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# The Rock Salt Deposit at Saltville, Virginia

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## Abstract

Salt was obtained from brine springs near Saltville, Virginia, in prehistoric and colonial times. Since 1796 the deposit has been commercially operated and figured importantly in several Civil War battles. Olin-Mathieson Chemical Corporation has utilized brine from wells drilled to depths of near 2300 feet to produce soda ash, chlorine, hydrazine fuel and other chemicals. Salt and gypsum occur in the Maccrady Formation shales of Late Mississippian age. Presently known economic deposits are found near and beneath the 11,000 foot-displacement Saltville fault. These evaporites formed in salt pans or restricted embayments along the Maccrady deltaic shoreline. Later deep burial formed restricted lenses or pillows of salt which are now enclosed in tectonically contorted masses of incompetent shale along the footwall of the Saltville fault. Water solution from industrial wastes will soon force cessation of a large portion of the salt production.

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## General Features and History of Development

History and salt brine seep from the valleys of Southwest Virginia. Salt licks and seepages found in a swampy area of Holston Valley near Saltville, Virginia (Fig. 1) were utilized by Indians and wild animals long before the first settlers came to the area over 200 years ago (Rachal, 1953). Pleistocene gravel deposits containing Mastodon and other animals are found at Saltville and Indian artifacts are present in abundance through this region. Early settlers extracted small quantities of salt from the brine by natural evaporation or boiled off the water in small iron pots (Stose, 1913). A patent covering 330 acres of the salt lick was issued to Charles Campbell in 1753. Thomas Jefferson in 1782 made reference to the occurrence of salt brines in the Holston Valley and shortly after, the first brine well was in production by 1790 (Lonn, 1965).

In 1840 a shaft was sunk in an attempt to intercept the brine stream; however, at a depth of 210 feet rock salt was encountered (Watson, 1907). Additional shaft extension and boring indicated that the salt was at least 166 feet thick. Rev. Steven Taylor of Abingdon, Virginia, described this discovery in 1841 and noted that gypsum was found at a depth of 30 feet and that "slate and blue clay" occur with the rock salt. At the time this was the first discovery of a bed of rock salt in the United States, although outcrops were previously known from western areas which later became states (Cox and Edgerton, 1968). An early analysis of the rock salt reported by Radcliffe (1[illegible]) attests to its high purity : 99.084 % NaCl, 0.446 % $CaSO_4$, trace of CaCl, 0.476 % Fe, Al, etc. Rogers' (1[illegible]) remark that the purity of the deposit is "scarcely excelled by any in the world" is substantiated by a comparison with analyses from many other United States and foreign samples (Eckel, 1902).

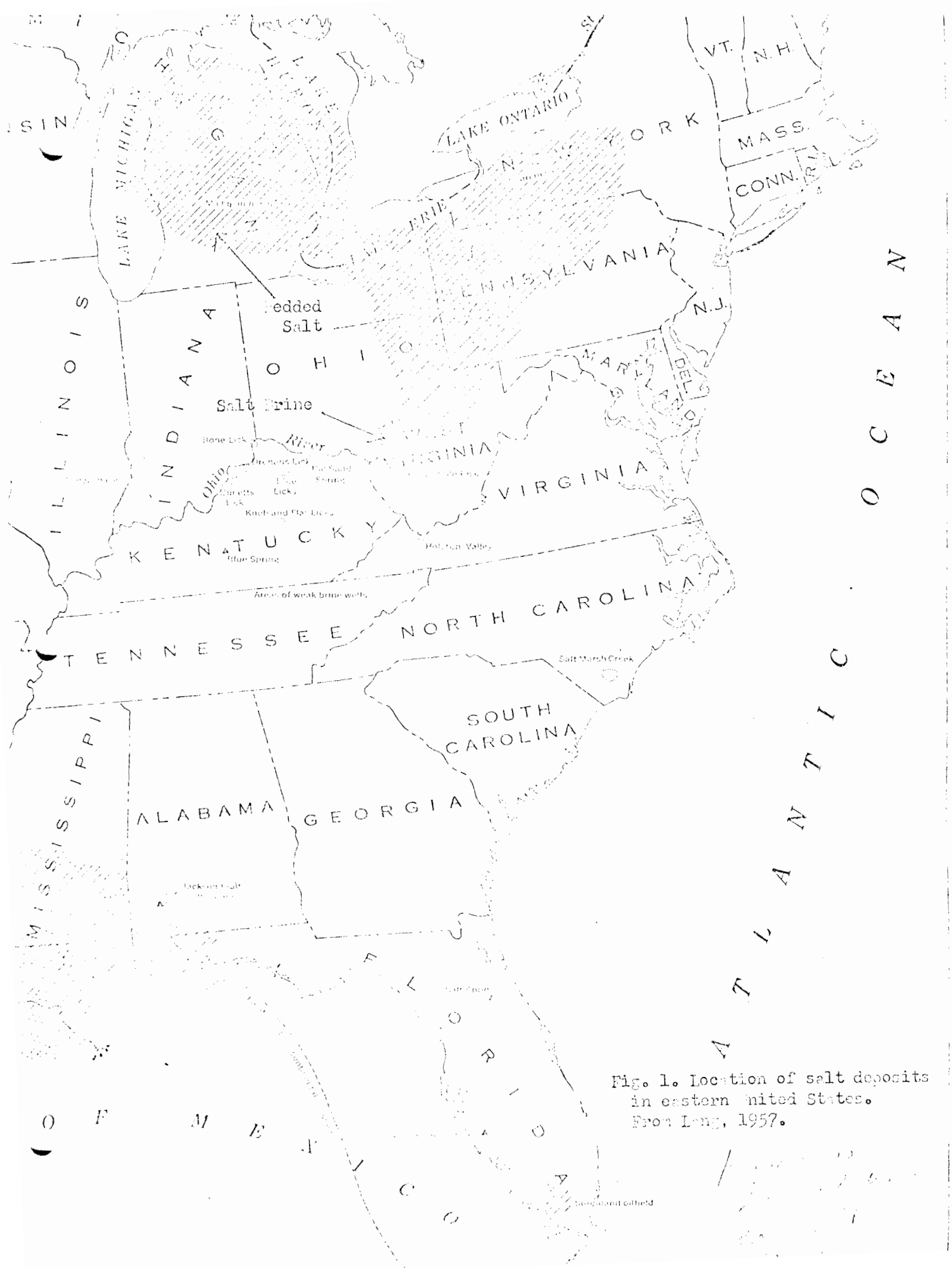



Fig. 1. Location of salt deposits in eastern United States. From Long, 1957.

Commercial production, plus by brine extraction methods, began in the late 1700's (Mittinger, 1965). The marshes were drained in the early 1800's by cutting channels to the North Fork of the Holston River. By 1842 production from six wells reached 200,000 barrels of salt annually. During the Civil War this deposit was the principal source of salt for the Confederate States and production soared to 10,000 bushels per day (Eckel, 1902). Due to a lack of refrigeration at that time, per capita salt consumption was estimated at 100 pounds per year (Dietrich, 1970).

The Confederacy recognized the strategic importance of this deposit and stationed as many as 4000 troops at Saltville. Union forces made calvary raids in 1863 which were repulsed and in a major battle on October 2, 1864, the Saltville defenders soundly defeated a Union force of 5000 led by Brig. Gen. Stephen G. Burbridge. This only delayed the inevitable, for on December 21, 1864, a Union army under Maj. Gen. George Stoneman overran the defenses and demolished the furnaces, burned the buildings and filled the wells with debris before retreating. Production resumed with little delay but at a reduced level (Rachal, 1953).

In 1907 Watson reported brine recovery from 24 producing wells with a maximum depth to 2300 feet. Production has continued to the present; however, due to rising public concern for stream pollution and enforcement of State and Federal regulations, the soda ash production facilities of Olin-Mathieson Chemical Corporation are being phased out and will probably cease operation before the end of next year.

Distribution of United States Rock Salt Deposits

In 1964 common salt (halite) was being produced in 17 states and occurs in non-commercial amounts in at least six others (Phalen, 1949, Cox and Edgerton, 1968). A study by Cox and Edgerton (1968) shows that rock salt at least 50 feet thick lies within 6000 feet of the surface

under an area of 20,000 square miles in the Appalachian Region. Salt of a composite thickness of over 800 feet is known beneath a portion of southern New York and northern Pennsylvania. Murray (1966) estimates that 200,000 cubic miles of salt may underlie 200,000 square miles of the Gulf Coast and Gulf of Mexico region. Thus, it can be seen that common salt is indeed quite common in the United States but the deposit at Saltville has several unique features and its origin is still in question.

Stratigraphy

In the Saltville area, salt, associated with gypsum, is apparently confined to the Maccrady Formation, the lowest unit of the Upper Mississippian sequence. Because of its high solubility the salt has never been reported from surface exposures along the outcrop belt of the Maccrady which is traced from near the Virginia-Tennessee line through Scott, Washington, Smyth, Wythe, Pulaski and Montgomery Counties to near Blacksburg, Virginia, a distance of about 150 miles (Fig. 2). Gypsum has been found and extracted from localities along a 20-mile segment of this belt between Plasterco and Locust Cove but commercial quantities of salt are only known in the area just south of Saltville. Along most of this belt the Maccrady is less than 200 feet thick but may reach over 800 feet southwest of Blacksburg before being obscured by the Pulaski thrust fault (Butts, 1940).

The Maccrady Formation was named by Stose (1913) for exposures near the village of McCready (Fig. 2); however, Butts (1940) restricted the unit to the red shale bearing portion, a practice followed by field stratigraphers since 1940. As now defined the Maccrady outcrops consist of maroon and pale green shales and mudstones with some beds of maroon and light-gray fine-grained sandstone or siltstone. A complete section recently measured by the author at Tumbling Creek, about 4 miles west of Saltville, was found to contain 131 feet of beds that can be assigned

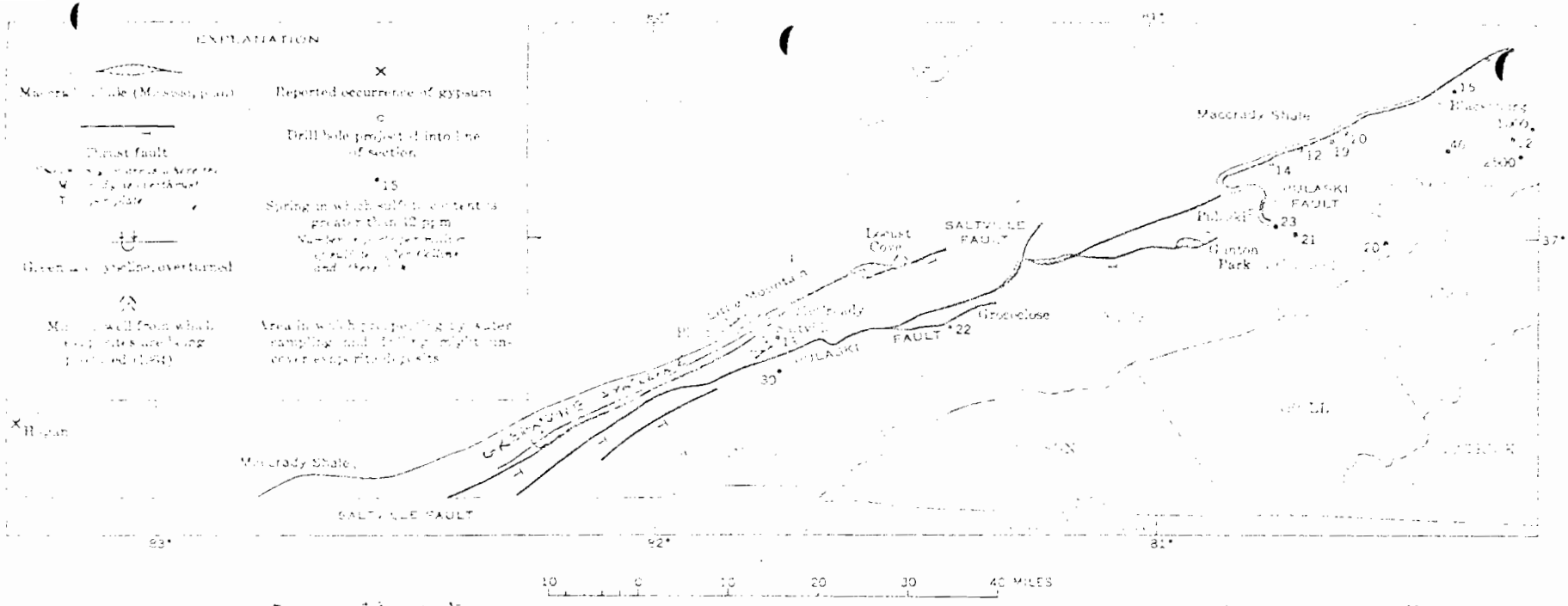



Fig. 2. Map of southwest Virginia, showing outcrop of Macrady and trace of thrust fault. Modified from Withington, 1965.

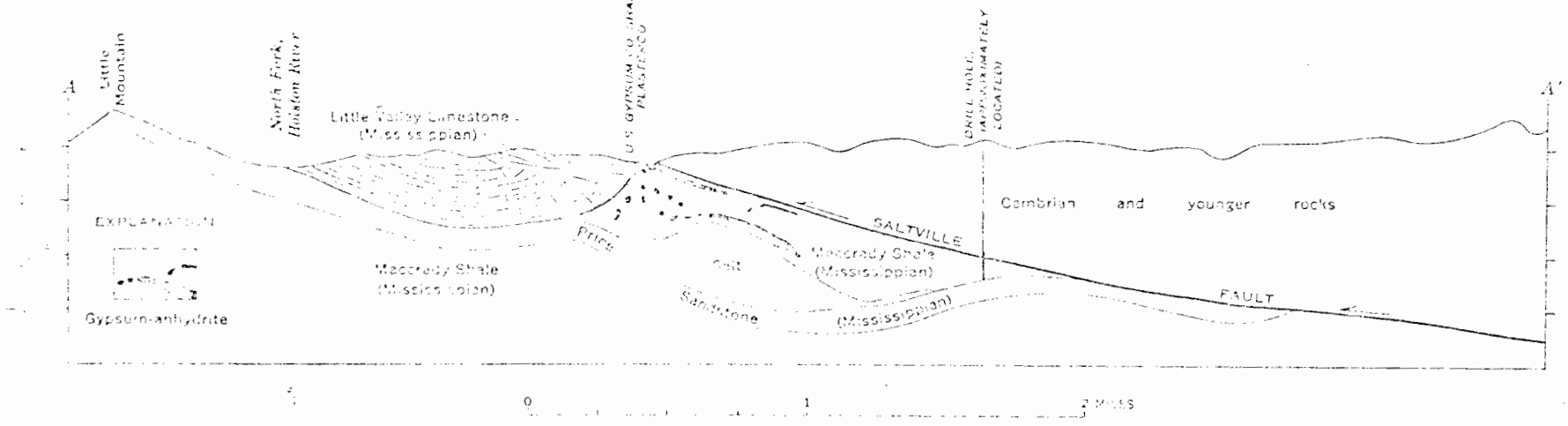



Fig. 3. [illegible] after Carter, 1934. Schematic [illegible] relation of [illegible] to the Saltville fault (after Cullison, 1938; Nelson, 1958; topographic profile from Saltville and Glade Springs 7½' topographic maps). From Withington, 1965.

to the Maccrady. This is underlain by the Lower Mississippian Price Formation which is comprised of arkosic sandstones, glauconitic shales and capped by black shales and coal lenses. The Price sandstones form the resistive ridge called Little or Brushy Mountain to the north of Saltville. The Little Valley Formation of the Upper Mississippian overlies the Maccrady and includes argillaceous limestones, gray shales and thin beds of light-gray sandstone.

## Structure

Maccrady and other Mississippian age beds have been folded into the southwest trending Greendale syncline (Fig. 2). Early structure cross-sections appear in the papers by Fontaine (1881) and Eckel (1902, 1904). Beds on the north flank dip less than 35 degrees to the southeast. The southeast flank of the Greendale syncline is mostly concealed beneath the overthrust plate of the Saltville fault. Honaker dolomites (Middle Cambrian), Kolichucky shales and limestones and Copper Ridge dolomites and limestones (Upper Cambrian) comprise the lower 3000-4000 feet of rocks in this block. Stratigraphic throw on the fault is about 11,000 feet (Bartlett and Webb, in press). Nelson (1958) reported that a well drilled in 1956-1957 about one mile south of the Saltville fault trace encountered Maccrady beds below the fault plane at 2401 feet. This indicates a fault plane angle of about 20 degrees inclined to the southeast (Fig. 3). Fault plane exposures near Broadford, about 10 miles northeast of this well, define a dip of less than 40 degrees (Stose, 1913). The low angle of the fault plane is also indicated by reentrants along its irregular surface trace. Cambrian beds of the headwall are inclined 30 to 40 degrees southeastward. Thus, the Saltville is a low-angle, near bedding-plane, thrust fault which probably slid along the upper incompetent layers of the underlying Rome and Pumpkin Valley shales of the Middle and Lower Cambrian.

At Plasterco (Fig. 2) Little Valley limestones occupy the synclinal trough but erosion and structural rise has brought the Maccrady to this position northeast of Saltville. Due to compression and proximity of the Saltville fault, beds on the southeast flank of the Greendale syncline are steeply inclined or overturned to the northwest. Drilling along this southeast limb has revealed over 2000 feet of Maccrady beds within which lie pockets of gypsum and the large salt deposit. The interpretation of the origin of this greatly thickened body of Maccrady is still in question.

Cooper (1964) has claimed that this synclinal thickening supports his contention of syn-tectonic deposition and thickening of units in downwarps that began in the Appalachian basin as early as the Devonian (Fig. 4, Fig. 5). This proposal requires a 5 to 10 times increase in deposition rate in less than two miles. Withington (1965) proposed that at least a part of the Maccrady thickening is due to plastic flowage of salt and gypsum squeezed out ahead of the advancing Saltville thrust (Fig. 3).

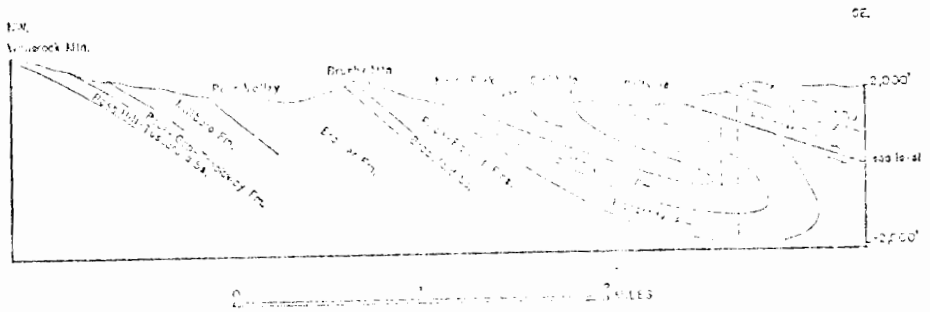



Figure 4. Cross section of Greendale syncline through Saltville, Virginia, showing down-flip thickening of Maccrady and Little Valley formations [illegible] Vertical lines indicate well locations. From Cooper, 1964.

## Origin

An Analysis of the origin of the Saltville deposit involves two problems: (1) the initial deposition of the salt and (2) the emplacement of the salt in its present position.

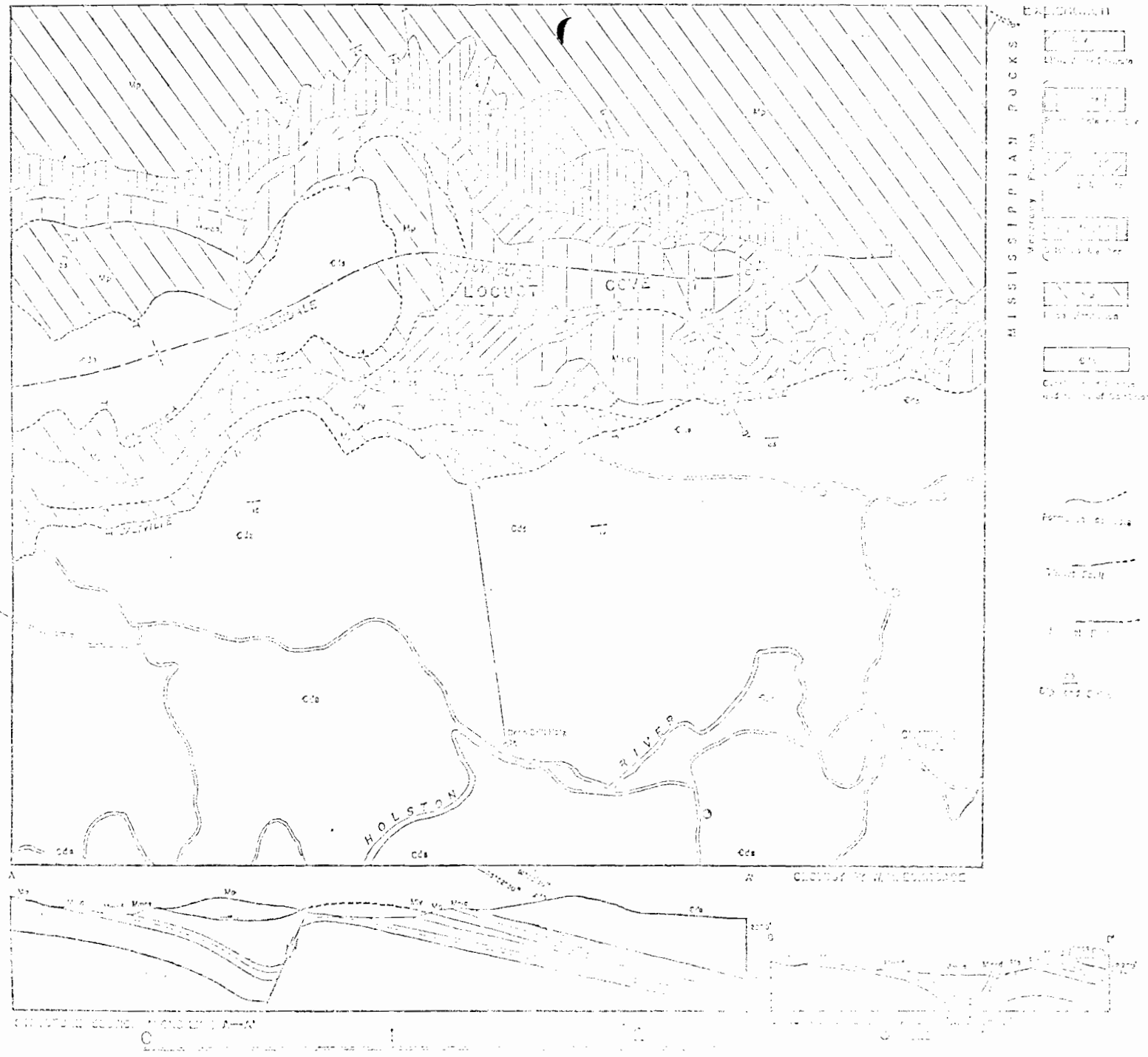



Figure 5. Sketch map and [illegible]

From [illegible]

Salt Origin

The literature on salt origin is extensive and is expanding rapidly. A recent volume of the American Association of Petroleum Geologists Bulletin (April, 1969) considers several viewpoints for the origin of layered evaporites. One "school" argues for precipitation of salt from density-stratified water in a deep water basin, citing the affinity of great salt deposits in the world for the interior portions of subsiding basins (Sloss, 1969). Cratonic interior basins generally recieve evaporites when the basin undergoes subsidence without an influx of major volumes of terrigenous clastics from their borders. Under these conditions and if the evaporation rate maintains equilibrium with inflow the dense salines settle to the deeper portion of the basin, ultimately reaching a condition of supersaturation followed by precipitation of salts. The problem of precipitation from such brines remains in the realm of speculation (Sloss, 1969) but Schmalz (1969) presents a model that he claims is "geologically reasonable and oceanographically tenable". Earlier theories relied on barrier bars to restrict circulation of water (Ochsenius, 1877) or great moon-caused high tidal floods which filled arid inland basins from time to time (Wilfarth, 1933; Phalen, 1949).

The shallow-water or saline proponents explain the origin by the evaporation of restricted shallow shelf (Dellwig and Evans, 1969), enclosed basins (Bateman, 1950) or salt flat (sabkha) waters (Kinsman, 1969). That salt forms in shallow water is no longer in question but it would not seem to account for the thickness of many deposits which would require an unreasonably long balance between subsidence and evaporation (Sloss, 1969; Yates, 1960).

Brief mention should be made of some early ideas for the origin of the Saltville deposit. R. D. Rogers (1854) believed that the salt formed in surface boiling springs and in small basins along the

fracture line later named the Saltville fault. Along this fracture chimneys jets of volcanic steam charged with salt and sulfate of lime dissolved from buried older rock layers. Stevenson (1884) modified this hydrothermal theory by explaining that two different systems of surface waters met, one from a lime area and the other from a region furnishing an abundance of "copperas waters", resulting in salt and gypsum precipitation during the post-Mesozoic time. W. B. Rogers (1884) relied on chemical decomposition of shale and limestone to account for the gypsum deposit. He suggested that oxidized iron pyrites in the shales reacted with limestone to form $CaSO_4$. Eckel (1902) supported the original precipitation of shallow sea evaporites during Maccrady deposition and he believed that the evaporites were interbedded with the shales deposited in a partly or entirely enclosed basin.

Secondary enrichment and replacement was proposed by Stose (1913) who made the first extensive examination of the workings at Plasterco and summarized earlier literature on Saltville. He discounted Eckel's explanation because of the variable thickness of the gypsum masses with intervening barren areas and the apparent concentration of gypsum in upper beds and salt in the lower (see Fig. 3). To explain this distribution Stose called upon postdepositional solution of originally disseminated grains and thin laminae of gypsum. Circulating ground waters along the Saltville fault concentrated the salt and gypsum in pockets of dissolved $CaCO_3$ of the earthy limestone layers in what is now the Little Valley Formation.

Salt Emplacement

It has long been known that rock salt has a comparatively low specific gravity of 2.19 and that below about 1750 feet compaction would cause surrounding sediments to become denser than salt; therefore, below about 2000 feet there would be a natural buoyancy for rock salt beds and they might be capable of flowing by plastic deformation

(Murray, 1966).

Many geologists have studied the salt domes and ridges of the Gulf Coast, Germany and other areas and a number of theories have been proposed for their formation. Prior to 1910 granitic intrusives (Hager, 1904) or pressure of crystal growth (Harris, 1907, 1910) were called upon to explain their position. Lachmann (1911-1913) first proposed the geostatic theory which was later expanded by Barton (1933) and Nettleton (1934). Taylor (1955) explained that a minimum of 15,000 feet of overlying sediments might be required to cause plastic flow of the "mother" salt bed which feeds an upward intruding salt structure. The Zechstein salt deposits have been explained by tangential compressive pressure, the geodynamic origin theory, but Trusheim (1960) has presented geophysical evidence which supports the geostatic origin for these salt bodies in Northern Germany. He notes that salt flow in the Zechstein basin occurred at depths of 1000 meters on salt of 300 meters thickness and with greater ease where the bedding dip exceeds one degree. Thus, it seems that salt flow depends on thickness of overburden, thickness of salt, salt purity, intensity of deformation and inclination of beds.

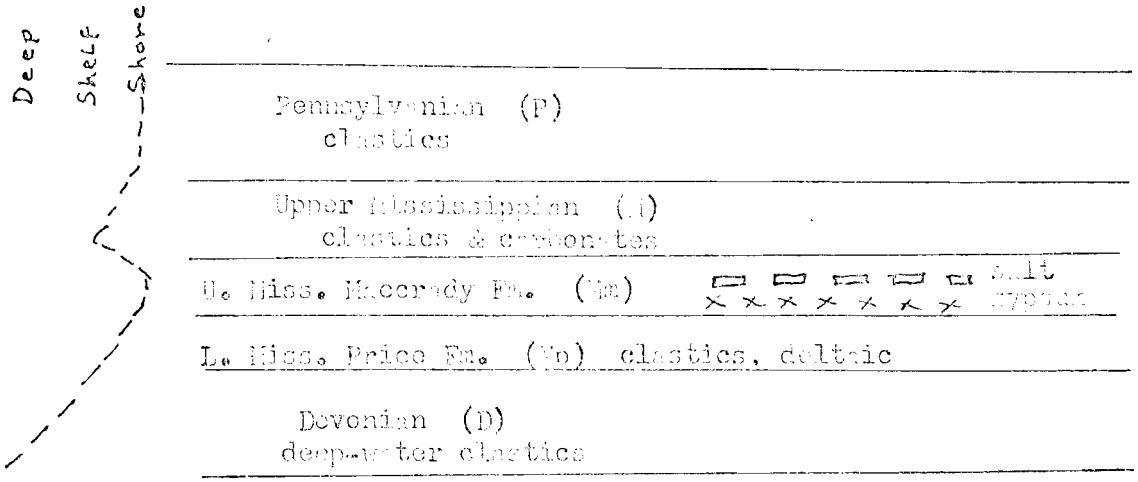
A "Tecto-static" Theory

An examination of the lithologic features of Price, Maccrady and Little Valley sediments provides adequate proof of the original shallow-water origin of the Maccrady evaporites. The upper Price is a deltaic sequence deposited during a marine regression, culminating with continental swamp deposits of ostracod-bearing black shales, highly carbonaceous shales and coal lenses. Exposure and oxidation are reflected in the red colored shales of the Maccrady. The lack of fossil remains and the dolomitic character of some shales reflect a supratidal environment for much of the Maccrady. The return of a shallow

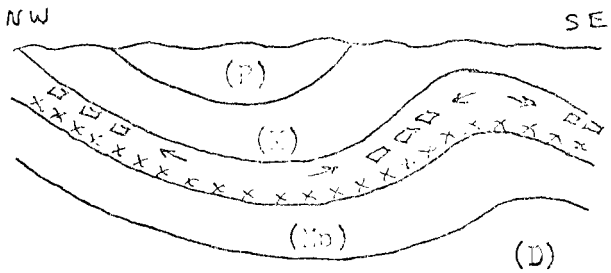
shales of the Little Valley . Therefore, it seems reasonable to suggest that evaporites formed in shallow salt pans or in restricted embayments along a deltaic coastal region. Evaporite beds were probably originally only a few feet thick individually but with slow coastal subsidence, due to the accumulation of the mass of deltaic sediments, a succession of a few tens of feet of evaporites might be expected.

Stose's theory is untenable since a replacement of the evaporite for limestone layers should find the salt and gypsum still in beds that laterally change to the original limestone. This is not the case, since limestone is present only in the overlying Little Valley and the salt and gypsum are found only in the Maccrady shaly beds. This explanation and others ignore the apparent theoretical conflict of gypsum overlying the salt.

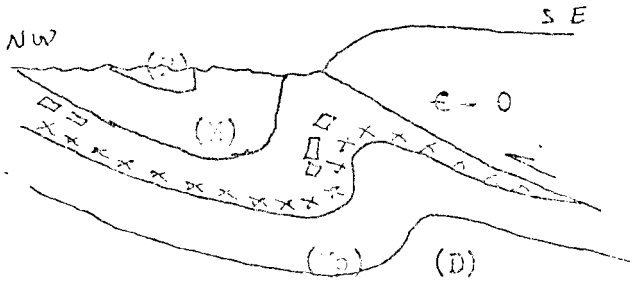
The present emplacement of salt and gypsum might be explained by a combined geostatic and geodynamic sequence of events. It is known that nearly 6000 feet of Upper Mississippian beds were deposited in the Greendale syncline (Bartlett and Webb, in press). Also, many thousands of feet of Pennsylvanian age clastics probably covered this region and have been removed by erosion. The thickness of strata overlying the Maccrady was probably sufficient to cause some plastic flow of the salt (Fig. 6a, 6b), which formed pillows or lenses of salt. Individual salt layers may have intruded the soft Maccrady shales to form a coalesced salt body. In the late Paleozoic folding and faulting caused a gradual salt flow northward away from the advancing thrust. Compression and fault drag caused an overturning of the lower gypsiferous beds (Fig. 6c, 6d). This would explain the occurrence of gypsum over the salt body. The greater thickness of the Maccrady at the Salvania fault trace is due to salt flow, the recumbent fold, some tectonic thickening, possible repetition of section by associated small thrusts, and [illegible] drilling through steeply inclined beds whose actual stratigraphic



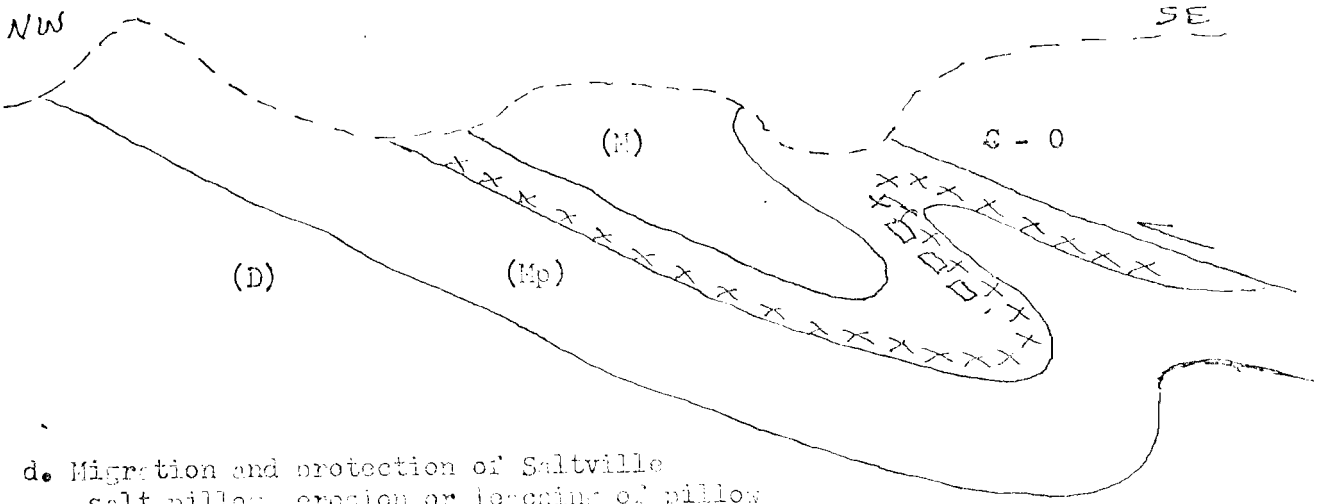

a. Deposition of repressive-transgressive-repressive sequence from Devonian to Pennsylvanian.




b. Folding, with formation of salt pillows, erosion of some Penn-Miss beds.




c. Thrust faulting, erosion, Macerady thickened.




d. Migration and protection of Saltville salt pillow, erosion or lowering of pillow on northwest flank. Present surface shown.

Fig. 6. Sequence of events in "tecto-static" formation of Saltville salt deposit.

thickness is much less than the drilled thickness. The gypsum pods may be due to tectonically formed pull-aparts and thickening of originally semi-continuous deposits. It seems unlikely that they are replacements in a low solubility shale mass but tectonism could have created voids that were filled by gypsum. Such an interpretation would encourage further exploration for evaporite deposits along the Macerady paleo-shoreline, especially where it coincides with thrust faults.

## Production

Olin-Mathieson Chemical Corporation has exploited the salt deposit at Saltville since 1895, producing sodium bicarbonate, soda ash ($Na_2CO_3$), sal soda, caustic soda, chlorine and, more recently, hydrazine fuel for the Air Force (Kusler and Calver, 1967). U. S. Gypsum Company operates gypsum mines in Smyth and Washington Counties and has a processing plant at their mine at Plasterco.

At Saltville brine is obtained from wells drilled as deep as 2280 feet, the deeper ones being located near the Saltville fault trace. Warm water is pumped into the salt under high pressure and dissolved salt is circulated as brine to the surface (Dietrich, 1970). Trump (1947) has described the various methods of brine extraction. Brine is pumped into open reservoirs and thence to the preparation facilities near the North Fork of the Holston River on the north of Saltville. A typical brine analysis of the dissolved salts runs 97.792% NaCl, 0.033% CaCl, 2.17% $CaSO_4$, and trace amounts of AL, Si, and Fe (Watson, 1907).

Until 1968 Olin-Mathieson used a 3-mile long aerial tramway to bring limestone from their quarry to the Saltville plant. $CaCO_3$ is utilized in processing the salt into soda ash and other chemicals. The limestone is extracted from a quarry pit of Middle Ordovician age (Moshannon equivalent). A typical analysis of the limestone is 97.03 % $CaCO_3$, 1.24% $MgCO_3$, 1.64% Si, Al and FeO (Watson, 1907). Soda ash is used in chemicals and in glass manufacture, caustic soda in the

paper industry, chlorine in water purification and sodium bicarbonate in baking (and for upset stomach), to name only a few uses of these products. Production figures have not been released from official sources but the size of the operation can be shown by the fact that nearly 900 persons are employed by Olin-Mathieson at Saltville and 700 of these in the soda ash operation (Goldsmith, 1970).

## Pollution Problem

Extraction and production has created some problems from the early 1800's to the present day. Watson (1907) noted roof collapse problems were prevalent as early as 1842. A huge cave-in mars the hillside south of Saltville and cracked streets and cracked plaster in homes have been part of the price Saltville residents pay to the source of their livelihood. The most serious problem has been the downstream water pollution caused by discharge of industrial wastes into the North Fork. Even as far downstream as Knoxville the effect of the Saltville operation is an economic liability through the increased cost of chlorine removal in the preparation of Knoxville's public water supply (Washington County News, Jan. 8, 1970). The degree of water pollution can be seen from the following water analysis comparison (Collins and others, 1932):

| | Amounts in PPM | | |
|---|---|---|---|
| Location | Ca | Na | Cl |
| North Fork above Saltville | 29 | 2.2 | 1.5 |
| Mendota, Va. (ca. 35 miles downstream) | 419 | 401 | 1,347 |
| South Fork at Kingsport, Tenn. | 17-31 | 2.1-3.3 | 1.1-6.0 |
| Rogersville, Tenn. | 44-73 | 3.9-5.9 | 11-134 |
| Knoxville, Tenn. | 27-37 | 5.[illegible]-19 | 12-34 |

Compared to water above Saltville that at Mendota contains about 200 times more sodium, 15 times more calcium, and 900 times more chlorine. The water at Mendota is not suitable for any ordinary use during much

of the year and the entire North Fork is probably useless as a source of industrial or domestic supply, according to Collins' report. L. M. Roznoy, Olin-Mathieson spokesman, states that there is no technical method known by which to treat the wastes to meet the newly enforced standards of the Virginia Water Commission. As a result the soda ash operation is slated to close before December, 1972, and 700 workers will be given their last paycheck unless other industry can be brought into Saltville (Goldsmith, 1970).

## Conclusions

The Saltville evaporite deposit is a unique example of a transitional form, unlike the relatively undisturbed bedded salt of Michigan and the intruded salt masses of the Gulf Coast and Northern Germany, but combining features of both. Evaporites accumulated in shallow coastal basins during Maccrady deposition in Late Mississippian time. Subsequent deep burial in the Appalachian trough provided the geostatic force to cause segregation of the salt into pillow-like masses or lenses. Late Paleozoic folding and thrust faulting further concentrated these salt bodies along the compressional frontal footwall of the thrusts. Contortions in the incompetent Maccrady shale make the analysis of evaporite emplacement controversial and the exploration for additional deposits difficult.

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