 1878).

It may be assumed that in a brackish lake algae and related organisms create organic matter through photo-

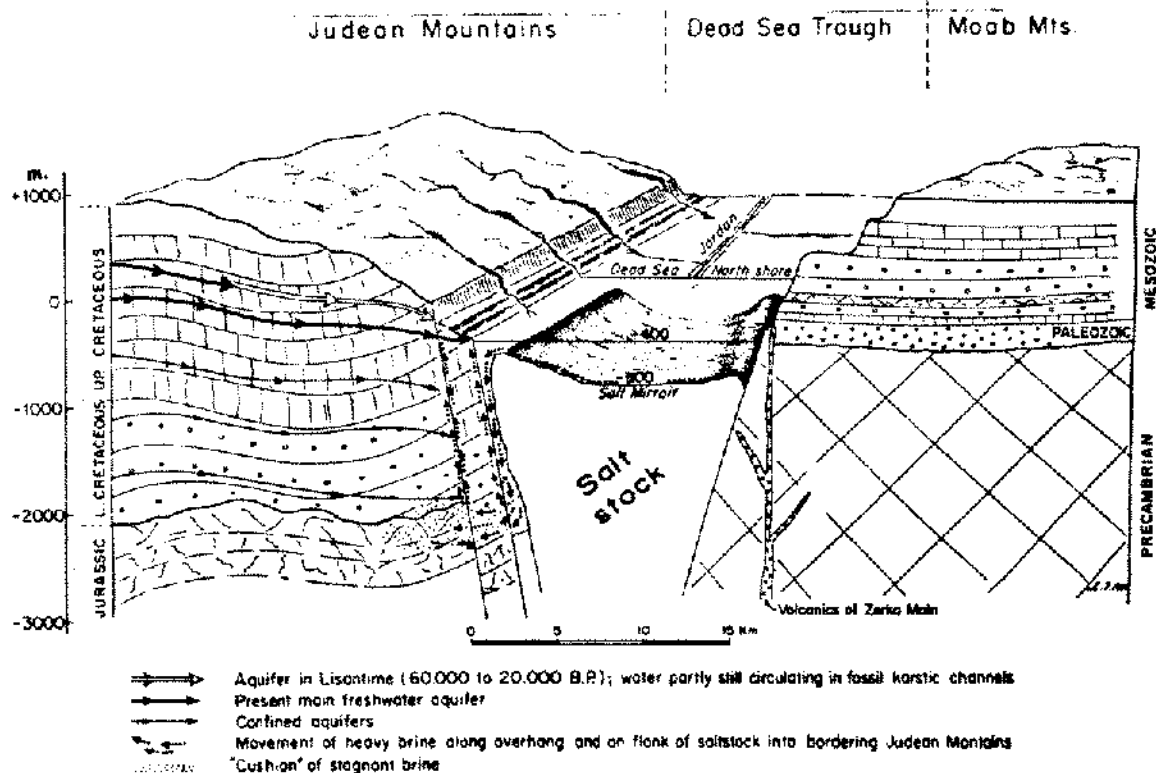


Figure 4. Block diagram of northern Dead Sea trough with assumed salt stock below "sinkhole" and model of heavy brine and freshwater fluid mechanism.

synthesis at a rate of about one gram carbon per square meter per day (Hirosh Tamiya 1955). If the bottom of the brackish lake is a salt mirror this organic matter sinks, as debris, into the concentrated salt solution which has formed on the surface of the dissolving salt mirror. There the organic debris is decomposed by sulphate-(gypsum)-reducing anaerobic micro-organisms (Müller and Schwarz, 1949). This solution consists of  $H_2S$ , consisting of aliphatic and aromatic acids, aldehydes, amines etc. in the stagnant salt brine covering the salt mirror. This brine with its load of dissolved organic material and  $H_2S$  continuously overflows the edge of the salt mirror to a great depth. A salt mirror underlying a brackish water lake of  $300 \text{ km}^2$  would release to a great depth some  $100 \text{ km}^3$  of saturated salt brine in less than  $10^4$  years, carrying  $10^8$  tons of carbon compounds to a depth of thousands of meters. When this brine with  $\sim 1\text{g/l}$  organic matter displaces fresh water in the surrounding aquifers, springs replenish the brackish water lake and a stratified deep salt brine aquifer underlies the remaining fresh water. This brine, lying at a depth of several thousand meters and loaded with dissolved  $H_2S$  and organic acids etc., is now heated well above  $100^\circ\text{C}$  by geothermal energy. However it cannot rise, because even when hot it still remains much heavier than the overlying colder fresh water (Fig. 3).

The heating of this stratified "geothermal pool" starts decomposing the dissolved organic matter. Acids lose their carboxylic groups,  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ , and hydrocarbons are formed. The  $\text{H}_2\text{S}$  present hydrogenizes double bonds and replaces OH groups. The resulting  $\text{SO}_4$  replaces part of the limestone usually present above diapir forming salt series and gypsum. The  $\text{CO}_2$  now formed combines with the water to make the limestone porous, thus forming a Ca-bicarbonate solution. In this way the brine makes its own "karst" formation where the hydrocarbons are generated as an "organic liquid" insoluble in salt water. It collects in the form of droplets which rise in the salt water and being so light, even in fresh water. If during their progress upwards in the aquifer, these oil drops meet an obstructing "structure" they collect and form a hydrocarbon reservoir, always underlayed by water "contaminated" with salt, which was carried up with the rising drops.

## CONCLUSION

The hypothesis of combined solar energy and geothermal action for the formation of mineral oil is consistent with the fact that oil is always found in association with salt water, that the chemical constitution of all mineral

oils is consistent with an origin from plant and animal life of halophilic character (Welte, 1965; Treibs, 1936) and that the oil underwent thermal decomposition under pressure and under reducing conditions at some 150°C. (Galimow, Ilev and Kuznetsova, 1970). Finally, the frequent occurrence of "circulation loss" when drilling for oil caused by karst at a great depth is comprehensible as well as the formation of gypsum and sulphur differing in genesis and age from the so-called source rock gypsum. The migration of organic matter dissolved in saltbrine to a great depth is plausible; the geothermic decarboxylation and hydrogenation under pressure and at high temperature is understandable. The generation of insoluble hydrocarbons in saltwater explains the easy upward migration of oil drops in an aquifer and their eventual accumulation in suitable structures.

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