Geology of the Salt and Gypsum Deposits in the Saltville Area Smyth and Washington Counties, Virginia

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ABSTRACT

Salt and gypsum deposits in the Saltville area of Smyth and Washington counties, Virginia, occur in the Maccrady and overlying Little Valley Formations of Warsaw (Mississippian) age in the great Greendale syncline which was a depositional syncline. Much of the salt and most of the gypsum occur in the upper, plastic-shale member of the Maccrady Formation in association with anhydrite, gypsum, dolomite, and impure limestone. The salt, at least in the overturned limb of the Greendale syncline, occurs largely, if not wholly, as tectonic breccia that was apparently generated in localized quasi-straligraphic zones so as to incorporate as cataclasts pieces derived from intercalated anhydrite, dolomite, gypsum, and shale. The characteristic pinkish or salmon-red color of the salt matrix of the tectonic breccias is the result of fine dissemination of red shale which abounds in the upper Maccrady. Some salt and gypsum occur also in the Little Valley Formation. Some of these evaporitic beds appear to be primary, but there is also considerable salt and gypsum-anhydrite occurring as matrix minerals in autoclastic breccias and in veins. The original sulfate mineral must have been anhydrite. Some structural control of hydration is indicated, especially from North Holston northeast to Locust Cove.

The structure of the salt and gypsum beds is very complicated as a result of the overriding of the southeast recumbent limb by Cambrian rocks forming the sole of the Saltville Thrust. A double thickness of the Maccrady produced by strong overturning of the upper limb of the Greendale syncline occurs in the Saltville area. The salt- and gypsum-producing district is characterized by slices of older (pre-Maccrady) strata which must have been sheared off the footwall or tread of the Saltville Fault and carried along by ramping up the main fault surface along with the overlying older rocks.

From all indications, salt is restricted to the local vicinity of Saltville, which is the sole producing district. Gypsum, produced both at Plasterco and at Locust Cove, is considered the result of shallow hydration by seepage water. Considerable commercial gypsum is indicated to be present between Locust Cove and North Holston.

Saline seepages from Palmer Springs south of Saltville have been in existence probably for thousands of years and served as a lure for the Pleistocene mammalian hordes that roamed the Appalachians during Wisconsin time.

Salt is extracted by dissolution by high pressure brine wells. Gypsum is mined by various processes depending upon the structural condition of the gypsum masses which appear at Plasterco to be the result of some flowage into pods.

The two mineral industries operating in the district are U. S. Gypsum Company with mines at Plasterco and Locust Cove, and the Olin Mathieson Chemical Corporation which is situated at Saltville.

INTRODUCTION

Of all the known deposits of commercial-grade salt and gypsum in the United States, probably less has been written about the Virginia deposits than any of the others. The evaporite deposits in Smyth and Washington counties (Fig. 1) have been described in a brief way by Jefferson in 1781, Watson (1907, p. 21), Taylor (1840), Fontaine (1881), Hotchkiss (1881), Robertson (188 Stevenson (1885, 1887), Rogers (1836a, 1836b, 1884), Radcliffe (1884), Eckel (1902, 1904), Watson (1907), Stose (1912, 1913, 1920), Butts (1933, 1940), Withington (1965), and others. Of thes papers, only the contributions of Stose, Watson, Eckel, Stevenson, and Withington contain material that is pertinent to a fundamental understanding of the Virginia salt and gypsum deposits (Fig. 2).

Only the work of Stose and of Withington need be alluded to in any detail. Stose's geologic maps and cross sections (1913) provide an excellent interpretation of the geologic structure considering the information available at that time. These maps and sections show that he had a ver clear grasp of the general geology of the salt and gypsum deposits, and appreciated clearly the involvement of the Maccrady and other Mississippian formations in a major synclinal structure which was partially overridden by a thrust block that had moved northwestward along a low-dipp fault surface -- the Greendale syncline and the Saltville-Bland Fault of Butts (1942, p. 457). Stose's ideas on the origin and emplacement of the salt were erroneous. Withington's (1965) review expresses ideas and concepts that are unsupported by many of the basic facts of occurrence of the evaporites.

The writer began his study of the salt and gypsum beds in 1948 and has mapped these beds on scales varying from 1:8,000 to 1:24,000 between Plasterco and the southwest corner of the Burkes Garden quadrangle, near Ceres, Bland County, Virginia (Cooper, 1944), and he has studi most of the known occurrences of Maccrady red beds in Virginia, which is the main formation containing evaporitic deposits.

Probably the sparse attention that has been paid to these salt and gypsum deposits stems mainly from poor exposures and restricted access to certain critical areas and sources of information. Much of the information that is vital to an understanding of these deposits depends upon studies of well cuttings and diamond drill cores and detailed mapping.

This report is a general summary progress report which the writer hopes will be superseded by a much more comprehensive and detailed report to be accompanied by a 1:24,000-scale colored geologic map and cross sections covering the Chatham Hill, Maccrady, Saltville, and Glade Springs 1:24,000 quadrangles. It is not considered appropriate in this paper to present an exhaustive review of the literature or of previous work.

GEOLOGIC SETTING

The Virginia salt- and gypsum-bearing beds occur chiefly in the Maccrady Formation of Warsaw age in the Mississippian System. The Maccrady between Plasterco, Washington County (Fig. 2), and Locust Cove, Smyth County (Fig. 11), is exposed in one belt along the southeast base of a prominent northeast-trending ridge variously known as Little Mountain, or Brushy Mountain (Butts, 1933, 1940). This belt forms the northwest limb of the Great Greendale synclin Locally, as between North Holston and Locust Cove (Figs. 9-11), this belt is bordered by rocks overthrust along the Saltville Fault, but in other places, as at Locust Cove, at and northeast of Broadford, and at Saltville, there are segments of another more southeasterly belt of Maccrady red beds, which comprise exposed portions of the overturned or steeply upturned southeastern limb of the same syncline. The trough of the Greendale syncline northeast of Plasterco is well defined by reversals in direction of dip in the Mississippian limestone formations including the Little Valley, Hillsdale, "Ste. Genevieve," and "Gasper" Limestone Formations which form the hilly area between State Highway 91 and the North Fork of Holston River, which has been aptly named the Sinkhole Knobs.

Between Plasterco and Locust Cove, a distance of about 16 miles, the Saltville Thrust is marked in many places by subsequent fault-line scarp. The fault contact follows close to the bas of an irregular line of high hills upheld by Cambrian and Cambro-Ordovician dolomites and interalated shales. In many places, the fault contact is marked by springs which issue from the fractured overthrust Cambrian rocks forming the hanging wall of the thrust. The most unusual

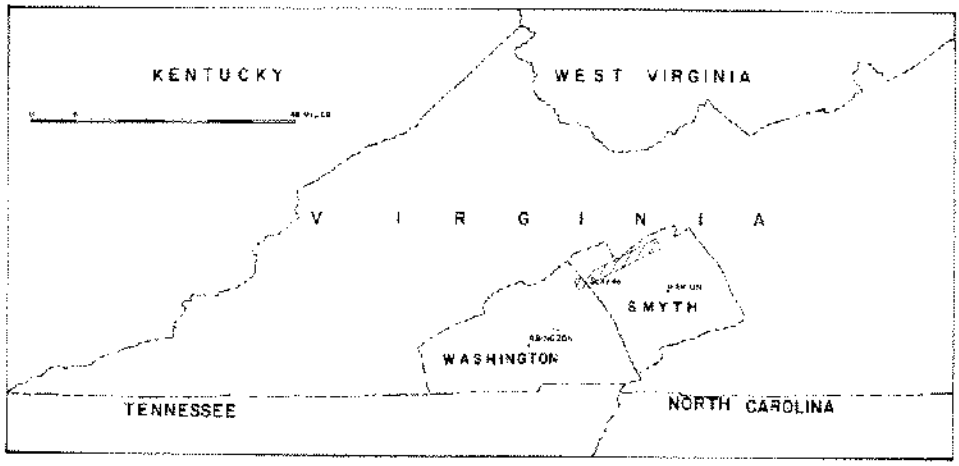


Figure 1. Index map of Saltville-Locust Cove district, Smyth and Washington counties, Virginia.

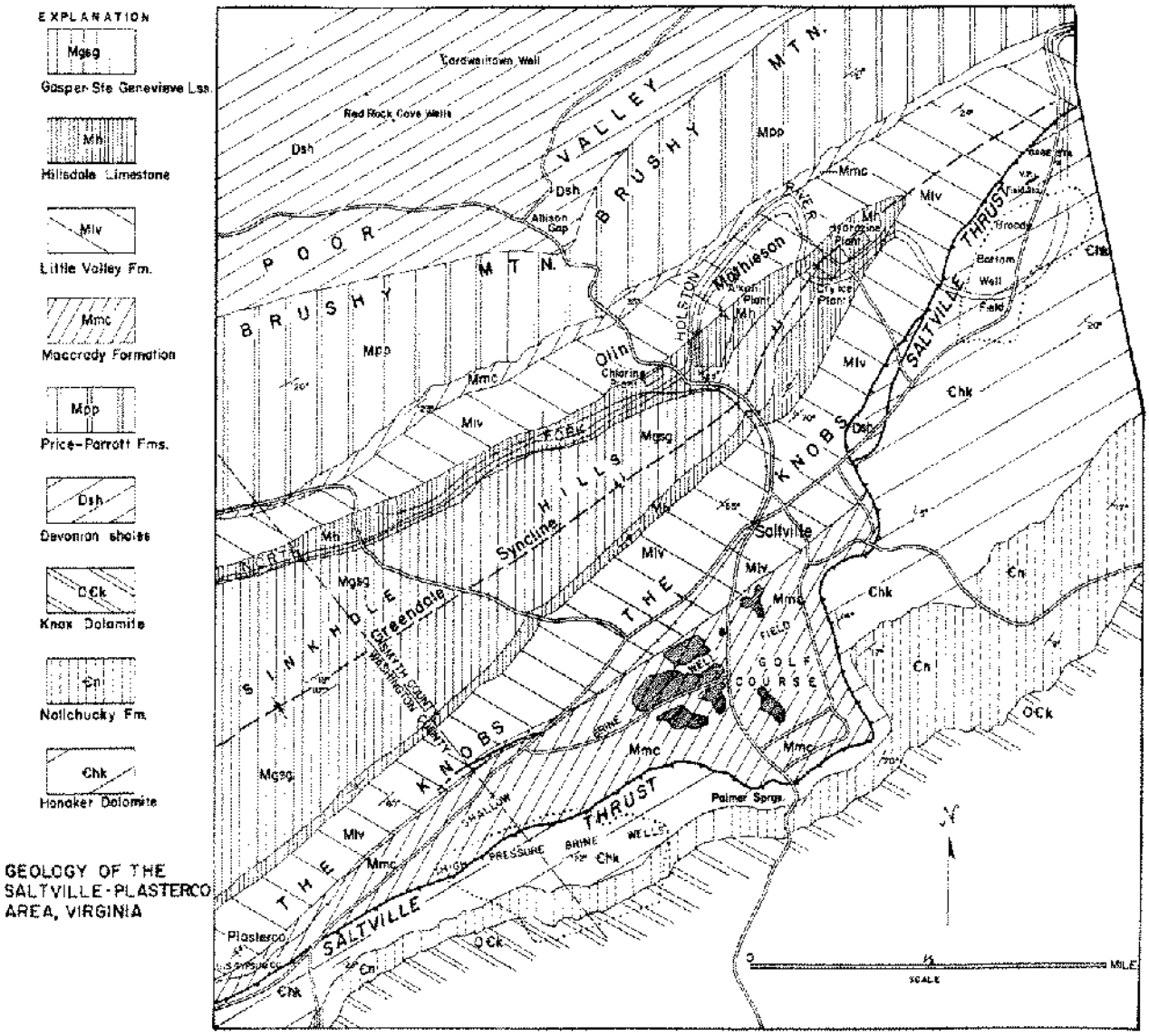


Figure 2. Geology of Saltville, Virginia, and environs.

one of these many springs is Palmer Springs situated in the deep embayment of the fault trace in the south environs of Saltville.

The area of study is a belt of relatively low ground, varying in width from 1 to 3 miles, and lying between the sandstone ridge on the northwest and the high hills of overthrust Cambrian rocks to the southeast of State Highways 91 and 42.

STRATIGRAPHY OF INDIGENOUS ROCKS OF GREENDALE SYNCLINE[1]

Price and Parrott Formations

The steep southeast faces of Little Mountain and Brushy Mountain are dip slopes armored with coarse quartzose sandstones and pebble conglomerates of the Osagean Price Formation and thinner-bedded rusty-weathering siltstones and sandstones of the Kinderhookian Parrott Formation The upper 40 feet or so of the Price, which is fully exposed along State Highway 91 just northeast of North Holston consists of thin sandstones, siltstones, and black shales with thin coaly streaks. The upper contact with the overlying Maccrady beds is arbitrarily drawn at the base of a prominent and persistent zone of chocolate-brown to maroon-drab siltstone and fine-grained sandstone characteristically variegated with green blotches.

The Price quartzose sandstones extend to or nearly to the top of the ridge and in places form an overhanging bluff on Brushy Mountain such as can be seen readily by looking southwestward toward the south side of Watson Gap near North Holston and in the same direction through Laurel Creek Gap at Broadford. The thickness of quartzose sandstones and associated shales and coaly zones is probably close to 450 feet at Broadford. The coaly zones are approximately equivalent to the Merrimac and Langhorne coals of the Price Formation in Pulaski and Montgomery Counties (Campbell, 1925).

The Parrott Formation underlying the Price is probably not included on the geologic maps shown in Figs. 3, 6, 9, and 10 but this unit, formerly constituting the lower part of the Price Formation, is included in belts mapped under the symbol Mpp.

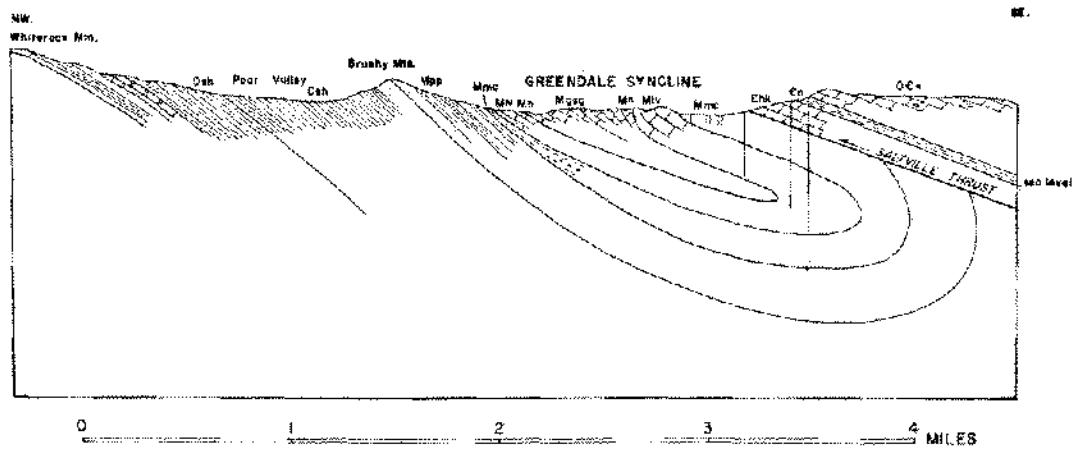


Figure 3. Geologic section through Saltville, Smyth County-Washington County line, Virginia.

Maccrady Formation

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.

[1]For purposes of this presentation only the beds between the limiting ridge on the northwest and the hills southeast of Routes 91 and 42 need to be described.

Along the southeast slope of Brushy Mountain between Allison Gap and Saltville, a well exposed section of Maccrady is about 135 feet thick. The greater part of that thickness is medium-bedded, somewhat concretionary-weathering red and green variegated sandstone with intercalations of red fissile shale. A few yellow-green shales and earthy limestones occur about 30 feet below the top, and the uppermost 10 or 20 feet of the formation are red, green, and gray unctuous shales in which bedding is characteristically somewhat distorted. This approximate thickness or, locally, even a little less is characteristic of the Maccrady belt along the base of Brushy Mountain all the way from Saltville and Allison Gap southwest to U.S. Route 91 north of Abingdon, Washington County, Virginia.

Northeastward from Allison Gap and Saltville, the Maccrady belt at the base of Brushy Mountain thickens gradually and at North Holston, 3 miles from Saltville, it is about 250 feet thick. The basal maroon-drab siltstone unit is about 100 feet thick, a medial zone of earthy dolomites and calcareous shales is about 25 feet thick, and the upper 125 to 130 feet is red, gray, and green plastic clay shales composed chiefly of illite but some of which is degraded into mixed-layered clays of montmorillonite type. These shales have unusual or rather remarkable physical properties, the most pronounced characteristic being the tendency to disintegrate and flocculate on contact with water. From Maccrady northeastward to Locust Cover, the upper or plastic shale member contains showings of gypsum (selenite and satin spar) but no salt, but few of the gypsum showings are anywise impressive. Much of the exposed gypsum is cross-fiber satin spar veins in red and green shales, but some soft massive gypsum is exposed in old pits 1.2 miles southeast of Broadford.

From Broadford northeastward to Locust Cove, the Maccrady Formation consists of these three well-defined members, as shown in Fig. 5. The progressive northeastward increase in thickness of the Maccrady in the Brushy Mountain belt is almost entirely achieved by thickening of the upper or plastic shale member toward Locust Cove. Northeastward from State Highway 16, which crosses the Maccrady belt 2 miles northeast of Locust Cove, the medial or limestone member and the upper plastic shale member begin to decrease in thickness and farther northeast are essentially absent beyond Lick Creek in northeastern Smyth County.

The cross section shown in Fig. 3 delineates the great change in thickness of the Maccrady in the Saltville area between the northwest outcrop belt and the southeast belt which is overturned and recumbent upon an infolded core of Little Valley Limestone (Fig. 3). In some of the deeper wells of the High Pressure Brine Field the Maccrady beds are 1,500 to 1,700 feet thick, including hundreds of feet of salt and lesser thicknesses of gypsum, anhydrite, dolomite, and limestone -- which are shrouded in the upper or plastic shale member of the Maccrady Formation. This inordinate increase in thickness signifies profound localized downwarping in an ancient evaporating basin with evaporating conditions suitable for localized deposition of salt and anhydrite. The full extent of these salt and gypsum basins is unknown and they cannot be inferred from geologic data that are available. Although the conclusion is somewhat intuitive and conjectural, the writer believes that the evaporite basins were very localized and virtually confined to a belt or area of very limited width and moderately limited length, but probably extending back under the Saltville overthrust block for perhaps as much as two miles.

The old brine wells marked by the old gray wooden sheds on the rolling bottoms of Saltville are located in the upper, recumbent limb of the Greendale syncline (Fig. 3). Some well records show an aggregate of 800 feet of salt, spread through 12 to 20 different zones. Dissolution of salt from these beds by percolating ground waters and due to the pumping out of brine for many years has led to the slow differential subsidence of the surface ground and consequent development of the hummocky, ponded topography which characterizes the Saltville area.

In Locust Cove (Fig. 6), core drillings discovered beds of commercial gypsum up to nearly 50 feet thick. A bore hole put down in the axial portion of the syncline showed over 1,250 feet of Maccrady, whereas less than 0.5 mile to the south the whole Maccrady Formation is only 340 feet thick. Locust Cove like the Saltville-Plasterco area must have been a part of the main evaporating basin, or possibly a separate one in which no salt and only anhydrite and possibly some dolomite were deposited by the evaporating waters. These evaporites were shrouded in clays and were more or less protected from subsequent natural dissolution.

To summarize, between Saltville and Locust Cove the Maccrady Formation thickens to the southeast and by the association of rock salt, gypsum, anhydrite, dolomite, and enveloping red, gray, and green shales surely must have been deposited under conditions of an evaporating salt basin whose profoundly differential consedimentation downwarp coincided approximately with the axis of the present Greendale syncline. The tectonic framework of sedimentation during Maccra time has been discussed by the writer in another paper (Cooper, 1963, pp. 93-95). Thickness variations in critical points are shown in Figs. 4 and 8.

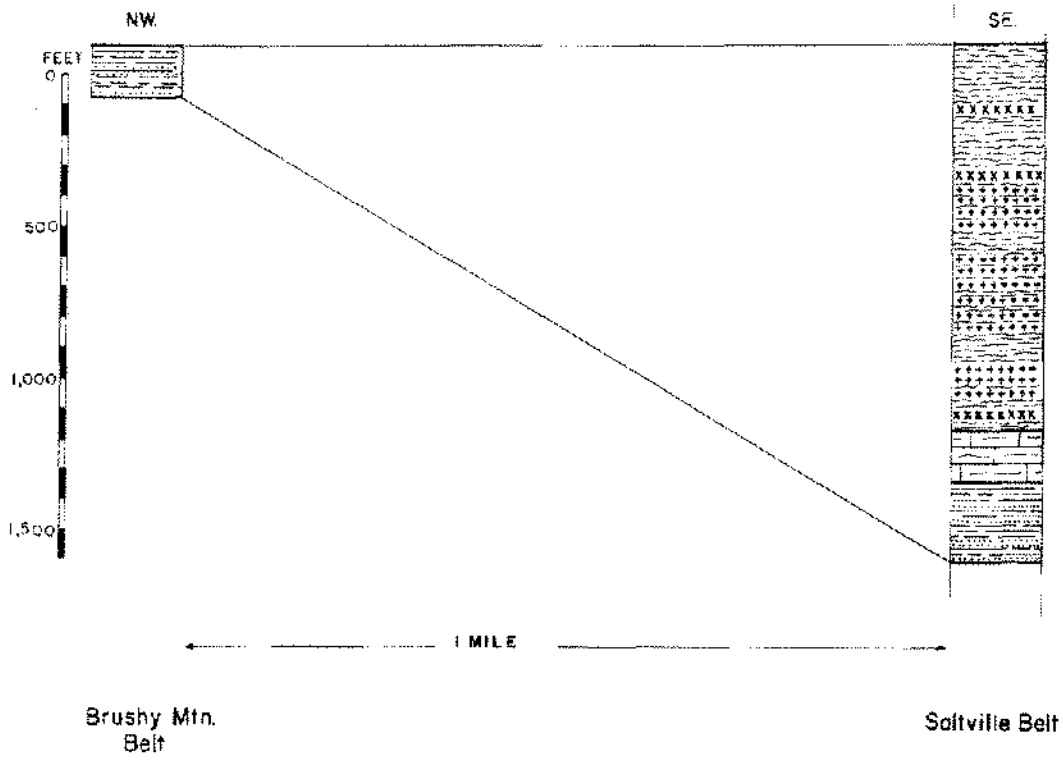


Figure 4. Thickening of Maccrady beds in Greendale syncline at Saltville, Virginia.

The name Maccrady poses some humorous aspects. Originally proposed by Stose in 1911, Maccrady was applied to a succession of beds exposed in a town of the same name, which was spelled Maccrady on U. S. Geological Survey topographic and TVA maps. Highway maps and markers and the newer 1:24, 000 contour map of the Maccrady Quadrangle spell the village name "McCready." The discrepancy needs to be resolved by the Department of Interior's Board on Geographic names. The writer interprets "McCready" as a corrupted spelling.

Little Valley Formation

This distinctive formation is composed of yellow- to brown-weathering impure limestones and calcareous shales and sandstones. Between Plasterco and Locust Cove less than 500 feet of Little Valley beds are present but the upper portion is not preserved. The line of conspicuous knobs immediately northwest of the flats of Saltville is upheld by a prominent zone of brown-weathering calcareous sandstone 25 to 50 feet thick. The rest of the formation, where fresh, is blue-gray, as exposed along State Highway 91 just southwest of Maccrady. But in the area from Broadford to Locust Cove, the Little Valley Formation as exposed is nearly all yellow- to brown-weathering punky shale largely leached of original lime. In places the Little Valley beds as exposed are hard to distinguish from the overthrust Cambrian beds which also weather a light yellowish color. Fossil fragments including crinoid columnals, small corals, and brachiopods,

but mainly fragmented bryozoans provide a reliable basis for identifying beds as Little Valley rather than part of the overthrust block of Cambrian rocks.

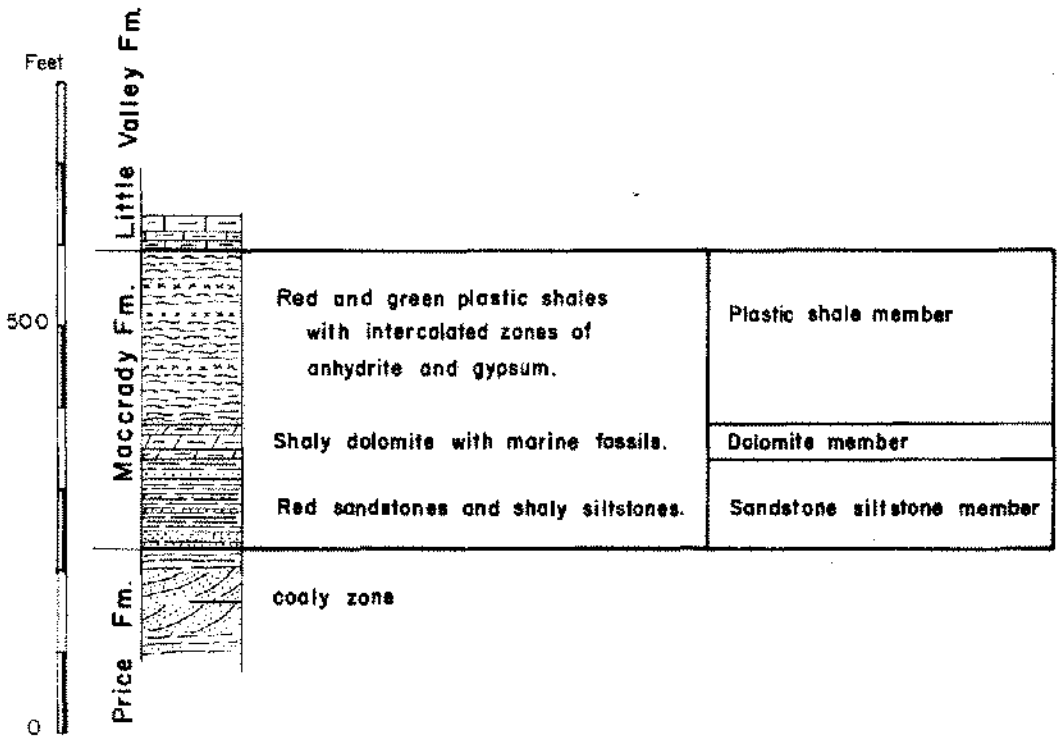


Figure 5. Maccrady Formation as developed along the northwest belt of outcrop between Broadford and Locust Cove, Smyth County, Virginia.

The lower part of the Little Valley Formation -- lithologically transitional with the upper plastic shale member of the Maccrady Formation -- locally contains evaporitic beds of salt, gypsum, and shaly dolomite, but these beds are known only from well cuttings and cores in the Saltville-Plasterco sector.

Hillsdale Limestone

In the Sinkhole Knobs country formed by thick limestones in the Greendale syncline, as shown in Fig. 4, the Little Valley Limestone with a total thickness of about 550 feet is overlain by about 250 feet of beds most of St. Louis age and which in the past have been commonly referred to by that name. The correlation is not self-evident from the faunas in the succession, and the name Hillsdale Limestone (Reger, 1926; Cooper, 1944) is considered more appropriate. The lower 30 to 50 feet of the Hillsdale is composed of exceedingly fossiliferous shales which yield superb fossils different from those normally noted in the Hillsdale in other Appalachian belts. The shales and siltstones are underlain by black, cherty limestones containing characteristic fossil algae, Lithostrotionella, and Syringopora corals. The upper boundary of the Hillsdale is transitional with the overlying limestones. The Hillsdale is abundantly exposed in the Greendale syncline southwest from Saltville, but the southwest plunge of the syncline terminates the Hillsdale belt of outcrop within the town limits of Saltville. The Hillsdale has about three times the thickness it has in the more northwesterly Hurricane Ridge syncline of Tazewell County, Virginia.

"Gasper" and "Ste. Genevieve" Limestones

The youngest beds in the Saltville District comprise hundreds of feet of dark-gray fossiliferous limestones which Butts (1933, 1942) referred to as Gasper and Ste. Genevieve Limestones.

The fact that these formations in aggregate are five to seven times as thick as the Mississippi Valley formations so named and the added fact that the faunas of these beds in Virginia are very poorly known make it advisable to use the names "Gasper" and "Ste. Genevieve" only in a very loose stratigraphic sense.

The thickness of limestones above the Hillsdale in the Sinkhole Knobs of the Greendale syn cline north of the High Pressure Brine Field probably does not exceed 300 feet, and, therefore, is likely that all these beds are actually referable to the "Ste. Genevieve" division. The charac teristic lithologies of the "Ste. Genevieve" are sparites and oolites, some of which bear the spi nose, elliptical columnal plates of the crinoid Platycrinites which Butts regarded as a positive indication of the "Ste. Genevieve."

STRATIGRAPHY OF THE OVERTHRUST CAMBRIAN ROCKS

Rome Formation

The Cambrian Rome Formation crops out northeast of Broadford. It is composed of red, green, brown, and blue-gray shales interbedded with sienna-brown-weathering dolomites and blue-gray magnesian limestones. The shales have been subjected to intimate crushing and brec ciation, and much of the weathered rock at the surface has the consistency of saw dust. The limestones and dolomites are commonly impregnated with vein calcite that defines fine fracture systems. The outcrops of the Rome are poor which is further evidence of brecciation. Howeve the abundant shale chips in the soil are a diagnostic criterion for recognizing the formation whe it is covered. The thickness can only be estimated in a general way to be at least 800 to 900 fee

Honaker Dolomite

From Plasterco to North Holston and also in the Locust Cove region the sole of the Saltvil Fault is made by the Honaker Dolomite of Middle Cambrian age. Except for the basal 300 feet o so, which contains laminated limestones like the Maryville Limestone of Tennessee, this forma tion is composed primarily of dark-gray to light-gray fine-grained dolomite much of which is so intimately autobrecciated as to constitute a rubble. This intimately fractured condition is not possessed by any other dolomite in the Appalachians except by equivalent beds in the Elbrook Formation which is not recognized northwest of the Pulaski block. In some places the Honaker Dolomites are so broken that the rock can be quarried without blasting. Typical exposures occu just south of North Fork of Holston River bridge near Broady Bottom; at several places along Route 42, near Riverside and New Cove School; and in a small roadside quarry on Route 42 abo 1 mile northeast of Locust Cove.

There are zones of irregularly striped buff and blue-gray magnesian limestone sandwiche in with the more preponderant dolomites. The limestones are never as brecciated as the dolo- mites. The total thickness of the Honaker is probably 1,700 feet in the Chatham Hill-Locust Co area, but there are no exposures offering conditions for accurate measurement. In the High Pr sure Brine Field some wells cut nearly 1,000 feet of overthrust most of which is Honaker Dolo- mite.

Nolichucky Formation

Although this formation does not form the sole of the fault, the Nolichucky plays a vital ro in the economic geology of the salt-producing area of Saltville. The Nolichucky is predominantl shale and shaly limestone with a thickness of close to 400 feet. The shale is commonly gray- green to brown with the latter color invariably developed wherever the shale has been oxidized and decalcified. The Nolichucky constitutes an impermeable membrane or canopy which has pr vented to some extent the drainage from the superior areas of Rich Valley to the southeast from feeding freely into the fractured Honaker along the Saltville Fault. Nevertheless, considerable water has impregnated the fault zone to produce the saline egress at Palmer Springs but this must be local ingress water derived northwest of the ridge country defining the northwest side o Rich Valley. Northeast of Saltville and also southwest of town streams have deeply embayed the outcrop of the Nolichucky, allowing the abundant ground waters and surface runoff to impregnate the Honaker and remove salt if any were ever present. Thus in these sectors the effect of the

Nolichucky to deflect underground drainage from Rich Valley from freely invading the Honaker Dolomite along the fault and moving freely down into the Maccrady Formation -- particularly in the five-mile segment of Nolichucky which has remained unbreached by surface streams heading in Rich Valley, between Plasterco and North Holston. This unbreached segment contains the only known deposit of salt.

Knox Dolomite

The Nolichucky Formation is overlain by a thick succession of dolomites and limestones, the lower part of which forms the crest of the prominent line of ridges separating Rich Valley from the lower country along the North Fork of Holston River. These lower Knox beds, commonly identified as Copper Ridge Dolomite, are characterized by blocky oolitic cherts and by sandstone zones one of which occurs at the base of the Knox.

In the southern portion of the High Pressure Brine Field, the Copper Ridge cherts and sandstones are prominently exposed. Mention of the beds is made here only to provide minimal description of all the rock units shown on Figs. 2 and 3.

STRATIGRAPHY OF SLICES ALONG THE SALTVILLE THRUST

Between Saltville and State Highway 16 north of Chatham Hill, Smyth County, Virginia, there are three separate, wedgelike slices of highly deformed beds, which occur between the overthrust Cambrian beds of the Saltville block and the indigenous beds involved in the great Greendale syncline. As shown on Fig. 2, there is a prominent slice of Upper Devonian sandstones and shales which reaches from hills just south of State Route 91 across the road and thence northeasterly nearly to Elizabeth Cemetery, adjoining portions of the site for the new elementary school. Devonian shale occurs below the Saltville Thrust in well no. 1 in the Broady Bottom Well Field of Olin Mathieson Chemical Corporation near the river. This slice has a maximum thickness of about 400 feet and in a few places the beds composing the slice appear to be upside down.

In the vicinity of Maccrady (Fig. 9), there are slices of overturned beds containing a much thinned succession of beds varying from the upper Martinsburg to the Upper Devonian Brallier Formation. These slices, delineated in Fig. 9, have been recently mapped in detail by A. E. Ross, a former graduate student in the V. P. I. Department of Geological Sciences.

The bedrock formations composing the slice brought up by the Saltville Thrust between eastern Saltville and North Holston pose some of the perplexing problems of Appalachian geology. As shown in Table I, the noted thicknesses of different parts of the succession of formations suggest abnormal thinning. The Huntersville and Rocky Gap on Clinch Mountain normally aggregate 100 to 125 feet of beds; the Tonoloway and Keefer 200 feet; the Rose Hill 125 feet; the Clinch 100 feet; and the Juniata about 300 feet.

The fact that the succession in the slice is upside down encourages one to rush to the conclusion that the beds are thinned by faulting attending thrust transport up the tread of the Saltville Thrust, and, indeed, this may be true. However, it is not necessarily true and the alternate explanation must be given equal consideration. Possibly the formations in the slice represent a truly thinner succession that was deposited where there was less access of sediment. Possibly also the thinness of the succession might have tended to encourage detachment from the tread of the Saltville Thrust and to facilitate overturning of the beds by drag and detachment along the fault zone.

Too often Appalachian geologists have assumed quite incorrectly that all formations originally were deposited as great uniform sheets of strata each with a characteristic thickness that did not change very much from place to place. Any detailed study of Appalachian formations discloses overwhelming evidence of local stratigraphic variations both in thickness and lithology. One with the "layer cake" stratigraphic view of the Maccrady-North Holston Thrust slice would probably jump to the conclusion that the thin succession of normally thicker formations was the result of faulting. The writer confesses an inclination imposed by his particular experience to be biased the other way.

TABLE I

FORMATIONS COMPOSING SLICE BETWEEN HONAKER DOLOMITE AND INDIGENOUS MISSISSIPPIAN FORMATIONS OF THE GREENDALE SYNCLINE NEAR MACCRADY, SMYTH COUNTY, VIRGINIA

Name of units	Thickness (feet)	Map Unit	Description
"Devonian shales"	1500	Dsh	Includes 500 feet of Millboro black shale and 1000 feet (at least) of the overlying Brallier rusty-weathering sandstones and drab-gray shales.
Huntersville and Rocky Gap Formations	40	Dhrg	Upper 25 feet composed of sandy chert, poorly exposed (Huntersville); lower 15 feet soft, crumbly sandstone (Rocky Gap).
Tonoloway and Keefer Formations	70	Stk	Upper 20-25 feet composed of gray dolomitic limestones, poorly exposed (Tonoloway); lower 20-25 fee is buff quartzite (Keefer).
Rose Hill Formation	45	Srh	Shale and hematite-cemented sandstones, poorly exposed.
Clinch Sandstone	50	Sc	Buff-gray blocky thin-bedded orthoquartzite.
Juniata and Martinsburg	200±	Ojmb	Upper 50 to 60 feet is red shale and red cross-laminated sandstone; lower 150 feet includes at least "Maysville Division" of Martinsburg Formation, composed of calcareous siltstones and shales with Lingula nicklesi.

By far the most extensive slice occurring along the Saltville Thrust is that located between New Cove Church and Locust Cove (Fig. 8). This great slice of somewhat crumpled shale, siltstone and sandstone contains portions of the Price and Parrott Formations and possibly Portage and Chemung clastics -- all of which are of the same general lithofacies. Brecciation of the sandstones and siltstones in this slice is intimate and in places the slice appears to have been somewhat dismembered by being crushed and rolled out. Very high Devonian or basal Mississippian brachiopods have been collected from the slice on the hill west of Locust Cove. The beds seem to be upside down in the places where the structure can be worked out. As shown in Fig. 8, the extent of the slice easily makes it the largest of its kind known in southwest Virginia.

In the Locust Cove area, there is another slice between the main overthrust block and the indigenous beds, which is composed of right-side-up beds ranging from Price to Maccrady in age.

The general significance of all these slices is that they indicate a gentle dip to the Saltville Thrust back to the southeast from the trace of the fault and a strong overturning probably due to drag of a thick succession along the footwall of the fault during movement of the upper block, from which frictional movement dislodged portions of the tread rocks below the overthrust block so that the slices were 'dozed forward up the dip of the fault by the moving thrust mass. The mechanics of displacement are very difficult to visualize and understand. The slices are composed largely, if not wholly, of incompetent beds amenable to maceration and rolling out, yet the slices are remarkably sound -- even the Devonian and Mississippian shales.

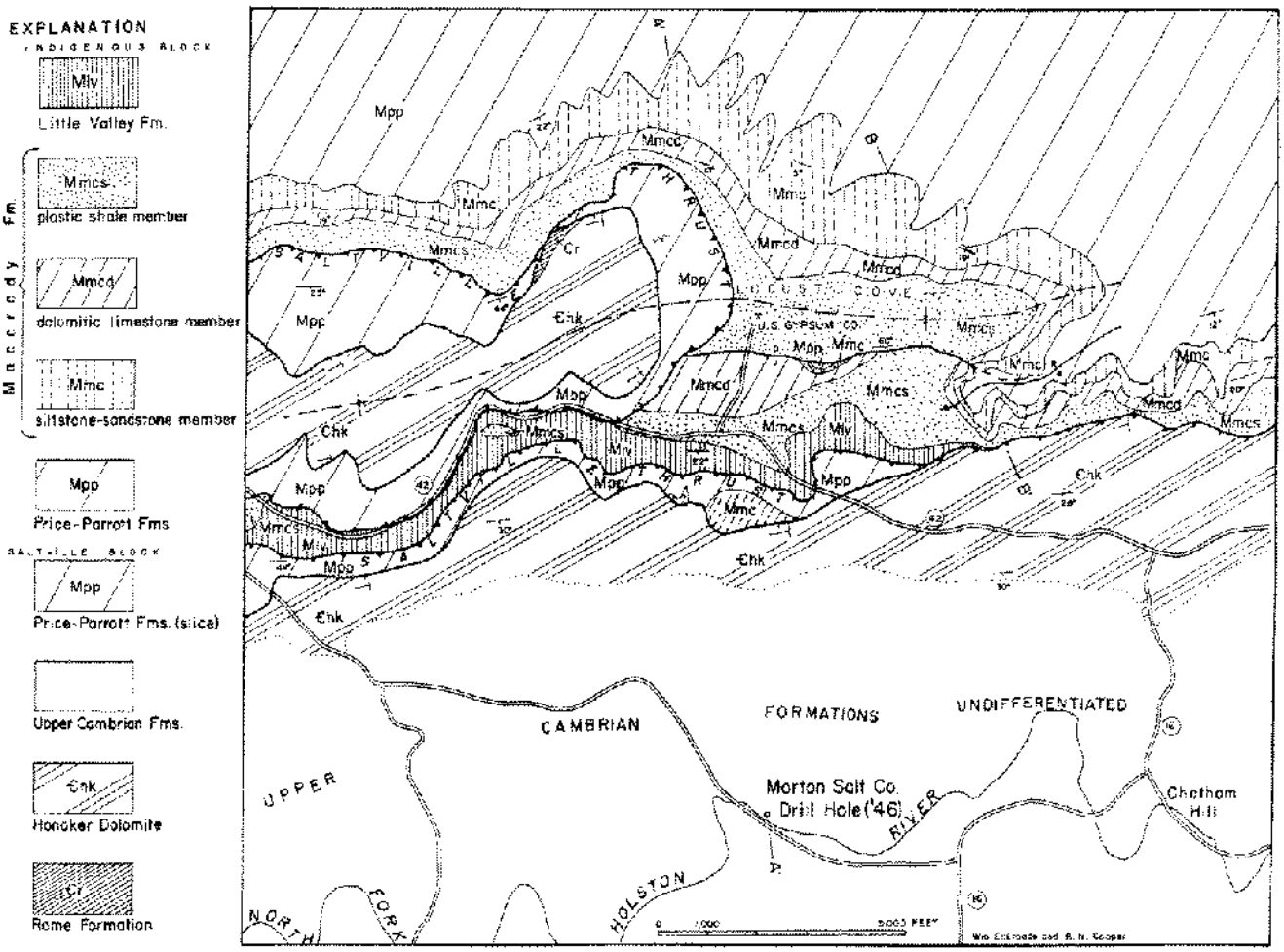


Figure 6. Geology of the Locust Cove area, Smyth County, Virginia.

STRUCTURE

The structure of the salt and gypsum succession and related beds above and below is delineated in Figs. 3, 7, and 11. The dip of the Saltville Thrust southwest of Palmer Spring is 15 to 18 degrees but it lessens to near horizontality in circling eastward around Saltville. Beyond the northeast deflection of the fault trace in the eastern section of Saltville, the fault dips about 20 to 25 degrees southeast and this general inclination holds nearly to Locust Cove where there is a general flattening of the thrust and a synclinal downwarp of the fault surface, a projecting salient of the supercumbent overthrust Cambrian beds coincides with and is lodged in a downfold in the indigenous Mississippian beds forming Locust Cove.

The fault is exceptionally well defined near the McKee Hospital along new State Route 107 (which is not shown on Fig. 2). From North Holston southwest to and beyond Plasterco, the fault contact is marked by a zone of secondary jasperoid produced by silicification in the bottom of the overthrust Honaker limestones and dolomites. Blocks of this siliceous rock litter the surface on the steep slopes below the fault contact. In places this silicified dolomite which breaks off in large blocks resembles the colluvium blocks from the Clinch Sandstone on typical obsequent slope of nearby Appalachian Silurian ridges. The dip of the fault in the High Pressure Brine Field is readily established from well records. Farther east the fault whose trace is essentially parallel to contours probably dips eastward but there are no well data to prove the direction or amount of dip.

Dips in the overturned recumbent Maccrady beds are highly contorted but in general the bed are strongly inverted and locally crumpled, and very likely the beds directly below the Saltville Fault are somewhat dismembered by frictional drag. The diagrammatic representation given by Stose (1913, p. 59) for the fault contact along Route 91 at the east limit of Saltville is quite accurate.

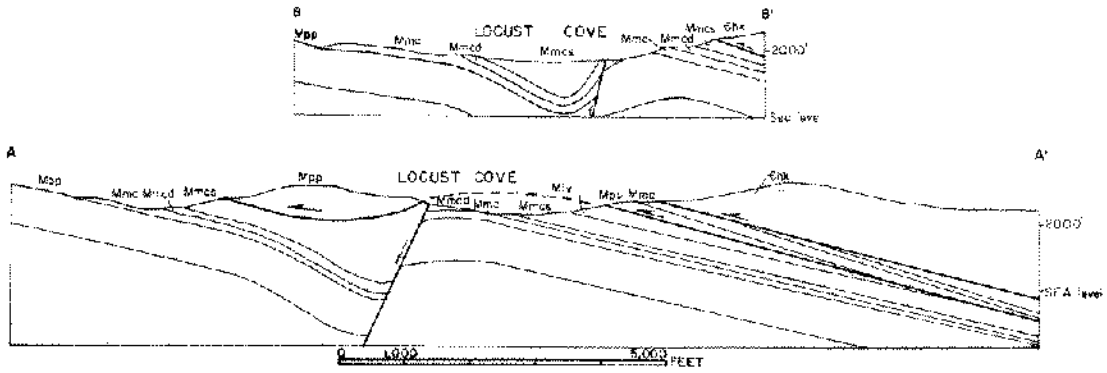


Figure 7. Geologic cross sections through Locust Cove, Virginia.

In the Saltville area the overthrust rocks dip southeast at angles up to 30 degrees, but northeast of North Holston to near the west edge of Locust Cove the beds along the fault are parallel to the dip of the fault.

In Saltville where the thrust deflects northeastward and runs subparallel to State Highway 91 a detached slice or "horse" of Devonian shale is evident between the overthrust Cambrian and overridden Mississippian. This slice was evidently plucked off the tread of the fault down dip and carried along with the overthrust rocks.

Beginning just east of the river in the eastern environs of Saltville, there is another fault slice including beds of Maysville to Portage age which was first recognized by Stose (1913, p. 56). The ridge south of the North Fork of Holston River at Maccrady is upheld by Silurian quartzites of this slice.

The Maccrady belt between Maccrady and North Holston is homoclinal -- the northest limb of the continuation of the Greendale syncline. This is the area in which Southern Gypsum Company and later National Gypsum Company mined down under the river and overthrust rocks until the spring of 1946 when the mine roof caved in and the workings were flooded with river water.

Still farther northeast from Broadford to the point where the overthrust rocks cut off the outcrop of the Little Valley Formation, the synclinal structure along the fault is evident. Two tear faults cutting both overriding and overridden blocks offset formation and fault contacts. Figure 10 delineates the geologic structure in that area. In all probability the syncline passes under the overthrust rocks and emerges in Locust Cove. Very likely commercial gypsum underlies the overthrust block, where it will probably be found to be continuous from the old pits along the river southeast of Broadford northeast into Locust Cove.

The structure of the Locust Cove area is unique in the Virginia Appalachians. Separating the overridden synclinal Maccrady-Little Valley succession from the overthrust Cambrian rocks is an extensive slice of mangled, macerated sandstones and shales which are right-side-up and 100 to 500 feet thick. The method of detachment of this slice is an enigma. Normally one would expect a detached slide brought up along a low-angle fault to be composed of competent rock, such as limestone or dolomite that defied dismemberment. The fact that the slice is shale is especially puzzling. Even more puzzling is the repetition of the Maccrady below the overthrust Cambrian south of the Locust Cove area (Fig. 7). This repetition is plainly recorded in the Morton Salt Company's core from a deep bore hole put down near the North Fork of Holston River south of Locust Cove (Figs. 5, 6, 7).

Another striking feature of the Locust Cove area is the downfolding of the northwestern salient of the overthrust block into the trough of the Locust Cove syncline. This particular condition in itself is not an uncommon structural situation in the southern Appalachians (Cooper, 1964). Such instances suggest that differential subsidence of indigenous beds continued even after thrusting had occurred so that overthrust rocks were downfolded into cores of indigenous synclines. As previously suggested (Cooper, 1961, 1964) such structures signify the dominance of vertical movements over horizontal movements in developing Appalachian structures.

Another very peculiar if not unique feature of the Locust Cove area is the Locust Cove Fault, a normal high-angle fault along which the northwest block of indigenous beds has been dropped down relative to the southeast block. The great overthickening in the trough of the Locust Cove syncline suggests that this fault may have been a consedimentation break that produced a

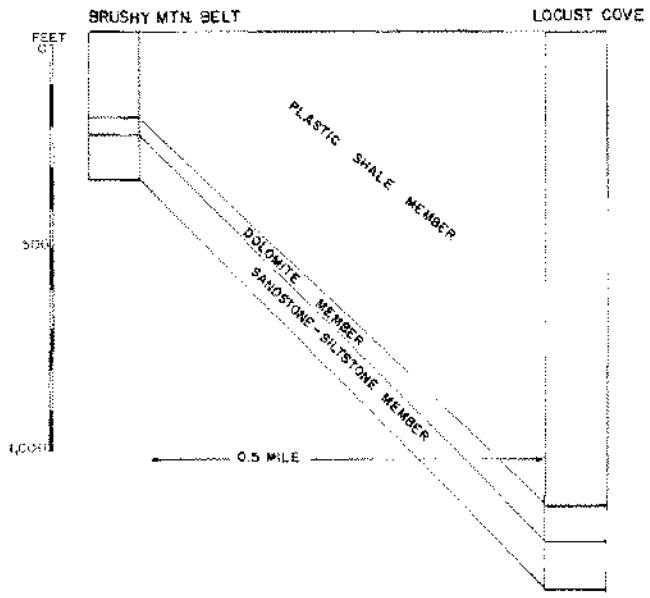


Figure 8. Thickening of the Maccrady beds in Locust Cove area.

local fault-trap zone of deposition. The increase in thickness of the Maccrady in less than 0.5 mile from 300 feet to over 1,250 feet requires a precipitous downward differential deflection of the floor of deposition in order to produce so drastic a change in thickness. Discovery of this fault was made by William Eckroade while working as an undergraduate research participant on a National Science Foundation research project at V. P. I. in 1959. This fault might have gone undetected if all three of the characteristic zones of the Maccrady Formation had not been involved.

GEOLOGIC OCCURRENCE

Salt Deposits

All of the known salt deposits are localized in the immediate vicinity of Saltville. Repeated sampling of the waters of the North Fork of Holston River at the North Holston bridge on County Road 633 shows less than 5 PPM of chloride, which must be assumed to indicate that there is no commercial salt upstream from that point. Saline waters occur downstream from Olin Mathieson's intake of river water which is about 1,000 feet upstream from the company office building. Reports of occurrence of saline waters in tributaries of the North Fork downstream from Plasterco

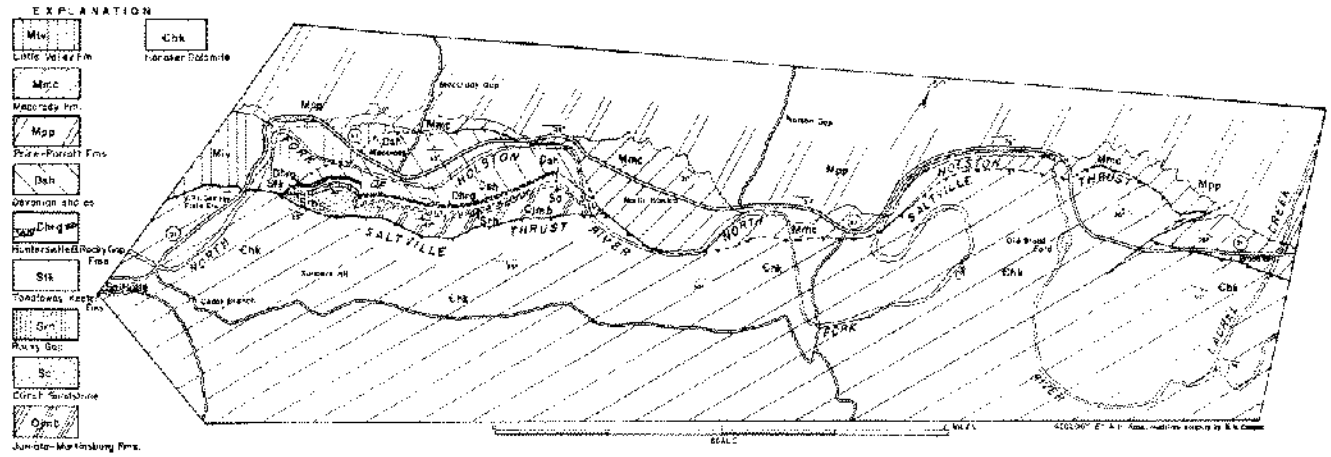


Figure 8. Geology of area between Saltville and Broadford, Smyth County, Virginia.

have been verified. The conclusion drawn from available information is that beds of salt must be essentially confined to the limits of Saltville and Plasterco.

The actual mode of occurrence of the salt has only recently been resolved. In 1961, Olin Mathieson Chemical Corporation core drilled the site for its new pumping station for the High Pressure Brine Field. These cores provided a wealth of information on the nature of the salt deposits.

Drill cuttings of wells penetrating the salt-bearing formations in the High Pressure Brine Field contain abundant salt, but the characteristic pink to red color was not fully understood until the salt zones and associated shales, dolomites, anhydrites, and limestones were core drilled.

The salt, at least in the overturned recumbent limb of the Greendale syncline, occurs actually as zones of tectonic salt breccia. The salt is reddened by fine dissemination of Maccrady red clay. The salt cores reveal abundance of cataclasts of red, green, and gray Maccrady shales, and of associated anhydrites, limestones, and dolomites, which are suspended in a matrix of salt. In most breccia zones, salt composes 60 to 75 per cent of the rock. All of the beds penetrated are not only brecciated but also the salt has actually flowed into the voids of the brecciated rock and commonly bears intrusive relations to the enclosing beds. Most of the breccias except those containing abundant salt are autobreccias.

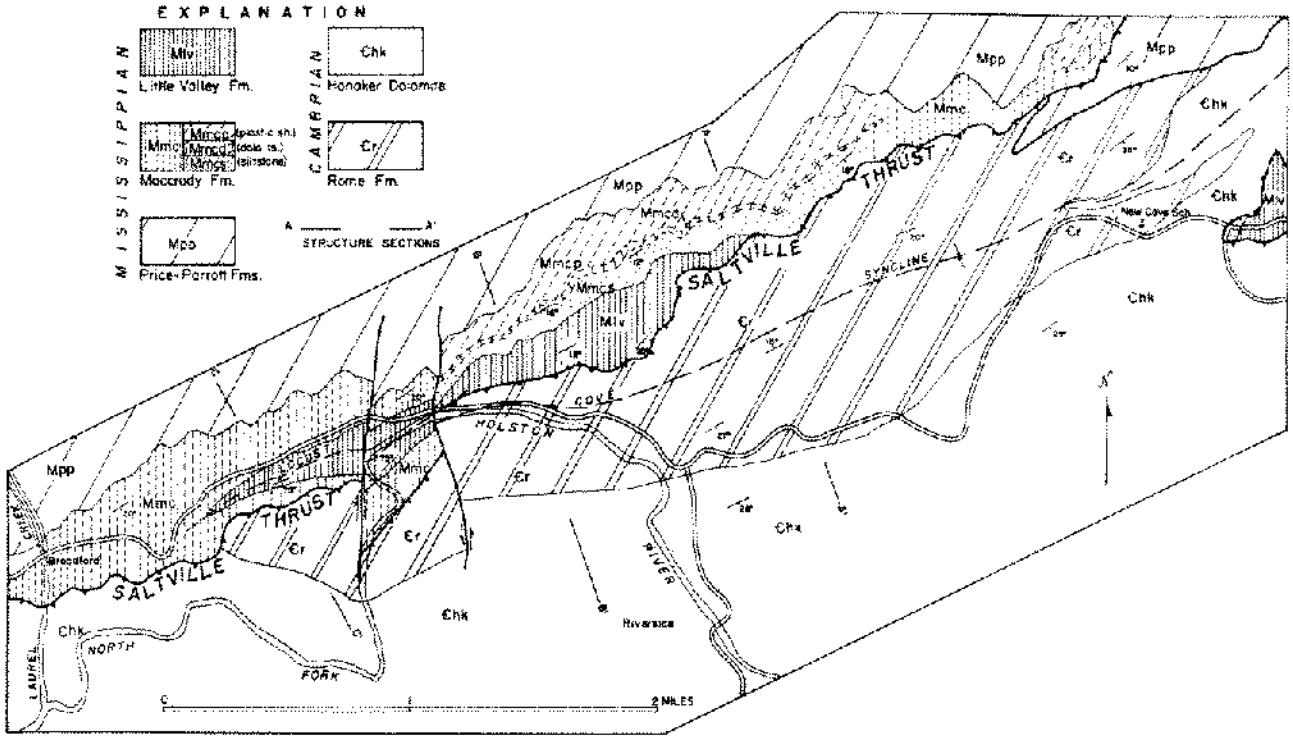


Figure 10. Geology of gypsum-bearing beds northeast of Broadford, Virginia.

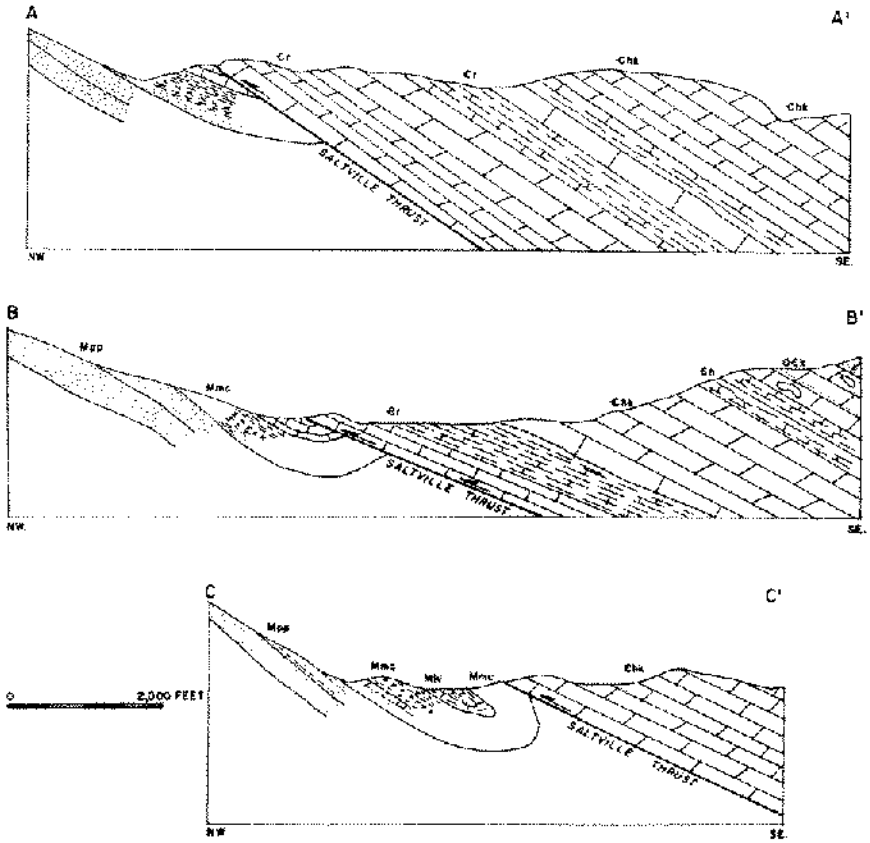
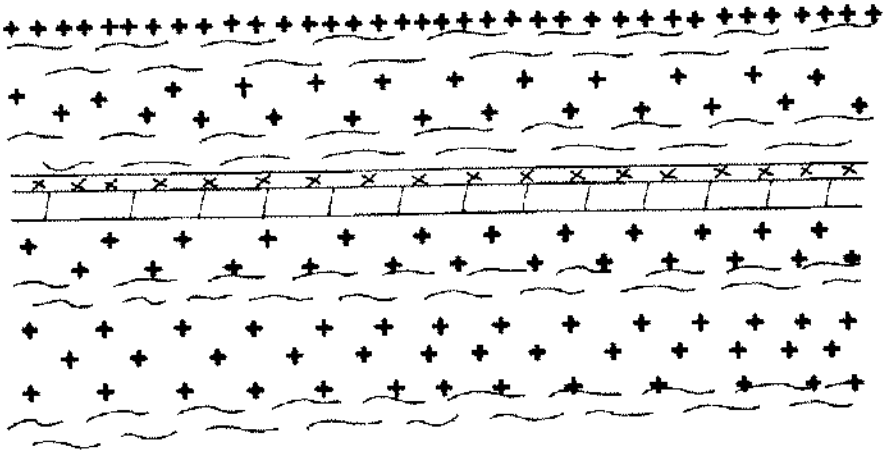


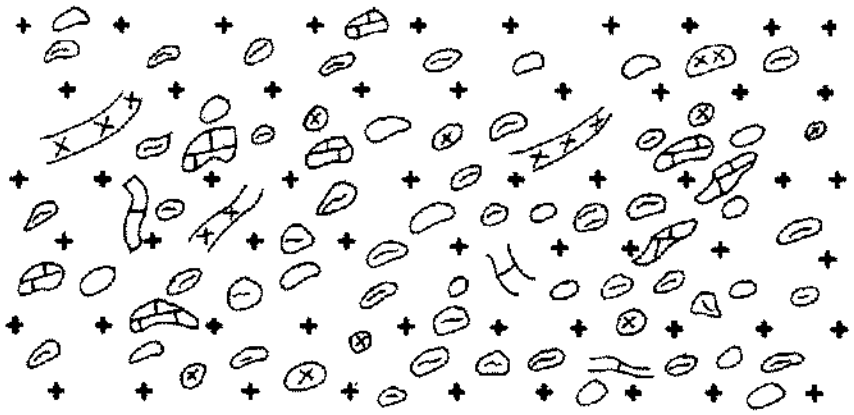
Figure 11. Structure sections northeast of Broadford, Virginia.

The origin of the tectonic salt breccias raises a question as to the probable shape and configuration of the salt bodies. Obviously the salt has been mobilized and has mixed by flowage with crushed shales, anhydrite, and dolomite. Has the salt been transformed into huge localized bulging masses, or are the tectonic zones relatively regular? Figure 12 presents the writer's interpretation. Salt zones, including the characteristic tectonic salt breccias are roughly correlative from well to well within a local area. The evidence for this conclusion is based largely on well cuttings which do not preserve the fabric of the breccia zones.

Based on study of the cores and also the well cuttings, the writer concludes that there is little if any original bedded salt in the upper, overturned, recumbent limb of the Maccrady Formation. Gray salt, first interpreted to be original bedded salt, is now better understood as tectonic salt containing only anhydrite and gray shale clasts.



BEDS AS DEPOSITED



TECTONIC SALT BRECCIA GENERATED IN OVERTURNED RECUMBENT LIMB OF THE GREENDALE SYNCLINE, SALTVILLE, VA.

Figure 12. Origin of tectonic salt breccias in the Maccrady Formation.

That these breccias were formed from dry rocks is clearly indicated by inclusion of red, green, and gray shales which would have disintegrated completely if ever in contact with water since their induration soon after deposition. The shale pebbles could only have been generated by cataclasis.

Interbedded salt, anhydrite, limestone, dolomite, and variegated shales were sheared and macerated during overturning. As the salt began to move, intercalated shale, anhydrite, and dolomite beds were brecciated and dismembered. Further flowage of the salt engulfed the fragments of the broken beds.

Very likely the apparent correlative salt "beds" represent redistribution of these various lithologies occurring in rather localized stratigraphic zones. Perhaps no more than 50 to 100 feet of such varied lithologic materials were revoked by cataclasis into a single zone of salt breccia. But it must be assumed from the abundance of salt that although the salt may have been in numerous layers it was the preponderant rock type in the plastic shale member. It is also possible that the zones of original bedded salt may have been mobilized -- affecting only the shales above and below the salt zones. This hardly seems likely because some salt breccias contain up to 40 per cent shale and anhydrite clasts.

The presence of salt breccias in the overturned, recumbent limb is not a certain indication that all the Saltville salt is tectonic. So far, only the upper limb of the syncline has been core-drilled and the occurrence of tectonic breccias engulfed in impure salt occurring there may be simply the localized product of structural inversion of the southeast limb of the Greendale syncline. In the upright, lower limb -- fully penetrated by some wells in the Olin Mathieson High Pressure Brine Field -- the cuttings show preponderant pink salt strongly suggestive of salt breccias, but they also show considerable gray to clear salt that could be from indigenous salt beds.

Salt also occurs in the brecciated Little Valley beds forming the core of the Greendale syncline, and much of it is clear. Its presence raises the question whether the salt in the Little Valley is indigenous bedded salt only part of which has been mobilized and moved or whether the associated salt is all tectonic and intrusive. Based upon associated anhydrite and dolomite in bedded zones, the writer has concluded that the salt was also essentially indigenous depositionally layered material. That the pink salt in the cuttings in the Little Valley core of the syncline may be vagrant salt out of the Maccrady Formation is considered a strong probability.

As previously mentioned, the average aggregate thickness of the salt zones in the upper limb alone is at least 800 feet. The long life of individual brine wells in the old shallow well field at Saltville is testimony to the abundance of salt.

One thing, however, is certain. The preponderance of pink adulterated salt precludes any possibility for mining commercial-grade rock salt by regular mining methods. The only way to recover the salt from the breccia zones is by dissolution. Based on all available drilling data disclosing abundant salt, Saltville is assured of a very long life as a salt producing area.

How much salt has been carried away by dissolution via salt springs draining into the North Fork of Holston River is conjectural, but evidently the natural saline water barrier in the North Fork of Holston River at Saltville, created by ingress of salt water from Palmer Spring in prehistoric time, has been in effect long enough to have allowed time for local speciation of the fishes in the headward portion of the North Fork above the Saltville saline barrier (Ross, R.D., personal communication, 1953).

Gypsum Deposits

Gypsum and anhydrite are known to occur from a point a few miles southwest of Plasterco northeast to Locust Cove. In the U.S. Gypsum Company's mine at Plasterco the gypsum occurs in large lenslike to pod-shaped masses with centers of dark-colored, fetid petroliferous material. The host Maccrady Formation is greatly deformed and is vertical to overturned. All the workings at Plasterco are in the upper limb of the Greendale syncline.

Although shrouded in clays in which contorted bedding is quite evident, the lenticular gypsum masses are products of deformation and some flowage. Anhydrite and gypsum occur together in these pods in varying proportions and the relationships between the two minerals indicate that

anhydrite was definitely earlier than the gypsum. The method and time of hydration are conjectural. But at Plasterco the steep inclination of the beds and lack of abundant salt (present less than a mile away at Saltville) suggest that slow downward permeation of surface waters through the fractured rock may have allowed hydration to take place to depths up to 1,000 feet or more. The fact that commercial 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. The association of gypsum with cross drainage courses that have notched the Nolichucky has already been noted.

At North Holston, where Southern Gypsum Company and later National Gypsum Company operated, the gypsum was definitely bedded and occurred in bodies up to nearly 60 feet thick, which were thoroughly hydrated near the surface but mixed with anhydrite down dip. Evidently the more nearly regular structure of these beds is accounted for by their situation on the northwest limb of the Greendale syncline.

Mining operations in Locust Cove were based upon discoveries of commercial gypsum from deep core drilling. The gypsum deposits encountered there are bedded deposits that are thoroughly hydrated. How far down stratigraphically and how far down structural plunge to the southwest the gypsum has been developed by hydration of anhydrite is still unknown, but there appears to be a strong possibility that the hydration may be continuous all the way from North Holston to Locust Cove.

The original anhydrous character of the calcium sulphate is clearly indicated by the anhydrite cores from the old Morton Salt Company's drill hole (Fig. 7) drilled in 1946. The bedded nature of the anhydrite-bearing sequence in that hole is clearly shown in the cores.

The fabric of gypsum formation in relation to the original anhydrite is exceedingly variable. At Plasterco the speckled anhydrite-gypsum rock has a matrix of anhydrite and inclusions of selenite. In some of the diamond drill cores from Saltville, the gypsum is so dense and uniform that it is rather difficult to distinguish from anhydrite except that it is softer than anhydrite. Massive hydration of the original material is evident from North Holston northeast to Locust Cove, but the absence of hydrated material in the Morton Salt Company's core from greater depths signified that the surficial gypsum is a secondary hydration product. Structure may have influence in determining depth and extent of hydration.

The number of beds or lenses or pods of gypsum and anhydrite in the Maccrady Formation varies from place to place, but nearly every well and boring of any consequence shows multiple stratigraphic occurrences of commercial material.

HISTORY OF DEVELOPMENT

Salt seeps and brines issuing onto the old marshy, ponded bottom land in Saltville were first discovered by the late Pleistocene primeval mammalian hordes that once roamed the Appalachians. Saltville was the great "salt lick" in the southeastern United States. It is not known that the Indians recovered salt before the advent of white men. These brines were first noted by Thomas Jefferson in 1781 (Watson, 1907, p. 21). "Bedded" salt was not discovered until much later (Robertson, 1840) when a well shaft dug in search of brine disclosed the rock salt. According to Hayden (1843), there were six brine wells in operation in Saltville in 1842. The strategic part played by Saltville salt in the Civil War is reviewed by Lonn (1933) and Boyle (1936); the former contains considerable information on early salt workings. Salt was recovered by evaporation of brine until sometime after the start of the Mathieson Alkali Works in 1891, but no rock salt was ever mined commercially. Watson (1907) reported 24 wells in operation in 1907, including the deepest one which penetrated to a depth of 2380 feet. Mathieson continued to produce brines entirely from the old well field until about 1930 when the original well in the High Pressure Well Field was put in operation. In the later field, there are wells that range up to a little over 4,000 feet in depth, some of which penetrate both limbs of the recumbent syncline.

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 and is

calcined 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.

Gypsum or "plaster" was prospected for and mined locally in the vicinity of Plasterco as early as 1815. According to Watson (1907) the Buena Vista Plaster and Mining Company mined gypsum extensively there and the Salt Works Company (predecessor of Mathieson Alkali Works) also mined some gypsum at Saltville. U.S. Gypsum Company has operated at Plasterco since 1907.

In 1906 Southern Gypsum Company began mining operations at North Holston and continued for many years, later becoming Beaver Products Company (formerly a division of Certainteed Products Company). In 1933, Mathieson Alkali Works acquired the holdings of Beaver Products Company and leased the gypsum mine and mill at North Holston to National Gypsum Company. In 1946, mining operations at the North Holston mine ceased when the river broke into the mine workings and flooded them out. Since that time repeated cave-ins have occurred at North Holston, which no doubt have rendered the mine useless.

Numerous small pits produced some gypsum southeast of Broadford and also in Locust Cove but significant production in that area dates only from the initiation of U.S. Gypsum's Locust Cove Mine in 1962. At the present writing, all gypsum produced in the district comes from the Plasterco and Locust Cove mines of U.S. Gypsum Company.

ORIGIN OF THE SALT AND SULFATE DEPOSITS

Evaporite deposits occurring in the Maccrady-Little Valley succession, mainly in the Maccrady plastic shale member, include halite, minor blue salt (probably containing excess sodium), anhydrite, gypsum, and dolomite. No doubt all these materials originally occurred as broad lenses or beds, but subsequently these materials were subjected to shearing, folding, and cataclastis, so that considerable disruption, flowage, and redistribution of these materials has been in effect in the upper limb of the syncline.

The conditions necessary for a dolomite-anhydrite-halite depositional sequence call for advanced evaporation of marine waters in a silled basin replenished from time to time by sea water. An extensive thin anhydrite zone has been reported in a number of wells in the Appalachian Coal Basin that have been drilled down into the Maccrady Formation which is only 50 to 100 feet thick in the localities of penetration. The relatively extensive conditions of evaporite concentration of sea water necessary to form anhydrite must have existed over an area of at least 2,000 square miles in Smyth, Washington, Russell, and Tazewell counties, Virginia, in McDowell County, West Virginia, and in portions of East Tennessee strike from Saltville.

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 and in some sectors much thinner than that, 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 portions of the Greendale syncline and its northeastward extension, the Locust Cove syncline. The fact that the locally thick evaporite sequence is nestled in the core of these synclines and that the Locust Cove Fault has also controlled downwarping very sharply leads to an inescapable conclusion, namely that the differential downwarps at the time of localized Maccrady deposition were embryotectonic forerunners of the Greendale syncline. The history of development of this great syncline must date back at least as far as Maccrady time.

The obvious tectonic control of deposition along axial zones virtually coincided with these two related synclines is one of many such expressions. Appreciation of these relationships involves a train of other conclusions not the least of which are: (1) that the major folds actively formed during deposition were synclines, and (2) that the major structures were initiated even while the beds were being deposited (Cooper, 1964).

The sparsity of core data and the present complicated structures prevent development of an accurate conception of the exact nature of evaporite accumulation during Maccrady time.

Numerous repetitions of anhydrite and dolomite within the red, green, and gray plastic shales suggest possibly cyclical conditions of evaporite formation. Salt in the Little Valley Formation may be, and probably was, in part original bedded salt, but some surely was intruded from the subjacent Maccrady beds during salt mobilization accompanying thrusting. Overturning of the southeast limb of the fold during thrusting probably mobilized the thicker anhydrite bodies to elongate into pods -- possibly accompanied by recrystallization which tended to concentrate the fetid impurities of the original anhydrite into the cores of sulfate pods which locally later, as in the Plasterco and Locust Cove areas, were hydrated wholly or partially to gypsum. Original beds of anhydrite in the open Locust Cove syncline may have been hydrated by movement of seepage water down plunge toward and possibly all the way to North Holston. Partial preservation of the salt and gypsum, both of which have probably been debilitated by dissolution over a long period of time is surely the direct result of shrouding of these evaporites by plastic shales. To the extent that these shales have warded off dissolution significant quantities of salt have survived.

The Nolichucky Shale is controlling and localizing surface water crossings of the outcrop of the Saltville Fault and subjacent salt- and gypsum-bearing rock has helped to preserve the Saltville salt deposits and promote surficial hydration of the anhydrite bodies.

The salt loss at Saltville resulting from continued discharge of Palmer Spring may eventually be quantified, but at present even any approximation would be unwarranted. Palmer Springs consisted of both fresh and salt-water discharges. This close association suggests the possibility that the springs may have at times been entirely fresh-water discharges, so that salt losses were intermittent.

Currently, Dr. Clayton Ray, Associate Curator of Vertebrates, Natural History Museum, Smithsonian Institution, and the writer are initiating a project to explore the flats of Saltville for vertebrate remains and also to study the pollen, spores, and invertebrates in the 20- to 30-foot layer of muck which underlies the irregular lowland. It is hoped from this study that we can shed much light on the absolute age of the entombed fossil vertebrates and also the Unio shells that are abundant locally. From studies of the ostracoda we may be able to tell how long or how much of the time springs created salt or brackish-water ponds that attracted the late Pleistocene vertebrates.

Shortly before this manuscript was completed, Withington (1965) published a paper summarizing his interpretation of the salt and gypsum deposits of the Saltville-Locust Cove District in Washington and Smyth counties, Virginia, and referred to other areas, notably in Wythe, Pulaski, and Montgomery counties, where high sulfate content of spring waters might be considere a valid guide for prospecting for gypsum.

This paper should be read by everyone interested in the origin and structure of the salt and gypsum deposits in the Saltville-Locust Cove District, because the author presents some provocative ideas. Withington's explanation of the principal cause for the tremendous thickening of the Maccrady at Saltville and for the concentration of salt and gypsum bodies is, however, based upon erroneous assumptions and is controverted by known facts about the stratigraphy of the Maccrady and related formations in the area of concern.

On page B-30, Withington states:

> "On the basis of stratigraphic conditions elsewhere, it can be assumed that near Plasterco and Saltville, the Maccrady originally consisted of bedded calcium sulfate, salt, shale, and thin sandstone in a unit that was about 100 feet thick. The Maccrady acted as a lubricant mass over which the thrust plate glided. In the process of thrusting, the overriding mass squeezed the Maccrady before it, concentrating the calcium sulfate and salt by plastic flowage, and thickening the formation."

Withington believes that the great thicknesses of the Maccrady that prevail locally at Saltville and at Plasterco are the consequence of 'dozing and piling up of Maccrady beds from an original more or less uniform sheetlike deposit about 100 feet thick. This conclusion is untenable for a number of reasons.

The plastic shales constituting the uppermost member of the Maccrady, which holds practically all the salt and gypsum deposits, comprises 600 to 800 feet of thickness where it has its

maximum development, but in the "normal Maccrady" of Withington, plastic shales are exceedingly thin or absent and the formation is made up almost entirely of siltstone and sandstone. Simply 'dozing and piling up of the 100-foot successions that Withington describes as normal Maccrady could not possibly give the extreme proliferation of plastic shales that occurs at Saltville and Plasterco sectors. Piling up of 100-foot sequences composed primarily of siltstone and sandstone would expectably give greater thicknesses for those lithologies, but this condition is not observed. Cores and well cuttings through the Maccrady show unmistakable stratigraphic zoning involving at least six lithic types of material, and the succession taken as a whole is not one of repeated sections but of varying character from bottom to top.

The section of the Maccrady south of Allison Gap, on the northwest flank of the Greendale syncline shows a thickness of 135 feet to 165 feet, and siltstone and nonplastic shale and sandstone make up about 90 per cent of the interval. Yet directly across the syncline in the area of the High Pressure Brine Field, the salt-anhydrite-dolomite-plastic shale sequence is 1,400 feet thick or more. That amount of material, including no doubt hundreds of feet of plastic shales, could not have been derived by piling up of thin Maccrady sections essentially lacking in plastic shale. The thickened masses of Maccrady are not structural chaos, as pictured by Withington. They show a remarkable amount of integrity and continuity, despite the fact that the salt has been mobilized in selective zones to form tectonic breccias.

The writer feels impelled to take strong exception to the first sentence in the paragraph quoted on the preceding page. To make stratigraphic assumptions about a specific area or locality on the basis of observed conditions in other areas is to deny the local, significant stratigraphic variations which any worker in the Appalachian region knows to exist and be exhibited all too frequently for his piece of mind. Such a concept of stratigraphy has to assume that all units are laid down as nice, uniform depositional sheets. This is a fantastic assumption to be made about beds deposited in a geosyncline. It presupposes a degree of uniformity in stratigraphy that is not even common on many areas on the interior craton. Sections measured by the writer on the northwest flank of the Greendale syncline between Allison Gap and Locust Cove show thickness and lithologic variations far greater than have been recognized by Withington. The writer must conclude that Withington has viewed the Maccrady with a stratigraphic frame of reference that is most unrealistic in any part of the section, particularly portions composed of clastics.

Withington also alludes to the fact that the Little Valley and Maccrady are "known to thicken along the axes of folds." With this, the writer would readily agree, but he would associate the thickening with differential downwarps -- forerunners of later structures we see today -- rather than assume that the thickening is a structurally induced modification of the original thickness.

Withington says that during the process of thrusting the overriding Maccrady squeezed the Maccrady before it, concentrating the calcium sulfate and salt by plastic flowage. Yet in the Plasterco mine where he evidently got many of his impressions about the Maccrady, he says (p. B-30):

> "The bedded gypsum found in the Plasterco mine at the top of the Maccrady was little disturbed by the overriding mass; evidently most of the ['dozing] action of the thrust took place east and southeast of Plasterco."

It is difficult to understand why one would discount the observable conditions in the Plasterco Mine and presume that the squeezing, 'dozing action took place down dip, out-of-sight, to the "east and southeast." The fact is that the observations made in the mine tend to argue against wholesale disruption and piling up of the Maccrady, and Withington's structural cross section must be rejected as a completely unsatisfactory explanation.

It may be well to record here also objections to some of Withington's interpretations of water analyses as a guide for future prospecting for evaporites. Sulfate concentrations in spring water are not necessarily valid indications of subsurface occurrences of gypsum beds. Even in the Plasterco area, surface waters and spring waters issuing from the Saltville Fault zone show relatively little sulfate. One would be inclined to expect higher concentrations than exist in the springs and in McHenry Creek itself.

Withington's reference to the high sulfate content of the springs in portions of Montgomery, Pulaski, and Wythe counties and his inference about the significance of these sulfate-bearing

waters as a likely guide to as yet undiscovered gypsum beds should be entertained with caution. There are other much more reasonable explanations for the high sulfate content of these spring For example, Yellow Sulfur Spring near Blacksburg issues from overthrust dolomites which hav overridden Maccrady beds. Yellow Sulfur Spring (Watson, 1907, p. 266) contains over 1,500 p of $SO_4^{=}$. However, in the immediate vicinity of the spring, the hanging wall of the Pulaski Fault shows the overthrust dolomites in contact with Ordovician graptolitic shales that are loaded wit pyrite. Pyrite converts directly to sulfates in the presence of limestone and dolomite when the Eh and pH are kept essentially neutral. Most of the cited examples of high sulfate spring water given by Withington, can be explained as generations of sulfate by interaction of limestone-dolomite waters picking up sulfur from bodies of pyritic shale. The highest known concentratic of sulfate spring water in western Virginia (Watson, 1907, pp. 261-263) occur in Blue Ridge Spi (Botetourt County) and Alleghany Spring (Montgomery County) are well beyond known limits of t Maccrady Formation but both are situated in areas where pyritic rock and dolomite occur close together.

Withington has considered the Mississippian red beds of the Pulaski-Montgomery counties area as virtually the same sequence of strata as the Maccrady Formation of the type belt of out crop. The red beds in the New River district have been renamed Stroubles Formation in consi eration of the fact that the red beds cover a greater stratigraphic range than those of the type Maccrady and exhibit considerably different lithology. Plastic shales, which characterize the thick Maccrady of the Saltville area are essentially absent in the Pulaski-Montgomery counties area. Plastic red and green clay shales of the type associated with salt and gypsum in the Smyt Washington counties belt are essentially absent. For that reason, it is considered likely that s and gypsum are not present in the New River district.

Based upon available information, it seems unlikely that commercial salt and gypsum can produced very far southwest of Saltville and Plasterco. The overthrust rocks above the Saltvill Thrust lap up and over the upturned or overturned limb of the Greendale syncline as developed the Maccrady and overlying Little Valley Limestone. Experience has demonstrated that prospecting for either salt or gypsum southwest of Plasterco is exceedingly expensive because of th deep burial of the Maccrady and Little Valley Formations (W. A. Nelson, 1953, 1958).

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