

## The Evaporite Deposits of Saltville, Virginia

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### Abstract

Suggestions by various authors for the origin of evaporite deposits in the Saltville, Virginia region are reviewed. Past tectonic activity and its effects on the evaporites are discussed. The geologic setting of the area is noted, and the mining and man-

ufacturing history in Smyth and Washington counties in relation to the evaporite deposits is briefly described. A preliminary young earth-Flood model for evaporite formation and subsequent tectonism is presented.

### Introduction

As you drive into the small, picturesque town of Saltville in southwestern Virginia you are greeted by the sign (Figure 1), Welcome to Scenic Saltville: Salt Capital of the Confederacy. Toward the end of the War Between the States, the facilities in this Smyth County town (Figure 2) produced most of the salt consumed by the Confederacy. Approximately 200 million pounds of salt were produced in Saltville during 1864 (Whisonant, 1996, p. 21). The salt was removed from wells in the Saltville Valley which is underlain by the Mississippian Maccrady Formation containing red, green and gray shales, siltstone, limestone, dolostone, and evaporite deposits (halite [NaCl], anhydrite [CaSO<sub>4</sub>] and gypsum [CaSO<sub>4</sub>·2H<sub>2</sub>O]). The various suggested mechanisms of formation of the evaporites will be presented including an origin of the minerals based on a Flood, young-earth model.

### Salt and Gypsum Production in Saltville Valley: History and Aftermath

In the colonial era, around the 1750s, Charles Campbell obtained a patent for the land containing most of the saline ponds and springs in the valley from King George II. After the death of Campbell, the grant went to his only son, William, who, during the Revolution, commanded Colonial forces at Kings Mountain and won the battle against Loyalists led by Major Patrick Ferguson. Many of the men who fought with Campbell were from southwest Virginia and participated in the overmountain march to Kings Mountain. It is ironic that these men are referred to as Patriots, whereas less than 100 years later, the Southern men



Figure 1. Sign at town limits of Saltville, Virginia.

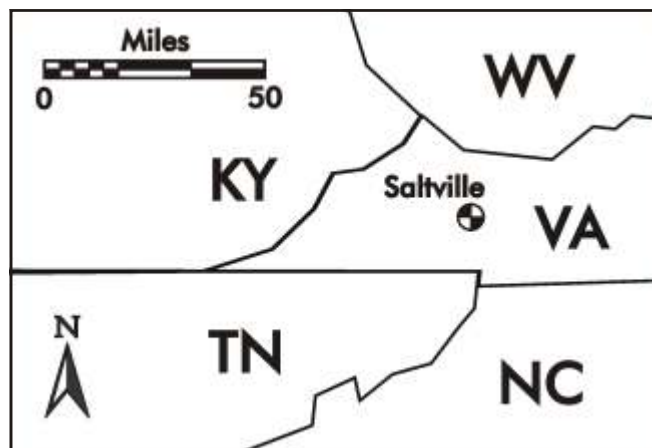


Figure 2. Location of Saltville in southwestern Virginia.

who attempted to defend their homeland are called Rebels. It depends on who wins the war!

The first known commercial development of salt was initiated in 1782 by Arthur Campbell, a cousin of William.

These early salt works of the late 1700s consisted of wells from which the brine was drawn, furnaces in open sheds in which saline waters were boiled in [8

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Figure 3. Replica of salt furnaces with kettles in which brine solutions were evaporated, Saltville, Virginia.

to 12-gallon] kettles, and salt houses where salt was stored... (Whisonant, 1996, p. 25). [Brackets added.] William King, who owned land adjacent to the Campbells, dug a mine shaft 200 feet downward into the Maccrady which almost filled with water. Therefore, he produced salt by the well and furnace method also. King was obtaining 200 bushels of salt per day by 1800.

Watson (1909, p. 119) claimed that the earliest borings for salt in the valley "...were in the old swampy lake-covered area near the present site of the town of Saltville." In 1840, a mine shaft 210 feet deep struck a bed of rock salt. But the mining of salt was never attempted, the mineral was always recovered from the salt brines in the wells. Reproductions of the salt furnaces with kettles and walking beam brine pumps to pump the saline solution to the surface can be seen at a Park located along Route 91 near the southern town limit of Saltville (Figures 3 and 4). The importance of Saltville during the War for Southern Independence and the battles fought over control of the town are covered in the excellent article by Whisonant (1996) along with a discussion of the geology of the area.

Two of the major salt operations were sold to the Mathieson Alkali Works which was chartered in 1892 and began salt production at Saltville in 1895 (Sharpe, 1985, p. 42; Craig, 1973, p. 7). The company continued to mine salt in the "old well field" until around 1930 (the deepest well being 2380 feet) when a high pressure well field was placed in operation with wells over 4000 feet in depth (Cooper, 1966, p. 28). By 1906, Mathieson had ceased salt manufacture and concentrated on producing salt by-products (Whisonant, 1996, p. 28). According to Cooper (1966, pp. 28, 29):

The Mathieson Chemical Corporation merged with Olin Industries in 1954. Olin Mathieson produces gaseous and liquid chlorine, soda ash, technical carbonate, and ammonia soda by processing brine. Limestone mined in Rich Valley is transported to Saltville by aerial tram [Figure 5] and is cal-

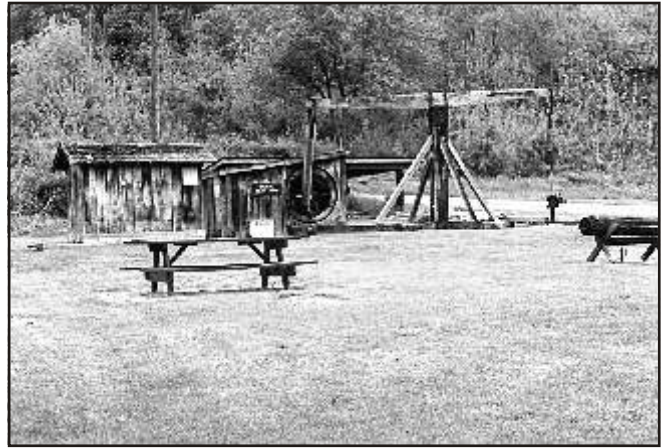


Figure 4. Replica of walking beam brine pump which was used to draw brine solutions from below the ground, Saltville, Virginia.



Figure 5. A portion of the former aerial tram can be seen beyond the post office in Saltville, Virginia.

culated to lime which is used in production of alkali. The carbon dioxide derived from calcination is recovered and processed into liquid carbon dioxide and Dry Ice. Hydrazine is also produced at Saltville. [Brackets added.]

All manufacturing and brine production ceased in Saltville in the early 1970s. Salty ponds still dot the floor of the valley (Figure 6). The movement of salt to the surface "...created the only salt marsh habitat in the western area of Virginia" (Ogle, 1999, p. 2). About 20 percent of the valley is covered with standing water (McDonald, 2000, p. 10).

Gypsum was found in the Maccrady and mined near Plasterco (Figure 7) as early as 1815 (Cooper, 1966, p. 29). The Buena Vista Plaster Co. operated mines, quarries and a calcining plant in Plasterco in the late 1800s to the early 1900s. The United States Gypsum Co. leased the Buena Vista facilities in 1909, and purchased them in the 1920s (Sharpe, 1985, p. 41). "The No. 6 mine [at Plasterco] was operated from 1911 to 1979 and was the





Figure 6. Some of the many salt ponds that dot the landscape in Saltville, Virginia, creating a salt marsh environment. Note highlands in the background.

deepest gypsum mine in the world” (Sharpe, 1985, p. 41) at that time [Brackets added]. At first during the 1800s, gypsum was sold strictly for agricultural purposes, then later for wallboard products also. Several mining operations for gypsum developed northeast of Saltville and the last mining of the mineral occurred at Locust Cove (Figure 7). All mines and wallboard plants are not now in operation. It bears mentioning that all the known salt deposits were located “in the immediate vicinity of Saltville” (Cooper, 1966, p. 24), whereas gypsum and anhydrite deposits were found from “...a few miles southwest of Plasterco northeast to Locust Cove” (Cooper, p. 27). Major modern mining of gypsum and anhydrite was accomplished at Plasterco and Locust Cove. Salt extraction was possible only at Saltville.

The Environmental Protection Agency presently is overseeing a Superfund Site Clean-Up operation around Saltville. The site description is as follows:

The Saltville Waste Disposal Ponds site in Smyth and Washington Counties, Virginia ...is a 125 acre site... The site consists of the Former Chlorine Plant Site (FCPS), two large waste impoundments, and areas to which contamination has migrated including the North Fork of the Holston River. The Saltville facility was in operation from 1895 to 1972. Several different waste streams were generated over that period of time. The primary contaminant of concern is mercury, which was in a waste product generated from the Chlorine Plant which operated from the early 1950s to 1972. Mercury contamination at the site has been found to threaten fish and other aquatic organisms in the River and presents a risk to those who may come in direct contact with the disposed waste or eat fish caught in the River. Mercury has contaminated the two waste ponds, the FCPS area and an undetermined length of the River (EPA, 2002).

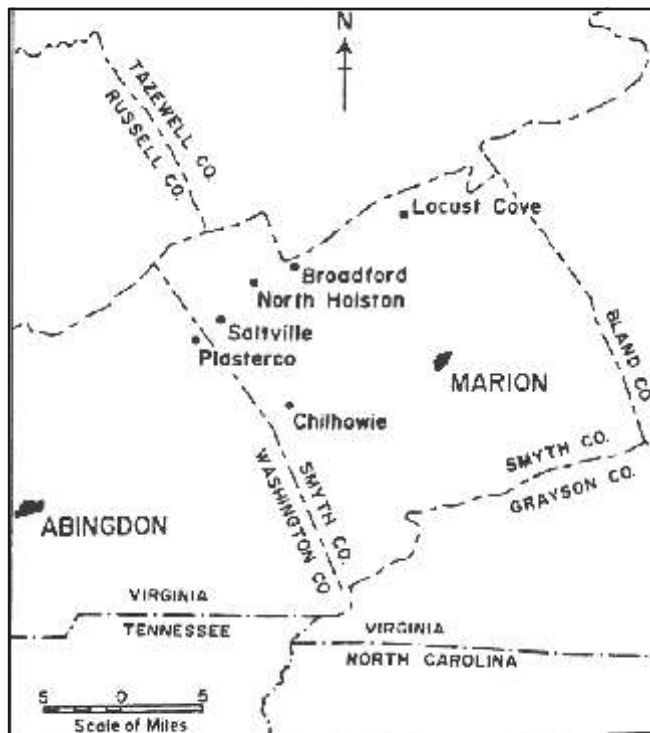


Figure 7. Location of the former evaporite mining and manufacturing facilities in Smyth and Washington Counties, Virginia (after Nelson, 1973, p. 540). Marion and Abingdon are county seats of Smyth and Washington Counties, respectively.

## Geologic Setting

Saltville, located in northwestern Smyth County in the narrow Saltville Valley near the Washington County line, is situated within the Valley and Ridge Province of the Southern Appalachians. As stated earlier, the valley is underlain by the Maccrady Formation. Overlying the Maccrady is the Little Valley Formation, whereas the Price Formation underlies the Maccrady (Figure 8). The floor of the valley is at 1740 ft. above sea level and is approximately 8000 ft. in length and 2750 ft. at its maximum width. The valley is surrounded by peaks and knobs ranging from 300 to 600 ft. above the valley floor (Figure 9). A break in the heights occurs at the northern end of the valley at Saltville Gap (McDonald, 2000, p. 10; McDonald and Bartlett, 1983, p. 454).

The evaporites were formed in the Plasterco-Saltville-Locust Cove region of Smyth and Washington Counties (Figure 7). This area is “...in the Greendale syncline... which is truncated on the southeast, overturned side by the Saltville Fault which thrusts Cambrian onto Mississippian strata” (Warne, 1990, p. 72). This overturned southeastern limb of the syncline lying in contact with the Saltville thrust is where most of the evaporite deposits are found (Nelson, 1973, p. 539). The Greendale syncline is consid-

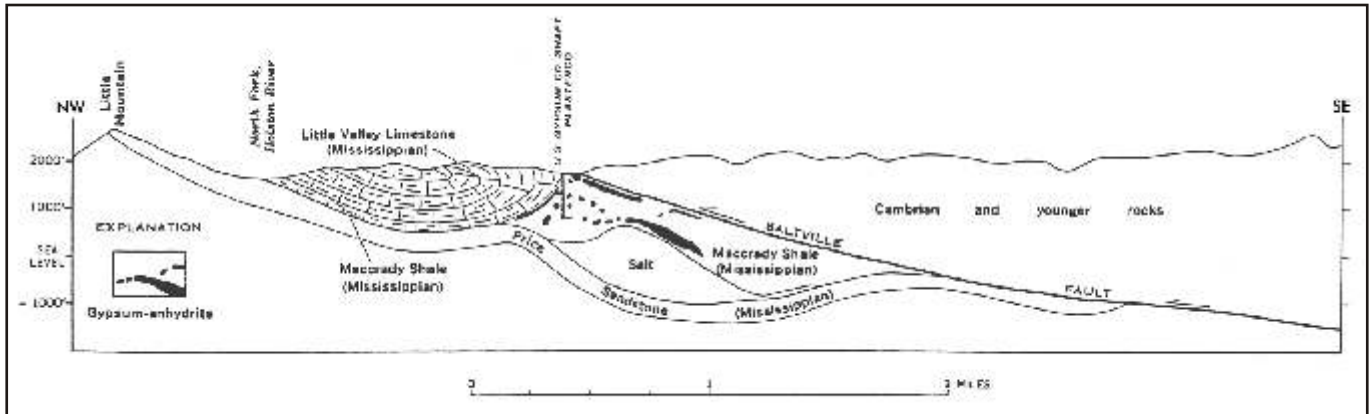


Figure 8. A geologic cross section of the evaporite deposits between Plasterco and Saltville (after Withington, 1965, p. 38).

ered important because it contains the youngest formations, the Mississippian strata (according to the geologic timetable), "...occurring in the middle of the Valley between the Blue Ridge and Appalachian Plateaus" (Butts, 1973, p. 457).

The Saltville Fault has a strike length of 430 miles from northern Alabama to southwestern Virginia (House and Gray, 1982, p. 833) and stratigraphic displacement of over 16,000 feet (Sharpe, 1985, p. 43). It is considered "...the best example of large-scale footwall folds at the end of a major Appalachian thrust..." along its trace in southwestern Virginia (Milici, 1970, p. 136). It is conjectured that the folding developed prior to thrusting as Brent (1985, p. 82) noted that large synclines were completely formed in southwest Virginia before northwest moving thrusts reached the southeastern flanks of the synclines.

## Various Proposals on How the Evaporites Formed

The first recorded account concerning the origin of the evaporite deposits in the Saltville region appears to have been given by W.B. Rogers (1836 reprinted in 1884). He suggested that since the pyrite-containing shale is found in fragments mixed with gypsum and clay of the salt wells, the iron pyrite ( $\text{FeS}_2$ ) was oxidized producing sulfuric acid which reacted with the surrounding limestone producing calcium sulfate. Recognizing that salt deposits occur along with gypsum deposits, Stevenson (1885) advanced a similar proposal concerning the origin of the gypsum deposits. The inpouring of water from sulfur springs into a littoral lake in the deep Saltville basin reacted with dissolved calcium carbonate in solution, forming gypsum deposits.

Eckel (1903) offered a model of deposition of the interbedded salt and gypsum deposits by the mechanism of evaporation of seawater in a partially or entirely enclosed



Figure 9. Highlands above Saltville Valley looking south from the town of Saltville.

basin. Stose (1913, p. 73) concluded that the gypsum and salt minerals were:

...derived from calcareous-argillaceous sediments which originally contained disseminated gypsum and salt precipitated in a partially inclosed [sic] arm of the sea during the deposition of the Maccrady formation, these minerals having been concentrated in the same formation by ground waters which circulated along the fault contact... dissolved the calcium carbonate from the earthy limestones, and segregated the gypsum and salt in gypsiferous and saline beds by chemical selection.

Withington (1965), observing that "...laminated gypsum, typical of bedded gypsum deposits..." (p. 39) had been found in the isolated gypsum blocks mined thus far. He assumed that the salt and calcium sulfate (likely in the form of anhydrite) were laid down as a portion of the original depositional sequence. The Maccrady near Plasterco and Saltville originally may have contained bedded calcium sulfate, salt, shale and thin sandstone in an approximately 100 feet thick unit. "The Maccrady acted as a lubricated mass over which the thrust plate glided" (p.40). During the thrusting process, the overriding matter ex-

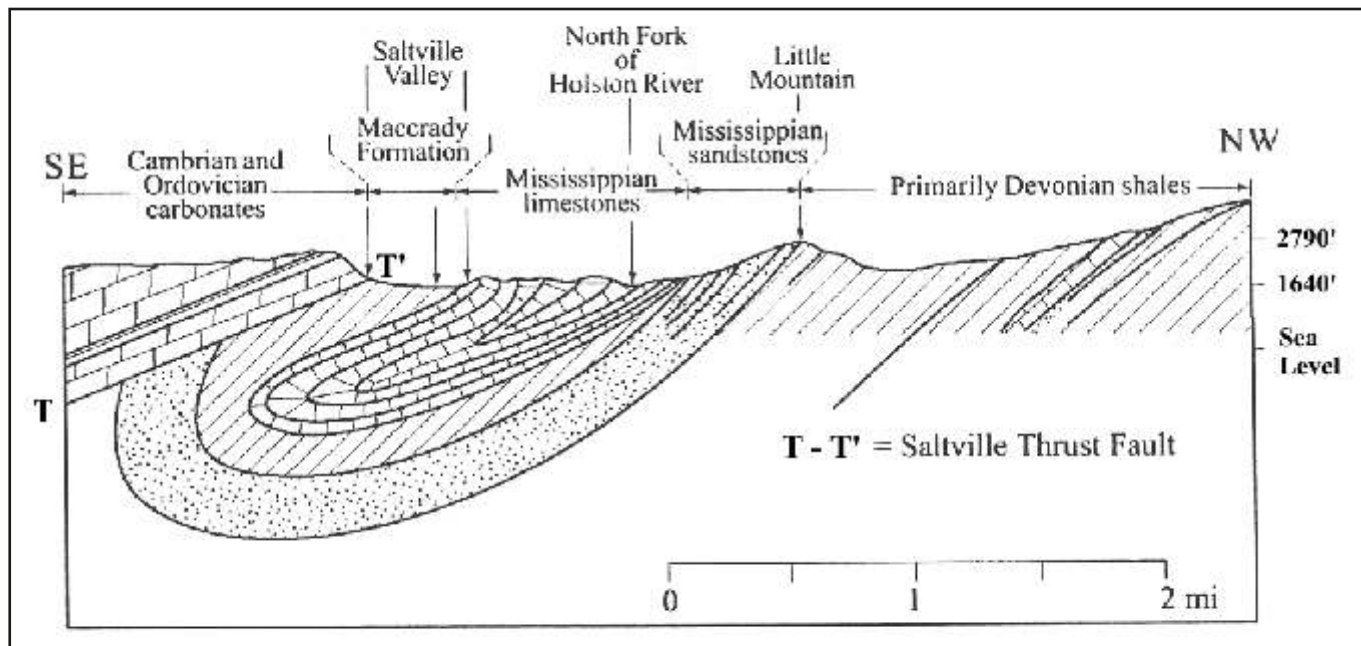


Figure 10. Geologic cross section showing the Greendale Syncline and the Saltville Thrust Fault trace in Saltville Valley region (after McDonald, 2000, p. 11).

truded the Maccrady in front of it which concentrated the  $\text{CaSO}_4$  and salt by plastic flow, thickening the formation. Simultaneously, limestones and other impurities were introduced into the evaporites by the force of the thrusting process. Fragments of the Little Valley Limestone and possibly the underlying Price were moved with and into "...the jumbled mass of the Maccrady" (p. 40). Bedded gypsum found at the Plasterco mine (in the upper Maccrady) was not disturbed very much by the thrusting process as the major movement "...took place east and southeast of Plasterco" (p. 40). Figure 8 is a cross section of the evaporite deposits in relation to his model of how the beds formed in the Saltville-Plasterco area.

Byron Cooper (1966, p. 14) observed that:

The Maccrady Formation in the Plasterco-Saltville-Broadford-Locust Cove belt of outcrop shows some of the most remarkable local stratigraphic variations of any formation in the southern Appalachians.

Cooper (pp. 11, 29) stated that the Greendale syncline was a depositional syncline where evaporites which include halite, minor blue salt, anhydrite, gypsum and dolomite occur mainly in the Maccrady plastic shale member. All of these materials originally formed as broad lenses or beds but were subjected to shearing, folding and cataclasis causing considerable disruptive flow and redistribution in the upper limb of the syncline. Salt in this limb is mainly found as tectonic breccia (cataclasts). The presence of salt breccias in the limb does not imply that all of the Saltville salt is tectonic. In the upright lower limb of the syncline, well cuttings from the high pressure brine fields have shown that some of the salt "...could be from indigenous salt beds" (p. 27).

As for gypsum and anhydrite in the mine at Plasterco, the minerals are present together as "...large lenslike to pod-shaped..." bodies in such a relationship "that the anhydrite was definitely earlier than the gypsum." The gypsum from the mines at North Holston was in bedded deposits and was completely hydrated "...but mixed with anhydrite down dip" (p. 28). The gypsum at Locust Cove is also bedded but completely hydrated (Cooper, 1966, p. 28). Later, Nelson (1973, p. 545) noted the presence of small amounts of anhydrite in some of the deepest gypsum layers at Locust Cove.

Cooper claimed that the environmental conditions necessary for a dolomite-anhydrite-halite depositional sequence are "...evaporation of marine waters in a stilled basin replenished from time to time by seawater" (p. 29). This evaporation probably occurred over at least 2000 square miles to have enough seawater to form the anhydrite found in the region.

The special depositional conditions that must have existed in the Saltville district are noteworthy. Whereas the Maccrady on the northwest flank of the Greendale syncline is generally only about 165 feet thick at most... the thicknesses of plastic shale and evaporites in the upper Maccrady of the southeast limb, range up to 1,700 feet, signifies profound differential subsidence in the axial portion of the Greendale syncline and its northeastward extension, the Locust Cove syncline (p. 29).

A geologic section (Figure 10) of Saltville Valley illustrates the above observation. Cooper considered that this differential downwarping during the local Maccrady deposition



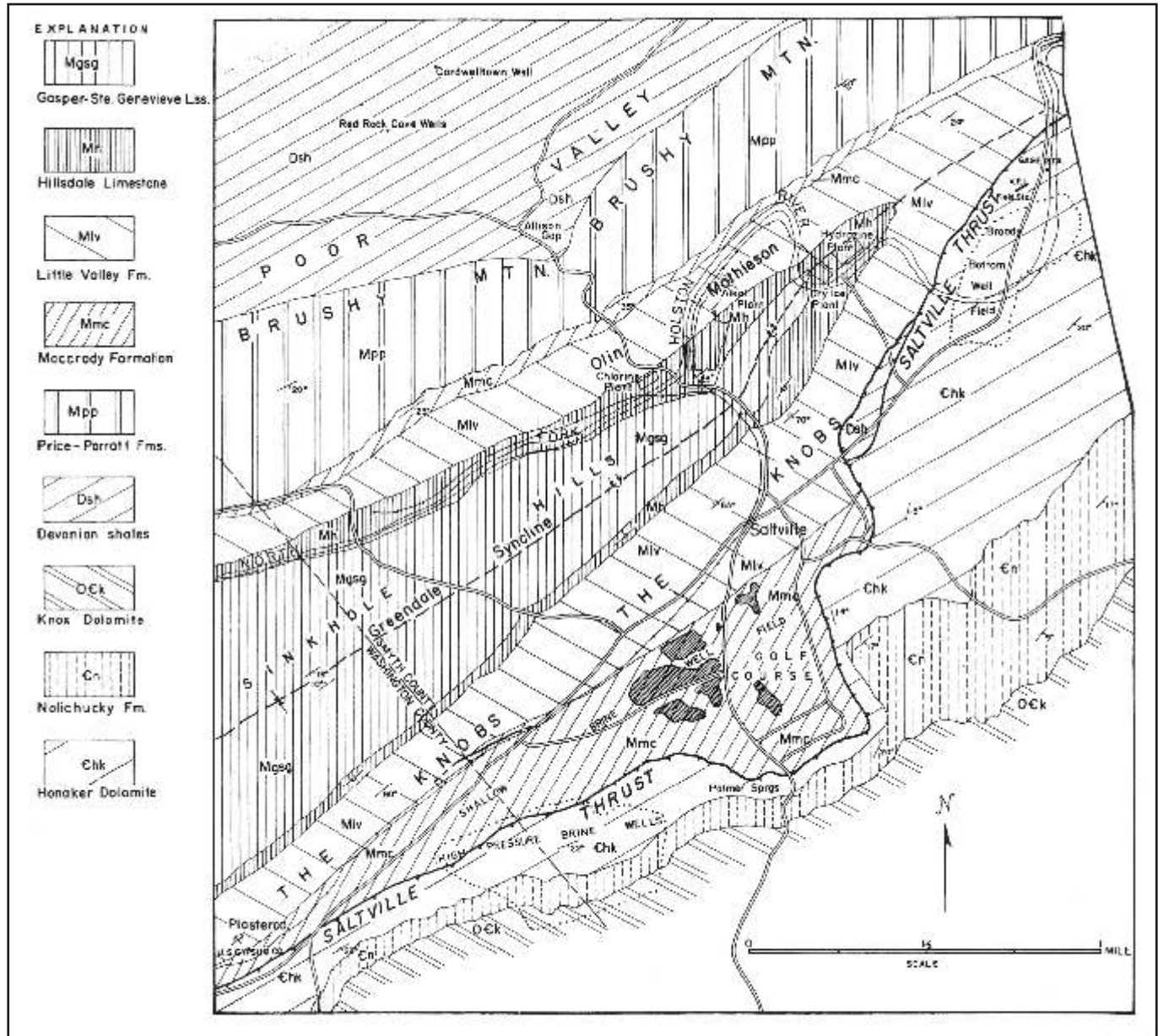


Figure 11. Geologic map of the Saltville-Palsterco region (from Cooper, 1966, p. 13).

was an “embryotectonic forerunner” of the syncline. Thus the synclinal folds were developing during the Maccrady depositional process. “Numerous repetitions of anhydrite and dolomite in the red, green and gray shales suggest cyclical conditions of evaporite formation... Overturning of the southeast limb of the fold...” (p. 30) caused anhydrite bodies to elongate into pods. The deposited anhydrite was “...hydrated wholly or partially to gypsum” (p. 30). Cooper’s interpretation of the geology of the Saltville-Plasterco area is shown in Figure 11.

The fact that ...gypsum bodies and salt bodies are not known to occur together in the Virginia deposits may imply that the hydration of the anhydrite and dissolution of salt went on simultaneously (p. 28).

Cooper (p. 15) conjectured that Locust Cove and the Saltville-Plasterco locations probably were part of the main evaporating basin and possibly the Locust Cove deposit could have formed in a separate basin “...in which no salt and only anhydrite and possibly some dolomite were deposited by the evaporating waters” (p. 15).

Sharpe (1985, p. 44) stated that “The Maccrady Formation was deposited in a mud-rich sabkha environment.”

Gypsum and anhydrite were deposited as diagenetic minerals within the tidal flat sediments... Ground water moves by capillary action through the sediments above the water table. Recharge occurs by lateral movement of seawater through the tidal flat wedge and periodic storm flooding (Sharpe, p. 45).

Gypsum and anhydrite were subjected to alteration and deformation after deposition forming the “boulder zone.” Lenslike masses of anhydrite and gypsum “...were deformed, folded and thickened by plastic flow...” when the Greendale and Locust Cove synclines were formed and the Saltville thrust was active (Sharpe, p. 46).

A thick bed of gypsum known as the “footwall seam” occurs at the top of the Maccrady Formation in the No. 6 mine (Sharpe, p. 46).

The seam was up to 50 feet thick and was mined to a depth of 1420 feet where it graded into anhydrite. Sharpe (p. 46) considered that the seam was a shallow subtidal deposit. The seam was not present at the Locust Cove Mine.

Warne (1990, p. iii) conjectured that the thick salt and gypsum deposits in the Saltville region were the result of local syndepositional subsidence, a change from humid to arid climate as the North American Plate drifted northward and an eustatic sea-level rise. These evaporite deposits could have been thickened and concentrated into boudins by movement of the Saltville thrust fault with thixotropic clays acting as principal lubricants (p. 90).

Vertical tectonic movement could have hindered marine water movement out of the subsiding basin which would have increased brine residence time so that the waters became saturated with halite and anhydrite. The rapidly subsiding Greendale basin acted as a deep water marine salina at first where bedded gypsum, anhydrite and halite were deposited. The basin was quickly filled and leveled by deposition with primarily halite in the deepest parts of the basin. Sabkha and mudflat deposits of evaporites then became the primary mode of precipitation. Siliciclastics flowed into the basin during minor sea-level fluctuations which resulted in interbedded shales and evaporites in the Maccrady (pp. 140–149).

## Some Problems with Evaporite Deposition Models

Many geologic models for the deposition of evaporites include the assumption of arid or semi-arid climate considered necessary to evaporate seawater. Krumbein (1951) cataloged the various evaporite deposits in the United States according to their position in the geologic column. Using the geologic timetable, he noted “...that evaporites occur in rocks of every system from Ordovician through Tertiary” (p. 63). Later in the article he stated that:

...there seems no need for calling upon “general aridity” during a geologic period to account for its evaporites. Rather, the implication for historical geology is that tectono-environmental conditions for evaporites were of common occurrence, and that the evaporites fit into the climatic picture of any period as normally expected phenomena (p. 80).

Thus, arid or semi-arid conditions may not be necessary to form evaporites. The modern geologic models that require aridity to cause evaporation include sabkhas, marginal salt pans, relict seas, desert lakes, mud flats, salt flats, barred basins and lagoons to name a few. Today, sabkhas are more frequently suggested as a mechanism for certain evaporite deposits that formed in the past. Kendall (1979a, p. 145) observed:

The dogma of the decade—supratidal (sabkha) evaporites—has become much too one-sided because there are other evaporite types that clearly are of subaqueous origin. It is probably true that, given the correct environmental conditions, evaporites can mimic most other sediment types.

A sampling of evaporite formation models can be found in the Appendix. There is no doubt that minor evaporite deposits can presently form in small amounts by the mechanisms noted previously. It appears unlikely that the massive evaporite deposits in the geologic record are the result of such mechanisms. For instance, consider the remarks of Austin and Humphreys (1990, p. 22) on halite deposition:

Many have assumed that the major pathway for  $\text{Na}^+$  removal from today’s ocean is the deposition of the mineral halite. However, the major halite deposits accumulate currently from concentrated river water on the continents, not from the ocean. Modern marine sedimentary deposits are nearly devoid of halite. Recent marine salt flats and coastal lagoons occur along the Persian Gulf, along the Gulf of California, and on the west coast of Australia, but they have very meager deposits of halite. When halite is deposited in marine salt flats and coastal lagoons, freshening of the brine after deposition often redissolves the halite.

The above observations support what Smith, Friedman and McLaughlin (1987, p. 826) claimed concerning salt deposition in a modern desiccating saline lake:

The initial purpose of our study was to understand better how “primary” crystallization processes in a desiccating saline lake carry an imprint in the species and isotopic content of the hydrated minerals that can be translated into a paleoclimatic record... It is perhaps ironic that what we have determined is that in salt bodies having this bulk composition, and crystallized in an area with marked seasons, there is no such record, because the “primary” hydrated-mineral assemblages never survive more than a few months. In determining this, however, we developed a basis for predicting that the record that will survive is the mineral assemblage existing after post-depositional diagenesis has ceased. This will happen only after a saline layer is buried to depths where seasonal changes cease and near-mean annual temperatures for the area prevail, and this is probably a more useful

component of paleoclimatic data than the one we set out to determine.

Preservation of “evaporites” may have depended upon rapid burial at depth to avoid resolution. Another controlling factor may have been the formation of evaporites in great depths of water under conditions not operating presently. Kendall (1979a, p. 145) noted that “...Areas of present day evaporite deposition comparable in size with those of the past are absent.” Continuing in this direction, Whitcomb and Morris (1963, p. 412) stated that present rates of evaporation are too slow to develop huge salt deposits which later tectonic activity formed into domes. Often domes have diameters of 1000 feet to two miles and extend downward several thousand feet. Evaporation of standing water would require a column of seawater 8000 feet deep to produce a 100 feet-deep deposit of salt (p. 413).

Nevins (1974, p. 243), in discussing the Castile evaporite beds of west Texas and southeast New Mexico, explained that the ratio of  $\text{CaSO}_4$  and  $\text{NaCl}$  in these beds is not in agreement with the ratio of the two compounds that would be expected from the evaporation of normal seawater. Nelson (1973, pp. 546, 547), in describing the salt deposits of Saltville noted:

The composition of brines obtained by dissolution of the salt deposits at Saltville is notably deficient in magnesium..., and neither magnesium nor potassium bearing salts have been found. The proportions of carbonate, sulfate, and chloride in the section do not conform with those expected by progressive evaporation of seawater... In common with many salt deposits, the proportion of sulfates is too high compared to chloride. Instead, the basin must have been a relatively small one connected to the open sea in such a manner that the residual brines could be refreshed after halite and anhydrite began precipitating.

Are evaporites properly labeled? Whitcomb and Morris (1963) stated “Modern writers are gradually coming to the opinion that even the stratified evaporite beds are very largely the result of metamorphic processes rather than simple sedimentation and evaporation” (p. 416). Kendall (1979a) commented:

Lastly but most importantly, evaporites are most susceptible to extensive post-depositional change. The solubility of evaporite minerals, the tendency for metastable hydrates to be precipitated, and the susceptibility of salts to flowage under burial conditions are features unique to evaporites and have the common result of obliterating original sedimentary characteristics during diagenesis. The profound effects of these changes means that some evaporites are better considered metamorphic rocks than sediments (p. 145).

## Creationist Models of Evaporite Formation

Whitcomb and Morris (1963) speculated it was possible that an evaporite bed merely had been transported by Floodwater “...from some previous location where it may have existed since the Creation” (p. 412). They suggested that a tectonic mechanism, rather than evaporation, may be more feasible to explain evaporite deposits (p. 414). Another suggestion they offered was the possibility of subaqueous volcanic activity during the Flood that would develop localized high temperature conditions which could cause the production of evaporite compounds (p. 417). Froede (2000) reinforced the concept of large-scale submarine volcanism occurring in the Flood event. Thus localized elevated temperatures necessary for hydrothermal formation of evaporites could have existed throughout the Deluge.

Nevins (1974, p. 243) noted that evaporites have been found at depths of 10,000 feet below sea level at three locations; in the Atlantic Ocean, on the margin of the continent of southwest Africa and in the Mediterranean Sea. Such deposits could not be the result of evaporation and he quoted Sozansky (1973) who suggested “...the emergence of hot brines from great depths during tectonic movements...” could have caused the precipitation of evaporites. Nevins then discussed the brine mixing experiments of O. B. Raup (1970, pp. 2246–2259) with the rapid precipitation of salt. The mixing of certain concentrations of brine solutions caused salt to precipitate in minutes. Gypsum can be precipitated rapidly by a similar mechanism (Raup, 1982, pp. 363–367). Nevins proposed a volcanic origin of brines during the Flood when the fountains of the great deep were released by tectonic forces (p. 243). In a Creation Research Society study on brine mixing, Wilcox and Davidson (1976, pp. 87–89) obtained results that indicated less rigorous conditions than those used by Raup still might achieve the precipitation of sodium chloride. Steve Austin (1984, pp. 120–121, 130–133, 223–224) abstracted several studies on evaporites as well as salt diapirism that pertain to the possibility of different mechanisms of deposition rather than evaporation. David Nutting, under the guidance of Austin, detailed a hydrothermal model for the formation of bedded salt deposits. For a brief synopsis of this treatise, see Williams (1989). The model requires the following circumstances (Nutting, 1984, p. 52) in order to be viable:

- A period of intense undersea volcanic or igneous intrusive activity.
- Widespread hydrothermal vent systems through which much water circulates.
- A basin for deposition of no specific water depth although large deposits require large basins.

Salts available for deposition are formed by a combination of two mechanisms (pp. 52–53):



- Enrichment of the salts in seawater by the circulation of normal seawater through the hydrothermal vent system.
- Direct addition of salts by magma effluence containing large proportions of salt mineral ions.

Salts can be deposited by the following mechanisms (pp. 53–54):

- Precipitation as the saline waters ascend and are cooled by the colder seawater above.
  - Precipitation of salts that are less soluble in hot saline water, such as calcium carbonate and calcium sulfate, due to the heating from hotter waters coming up from below or from variations in magmatic activity.
  - Precipitation resulting from the pressure release as the brine mass rises.
  - Precipitation resulting from a change in the Eh of the system.
  - Precipitation resulting from a change in the pH of the system.
  - Precipitation resulting from a process of brine mixing where two brines of different salinities react as described by Raup (1970) and Wilcox and Davidson (1976). Also note Raup (1982).
- The hydrothermal model of “evaporite” deposition is summarized and can be visualized in Figure 12.

### Young Earth-Flood Approach to Evaporites Near Saltville, Virginia

One possible model is simply that the minerals were present in the pre-Flood crust of the earth and were dissolved by the Floodwater and transported to the Saltville region. The deposition of the evaporite compounds occurred in the subsiding Greendale basin as brines of various concentrations mixed together resulting in the precipitation of  $\text{NaCl}$ ,  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$  and  $\text{CaSO}_4$ . Another possibility is based on the Austin-Nutting hydrothermal model. Involved in this model is increased volcanic and magmatic activity during the Flood. Also hydrothermal vents could have developed (possibly the breaking up of the fountains of the great deep—Genesis 7:11) and the likely exposure of Floodwater to hot fractured rocks. Both conditions would assure the release of hot brine solutions.

If such a situation developed near the Saltville region, the warmer brine solutions would mix with cooler Floodwater (see Figure 12) precipitating  $\text{NaCl}$ ,  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$  and  $\text{CaSO}_4$  in the subsiding Greendale basin. Anhydrite would likely precipitate from the hotter brine solutions.

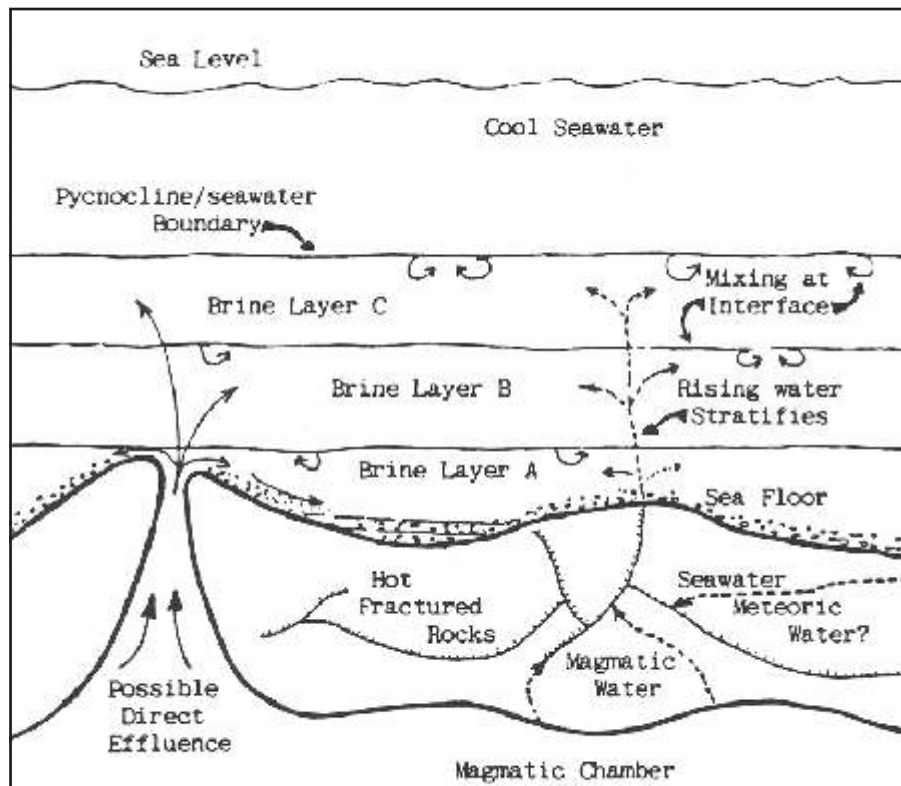


Figure 12. Hydrothermal Model of Salt Deposition (Nutting, 1984, p. 55).

Seyfried (1987, p. 320) claimed that at temperatures above  $150^{\circ}\text{C}$ , anhydrite precipitation is an important sink for calcium in seawater. Halite and gypsum would possibly precipitate from mixing cooler brine solutions.

Another interesting circumstance related to this discussion is that clays, particularly chlorites, tend to form in and around hydrothermal vents which would intermix with the rising brine solutions resulting in these clays being found in the evaporite deposits. Chamley (1989, p. 14) stated that chlorites “...chiefly originate from crystalline igneous or metamorphic rocks, or from the alteration of some volcanic rocks.” Nelson (1973) performed a mineralogical study of the Maccrady in the Saltville region and found that: “The evaporitic minerals are mixed intimately with clay minerals” (p. 539). Specifically he observed that:

The evaporitic or plastic clay member at Plasterco and Locust Cove usually contains dolomite, quartz, gypsum or anhydrite, illite or muscovite and chlorite. The evaporitic member at Saltville has the composition: halite, dolomite, anhydrite, quartz, muscovite and chlorite (p. 545).

Muscovite is a mineral of the mica group and chlorite is usually found associated with and resembles the micas (Bates and Jackson 1984, pp. 86, 341). Nelson felt that the growth of chlorite was primary evidence of authigenesis and that magnesium assimilation occurred with chlorite development (1973, p. 549). In discussing hydrothermal alteration at mid-ocean ridges and seawater alteration of

basalt, Seyfried (1987, p. 319) stated that chlorites and smectites form during experiments on the seawater alteration of basalt at 150–350°C (magnesium is removed from seawater during the reaction). Also SiO<sub>2</sub> is involved in the production of these clay particles and any unreacted SiO<sub>2</sub> (quartz) would likely mix with the clays.

Nelson differentiated between two varieties of chlorites present in the evaporites—a detrital variety (that possibly could have come from argillaceous sediments around the evaporitic material during tectonic movement?) and an authigenic finely crystalline variety (formed with the evaporites?). The detrital variety broke down into a friable or fragmented soil when exposed to weathering (exposure to water) as is typical of most Appalachian clays (p. 554). The authigenic “...red and green clays from the evaporitic facies flake and flocculate when in contact with water,... weathering produces a wet, cohesive and plastic clay mass...” (p. 554). Thus during weathering, the authigenic chlorites transform into an expanding clay, smectite (p.554). Chamley (1989, p. 422) noted:

The minerals most frequently encountered in hydrothermal vents and wall-rocks are magnesian species such as chlorite, talc, serpentine, fibrous clays, corrensite, Mg-smectite and numerous non-clay minerals.

Reporting on another investigation (p. 379) Chamley observed, “In the Douala basin, Cameroon, chlorite is supposed to result from the downward transformation of smectite in a magnesian environment.” He also noted that, “With increasing depth both smectite-bentonites and kaolinite-bentonites tend to be replaced by typical late-diagenetic clays such as illite-smectite, illite and even chlorite” (p. 413). Possibly the original clay formed in a hydrothermal or magmatic environment was a smectite which was transformed into a chlorite (by the magnesian environment and deep burial). Then the chlorite later weathered back into smectite? Or possibly the plastic clays are swelling chlorites or pseudo-chlorites which expand like smectites in water but resist heating like chlorites. “They appear to represent an alternation of smectite layers and octahedral brucitic sheets” (Chamley, 1989, p. 15).

In any case, the presence of chlorite and its diagenetic product, smectite, speaks of a hydrothermal or magmatic origin for the clays intimately mixed with the evaporites, supporting the hydrothermal model of Austin and Nutting. As a matter of fact, Hayden made the following remark in 1843 about the Saltville deposits:

The local occurrence of a fault, the generally disturbed condition of the rocks, and the anhydrous nature of the salt, all argue the action of heat contemporaneously with, or subsequently to the deposition of the salt (pp. 175, 176).

Thus, I prefer the hydrothermal model for the origin of the evaporite deposits in the Saltville region.

After deposition, the tectonic action on the evaporites should be considered. The lack of strength of the evaporite beds containing clays and shales would act as a zone of weakness rendering the mass susceptible to movement if subjected to tectonic forces. Adjacent recently subaqueously-deposited limestones, dolostones, sandstones, etc. likely would be semi-rigid and more competent. As Floodwater began to recede, the crust of the earth would be subjected to folding, faulting and uplift as the height of the water above the crust was reduced. A new crustal equilibrium would be established with decreasing water pressure during the period of water recession from the continent. Faulting and crustal adjustment likely would cause movement of the evaporitic layers, squeezing them upward and outward in the Saltville region. Possibly the evaporites would be thinned and pinched out northeastward beyond Locust Cove and southwestward beyond Plasterco. The movement of the Saltville Fault might cause fragmentation of strata adjacent to the shifting evaporite beds. Many of the fragments would be carried along with the Maccrady and if some of the detritus was argillaceous, more clay (detrital variety?) would be forced into the evaporitic mass.

Cataclasis would develop as the moving salts likely would intermix forming “boulders,” “pods,” or “boudins” particularly in upper layers of the evaporitic mass. The deeper deposits of evaporites may have remained relatively unaffected by the tectonic forces. If after uplift the deposits were exposed to receding Floodwater currents, considerable erosion and solution of the minerals could take place, scouring the Maccrady farther downward until all that remained near the present location of Saltville was a salty, swampy area or a saline lake in the valley as the sediments in the heights around the valley dried and hardened. Eventually the sedimentary layers around and below the Maccrady would harden, stabilizing the strata as tectonic movement lessened and then ceased.

The models offered are considered tentative and more study is necessary to reinforce or reject these ideas. There are likely other evaporite deposits that would lead an investigator to entirely different conclusions. The tectonism that occurred would destroy or disturb most of the original bedding of the evaporites, making any investigation a difficult undertaking.

## Glossary

argillaceous: containing clay  
 authigenic: formed in place  
 boudin: sausage-shaped segment  
 brucite: hexagonal mineral, Mg(OH)<sub>2</sub>  
 cataclasis: rock deformation by fracture, crushing or granulation

chlorite: a group of platy usually greenish clay minerals.  
 Chlorites are associated with and resemble micas.  
 corrensite: clay mineral with a structure that represents the interstratification of chlorite and vermiculite structures or of chlorite and smectite structures  
 diapirism: piercing or rupturing of domed or uplifted rocks by mobile core material  
 eustatic: pertaining to worldwide changes of sea-level  
 evaporites: sedimentary salts precipitated from aqueous solution and concentrated by evaporation  
 illite: general name for a group of three-layer, mica-like clay minerals  
 littoral: pertaining to the benthic environment or depth zone between high and low water  
 magmatic: pertaining to or derived from magma  
 muscovite: a mineral of the mica group  
 pycnocline: a density gradient; a layer of water in the ocean characterized by a rapid change of density with depth  
 sabkha: a supratidal environment of sedimentation formed under arid to semiarid conditions on restricted coastal plains just above normal high tide  
 salina: a body of saline water such as a salt pond, spring or playa lake  
 salt pan: a small shallow depression where water accumulates and evaporates leaving a salt deposit  
 serpentine: a group of rock-forming minerals with the formula  $(\text{Mg,Fe})_3\text{Si}_2\text{O}_5(\text{OH})_4$   
 smectite: a group of expanding-lattice clay minerals  
 talc: soft, green or gray mineral,  $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$   
 thixotropic: change from a gel to a sol when disturbed, a property of colloids such as bentonitic clay

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## Appendix

Interested readers may consult the following references for various uniformitarian models of evaporite deposition:

Dean, Davies and Anderson, 1975, pp. 367–372; Evans, 1970, pp. 1349–1352; Friedman, 1972, pp. 1072–1086; Hardie, 1984, pp. 193–240; Kendall, 1979a, pp. 145–157; 1979b, pp. 159–174; Kinsman, 1969, pp. 830–840; 1974, pp. 343–348; Presley, 1987, pp. 167–190; Warren and Kendall, 1985, pp. 1013–1023.

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## Book Review

*The Colorado Plateau, A Geologic History* by Donald L. Baars  
University of New Mexico Press, Albuquerque. 2000, 254 pages, \$21.95

From a geological standpoint there are few areas in North America that are more fascinating than the Colorado Plateau. Roughly centered on the "Four Corners Area" where Arizona, Colorado, New Mexico, and Utah meet, this immense area provides vast stretches of deep canyons, burning deserts, and sculpted spires. The scant vegetation and abrupt escarpments of the area allows a visualization of the topography that would be concealed by dense vegetation elsewhere.

A large number of books attempt a thorough but non-technical review of the geology of the Colorado Plateau, but few really succeed. This book is a delightful exception. While the author is a convinced evolutionist and uniformitarian, he nevertheless presents some refreshing insights into the dogmatism of classical historical geology. As a field geologist with more than forty years experience on the Colorado Plateau, his skepticism of several modern geological interpretations must be taken seriously.

Baars wastes no time in announcing some of his heretical thoughts in the Introduction. He states, for example, "We have learned many things about the fundamental structure of the earth thanks to the religious doctrine of plate tectonics, a widely and now almost blindly accepted theory that is based on continents skidding promiscuously across the crust of the earth. Although this doctrine is based on surmised oceanographic processes, all geologic features of the continents must adhere to prescribed policy, even though many of these interpretations make no sense . . . If the real geologic facts don't agree with plate tectonics principles, they are simply ignored."

The author also asks, "What constitutes windblown (eolian) sandstone? . . . Where did all the sand come from, anyway?" He notes that extensive literature exists on the internal structure of supposedly wind-blown sand dunes, but "One cannot find a single reliable technical paper on what is to be found inside water-deposited dune sands . . . So we

end up knowing everything there is to possibly know about windblown sand deposits, and virtually nothing about water-laid sand accumulations."

This issue is of immense importance to flood catastrophists who tend to view many classical sandstone strata as flood deposits. If many or most of the supposed wind-blown, cross-bedded sandstone strata are in reality water deposited, it would cast many geological processes of erosion, transportation, and deposition in an entirely new light.

Baars also expresses concern about the geological time tables as applied to stratigraphy. He writes, "Another problem of worldwide significance that affects our discussion of the geological history of the Colorado Plateau, or any other province, is that of the time boundaries of the geologic periods." His special concern is with the boundaries of the Permian Period, which he observes have "vacillated wildly since the Permian Period was established by Sir Roderick Murchison in 1841 . . ."

Young earth creationists will find much of Baars work to be a refreshing departure from the standard evolutionary dogmatism. Furthermore, it is clear from this work, as well as from many others, that the Colorado Plateau contains a vast goldmine of information awaiting careful analysis within the appropriate interpretive framework.

This work is highly recommended to any traveler of the back country of the Colorado Plateau. Though written at a semi-popular level, it is very readable for the non-specialist. In addition, its extensive bibliography and index makes it an ideal starting point for in-depth studies of this high, wide and lonely area.

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