taught him to believe in both evolution and the Bible;" ah, yes, but if his mind is developed so that he understands logic as a college student should, he will see that he can't believe both because they are contradictory; and he will give up one of them.

Listen to a wise modern scientist, A. E. Wilder Smith:[5]

> A great difficulty in dealing with this and allied subjects is the fact that the average layman is not presented with a coherent account of new discoveries. These new discoveries are beginning to resurrect some of the most ancient beliefs of mankind with respect to First Causes. For years now, perhaps for almost one hundred, the ancient beliefs have lain buried for fear of the scientific materialist. Now, as we shall see in later chapters, the mummies are being brought to life. It is as if wheat stored at the time of the ancient Pharaohs is suddenly beginning to germinate in the light and warmth of scientific progress. But students still continue to come to college and universities where they lose faith in anything divine because the newest developments are often not interpreted and made relevant to them.

Understanding the Bible

This article is written to Christians; remember that we believe the Bible. A liberal minister said in my presence that the first three chapters of Genesis are written in poetry. Pfeiffer, however, in his commentary on Genesis,[6] says otherwise. He mentions what he calls "The Song of the Sword" (Gen, 4:23) with his statement, "This is the first bit of poetry quoted in the Bible." This theologian does not agree with the minister, who seemingly did not want to believe the Genesis account, which sounds to us like plain prose, just as this theologian indicates. And wherever the New Testament mentions the subject it states clearly that creation was the personal work of God.

If you theistic evolutionists will come with your friends where you belong you can have the assurance that you are helping a great and succeeding cause. You can find out from the *Quarterly* how to join, and your part of the expense will be small compared with the good we are doing in many countries, including New Zealand, the farthest country in the world.

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A PROPOSAL FOR THE COMPARISON OF EVAPORITE FORMATION MODELS WITHIN A CREATIONIST FRAMEWORK

J. R. STRATE* AND JOHN M. CHRISTENSEN**

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The existence of evaporite deposits is one of the many unsatisfactorily explained phenomena in earth science. This discussion reviews various models of evaporite formation and their anomalies. Also, the authors propose a means of testing the uniformitarian assumption often associated with evaporite formation models. This is of interest to creationists in that uniformitarian models require more time for evaporite formation than is allowed by Biblical chronology.

Evaporite deposits are beds of salts often thought to be formed by evaporation of brines. Geologists observe this in regions known as sabkhas. These formations occur in arid regions adjacent to the sea, where sea water can seep under a sandy margin near sea level which is underlain by non-porous bedrock. Salt beds several inches thick form by the sabkha process. Sabkhas differ from evaporites in that according to most evaporite formation models the salts are deposited from the sea water as a precipitate. These evaporite beds often contain very pure salts, in contrast to sabkha deposits. They may be hundreds of feet thick, cover hundreds of square miles, and are often found thousands of feet underground.

Scientists understand sabkha formations fairly well, but the origins of the great salt beds remain puzzling. The uniformitarian belief is generally that by some means a brine evaporated over a period of millions of years depositing a precipitate. This implies that the salt at the top of an evaporite may be millions of years younger than the salt at the bottom of a bed.

Origin of Evaporites

Evaporite deposits have been known since antiquity, especially in arid regions where salt was used as a form of exchange. Only within the last 100 years have salt mines been explored with particular regard to their

*Mr. J.R. Strate is engaged in graduate studies in geochemistry.

**Mr. John M. Christensen's address is 330 Apache, Fort Morgan, Colorado 80701

origin. Friedrich von Alberti[1] in 1852 formulated what may be called the first scientific theory of evaporite production. He basically implied that evaporites were formed from deposition of volcanic "vapors" (magmatic fluids) arising from the depths of the earth. Although this is crude as stated, he had only a rudimentary chemical foundation on which to base his theory; and in this light his model appears quite interesting (expanded discussion *infra*).

In 1854 Bischof used the idea of a marine origin from evaporation of sea water in isolated basins behind a bar in which the sea remained after periods of high tides. Ochsenius, in his 1877 studies of the present-day lagoon at Kara-Bogaz-Gol on the eastern side of the Caspian Sea, was led to modify Bischof's original bar model. His model differed from Bischof's in that it allowed for an open outlet to the sea, brine filling the basin to the level of the bar. This would allow for continuous deposition of salt precipitates until the basin filled.

These models seem faulty in the light of the fossil record. This speculation (evaporating sea water) inherently implies that the salts would contain an abundance of marine fossils. Also, the salts would occur in layers whose chemical composition would follow the order determined by Usiglio[2] in 1849. These predictions do not match the data from the salt beds. The natural salt sequence only rarely matches the Usiglio sequence, and the salts rarely contain fossils; furthermore those fossils that do exist are exclusively non-marine.

Walther in 1900 proposed a "desert theory" in an attempt to explain these anomalies. He used a model in which the salts were deposited in a land-locked basin from evaporating brines formed by meteoric water containing dissolved minerals. However geologists have difficulty explaining the origin of the vast quantities of brines necessary to accomplish this process on the scale required by many large evaporite deposits. Furthermore, the lack of auxiliary sedimentary "sludge" in the evaporites argues against this model. Hsu[3] has recently resurrected this idea. He attempts to explain the recent DSDP (Deep Sea Drilling Project) discoveries of evaporites under the Western Mediterranean Sea. These authors maintain otherwise, since the aolian clay, the stromatolite formations, and the marine deposits which are found there more closely correspond with the conditions associated with sabkha formation[4] rather than evaporite formation.

Branson in 1920 realized that the bar hypothesis (any model involving an isolated lagoon) would not explain the frequently observed almost mono-mineralic evaporite sequences. The model he proposed consists of a series of evaporating bodies of sea water such that a single salt precipitates within each body. The least soluble salts precipitate in the first basins, and the brine flowing from one basin to another becomes preconcentrated with the next constituent. However, the small geologic probability of this occuring, and the fact that no examples of the formations suggested are known to exist either presently or in the geologic record, present difficulties for the model.

An excellent modification of the bar theory was made by R. King in 1947, in attempting to explain the thick, nearly pure anhydrite Castile Formation of Texas-New Mexico. He attempts to explain how the brine in an isolated basin could be kept continually enriched in calcium without precipitating the sodium. The only problem in the scenario is that there is no physico-chemical reason for the brine to remain saturated with respect to calcium and undersaturated with respect to sodium. (It relies on chance.) The model involved the notion of a basin that is refluxed with sea water, so that the denser sodium-enriched brine flows back to the sea. However, the authors point out that tidal action most certainly would interrupt this process, and this was never taken into consideration in the model.

Omer Raup[5] in 1970 published another possible mechanism for evaporite production. This model rests upon the fact that a precipitate may spontaneously be produced by mixing different solutions of different concentration of salts. That is, the combination of two (or more) solutions may result in a precipitation of one of the constituents even though each individual solution may be undersaturated with respect to a certain ionic pair. This mechanism interests creationists in particular since it does not require millions of years for the evaporation of vast quantities of water. Furthermore it could be Biblically feasible, having taken place according to the account in Genesis 7:11 (NASB) " . . . on the same day all the fountains of the great deep burst open . . . ".

Raup's model is particularly attractive in regard to the origin of sylvite (KCl) since it can be deposited directly through brine mixing. Previous to this the origin of sylvite deposits was considered to be not from primary deposition but from a secondary alteration product of the original mineral carnallite ($KMgCl_3 \cdot 6H_2O$). It was thought that the carnallite was then weathered by ground water to produce the sylvite. The reason for this is because sylvite would not have been produced through mere evaporation of sea water with increasing potassium concentration[6].

It seems that many authors have tried to formulate a universal mode of evaporite production. However, after observing the range of evaporite deposits presently known, one might assume that a suite of models may be required to explain them. The authors point out that with slight modification von Alberti's model could be quite feasible. In this model the brine has a magmatic origin and may be modified chemically and/or physically (by changes in temperature and pressure which affect the solubility and ionic activity of its solutes) as it travels through the host rock. The brine at some different pressure and temperature cannot hold its solute any longer; consequently some constituents precipitate. Note well that this may happen at the earth's surface, but by no means is it limited to this, as it may precipitate somewhere below the surface. This model places few limitations on the brine. It may still enter into further host rock reactions or may enter another brine pool to participate in a reaction suggested by Raup. This mechanism, too, may be reconciled with the Biblical account of Noah's flood, as far as the fountains of the deep and the time required for deposition are concerned.

Dating Evaporites

On the basis of time, all the evaporite models mentioned may be categorized into one of two types, those which demand a long amount of time (hundreds of millions of years) and those which require a geologically short period of time (thousands of years or less). There does not seem to be any gray area involved. Therefore a tremendous insight may be gained by finding how long it took to form a deposit. This can be done by comparing the age of the salt on top with the age of the salt on bottom (see Figure 1.).

Dating evaporites presents a serious problem. The situation calls for the use of a radioactive dating method. However, the only radioactive element available in evaporites in sufficient quantities for dating is potassium, as found in sylvite (KCl) deposits. Before Raup developed his model there was no possibility of using potassium to date an evaporite, since they were not thought to be original deposits. The dates obtained would reflect only the last time of alteration rather than the actual time of original deposition. Since Raup has shown that sylvite can be a primary deposit, the age of a sample dated radiometrically would then correspond to the time of formation rather than to the age of last chemical alteration[7].

Potassium decays through beta decay to produce a Ca-40 daughter and through electron capture to produce the Ar-40 daughter. At the present time the only widely used dating method using potassium is the K-Ar method. It fails here due to (1) the porous nature of the salt allowing atmospheric contamination of Ar-40, (2) the mobility of radiogenic argon and subsequent leakage. However, as noted by Strate[8], Ca-40 is a non-volatile daughter product and should not be lost during a deformation process. Therefore a K-40—Ca-40 dating method appears to be the only alternative available at the present time. Strate further suggests that the present status of K-40—Ca-40 dating may be improved by (1) the use of a Wetherill-like Concordia diagram[9,10], and (2) measuring the K-41/K-39 ratio in the sample when evidence of possible K-isotope fractionation is present, in order to calculate the actual K-40 content of the sample.

Note that it may be difficult to obtain a true date for the age of the deposit, but also note that it is not necessary to date the salt in absolute terms. One does not need to know the true age of the salt to test whether or not deposition occurred over a long period of time. The essential issue is how the age of the "older" salt compares with the "younger" salt.

Conclusions

The various models rely on either the slow evaporation of water (over millions of years) or the rapid change in chemical potential of an ionic species via brine mixing or changes in temperature and pressure. The authors propose a method of dating the time of deposition of evaporites using K-40—Ca-40 method to date layers of the lowest deposits and successively higher layers (the distance between layers depending on the time interval and precision of the age determination) in order to determine if the brine-mixing

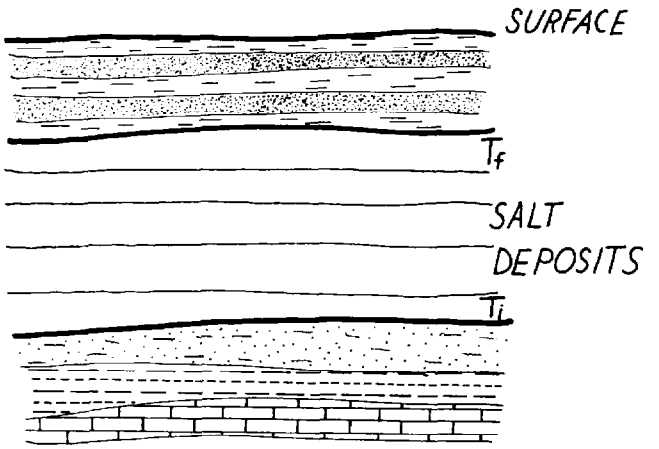

Figure 1. This diagram illustrates a typical evaporite deposit. If it took millions of years to form the deposit then the difference in the inital and final time of deposition (T_i-T_f) should be large. If the deposit was laid down quickly, then (T_i-T_f) would be small.

hypothesis of evaporite formation of Raup is correct. The implications are obvious. If a creationist's hypothesis is correct, then one should find a shorter time for the deposition of the evaporite bed as compared to the slow evaporation model.

The major North American deposits occur in three locations—Moab, Utah, the "age" of which is Mesozoic; the Carlsbad formation of Permian "age"; and the Saskatchewan formation of Devonian "age". There is also a sylvite deposit in the Soviet Union known as the Tonensk deposit along the Dnieper-Donets basins[11]. Thus, there are a number of samples which could be used to evaluate the rate of formation of sylvite evaporite deposits.

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[4]Sabkhas are rarely deep; there is frequently an algal sludge found near the margins (often associated with stromatolite forming organisms), and frequently, heavy metal sulfides are found underneath them. In addition, a variety of minerals are deposited: *viz.* anhydrite, calcite, halite and celestite ($SrSO_4$). See: Renfro, A. R., 1974. Genesis of evaporite-associated stratiform metalliferous deposits—a sabkha process, *Economic Geology* 69 (1):33-45.

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