Place: Gulf of Mexico: The Louann Salts and origin of the gulf

Abstract

The Louann Salts are a massive bed of primarily NaCl stretching from East Texas, northern Louisiana and southern Arkansas through the entire Gulf of Mexico, from Mexico to Florida and south to Yucatan. It occurs with its adjoining beds, Pine Hill anhydrite and aeolian Norphlet sandstone above, and Werner anhydrite and red bed Eagle Mills sandstone on crystallized basement below. That both the water soluble salt and anhydrite have survived required deposition under specific conditions which excluded water. Looking at the setting of the salt, none of the present models account for it in the Gulf of Mexico and a new depositional model in an impact cratering event is suggested.

Key Words: Louann Salts, Gulf of Mexico, anhydrites, evaporites, impact crater.

Introduction

The geologic origin of the Gulf of Mexico has been of interest since petroleum exploration recognized an association of hydrocarbons with the Louann salts. How can a mineral that is so highly soluble in water occur in large mass under the gulf's water? How did it get there? And, what can it tell us about formation of the gulf? While the Plate Tectonics model tries to answer these question, it fails.

For Flood modelers, the salt seems particularly difficult with its high solubility in water. This makes the claims to its being deposited in the midst of a flood seem equally unlikely, although some (Nutting 1984, Heerema and van Heugten 2018, and Walker 2019) have tried to address the problem.

Evaporative Basin for Origin

The difficulties of both northern and southern Grenville Orogeny and the Plate Tectonics Model when compared with the present geomorphology found in southeastern North America and the Gulf of Mexico were discussed in the last two chapters. If impact cratering is true, there is no room for Plate Tectonics or any other model that wants to moves the continents significantly from their present position, and such continental movements could not have happened since the cratering event. The geomorphology seen presently on the surface of the earth can be explained by cratering processes including the Gulf of Mexico.

The Plate Tectonics scenario for the Gulf of Mexico's origin starts about 165 million years ago and involves rifting and slow stretching through 25 million years (Stern and Dickerson 2010), centered in the Grenville Orogeny. Geologist, originally observing only the small sub-basins on the northern continental edge of the gulf, imagined this event to have involved the convergence of Baltica (Scandinavia), Avalonia (Middle Europe), and Gondwana (Africa and South America) with Laurentia (North America) (Hoffman 1988). Then the subsequent rifting of Gondwana to deliver the Yucatan block on South America's way to its present location leaving an evaporite salt pan across the entire basin. It required Florida and Mexico to accumulate irregular structures to accommodate this movement. Irregular bands of extended crust with varying ages were assumed to underlie sediments on the Florida Shelf (Ball et al 1988) and extend across the abysmal deep beyond the Sigsbee Salt (Figure 1) to Mexico. Much later the Tamaulipas-Oaxaca Fault was identified as the drag line's remnant (Padilla y Sánchez 2016) of that movement for the western tail of the Yucatan miniplate. However, Ball et al (1988) determined that no extension of crust took place under Florida, because extensive band of differently dated crust did not exist under the sediments. And, Rueda-Gaxiola (2003) determined that the movement of Yucatan had to be completed before the deposition of sediments *began* along its path because the sediments were continuous.

An intermediate position was taken by some that the Louann Salt had deposited by evaporation in a single broad basin occupying the northern half of the gulf, and thereby did not extend under Florida, but that the wide basin had eventually split in two as the gulf widened and half of it rafted south to become the Yucatan and Campeche salt basins (Hudec et al 2013).

A number of researchers have now realizing the opening of the complete basin needs to predate the deposit of the Louann Salts, and requires a basin already forming during the Triassic and Early to Mid-Jurassic (Hudec et al 2013, Steier 2018) and some like Sanford et al (2016) have produced cross sections from rim to rim of the Gulf of Mexico's basin (Figure 1 and 2), showing the continuous nature of the Louann salt and its associated strata.

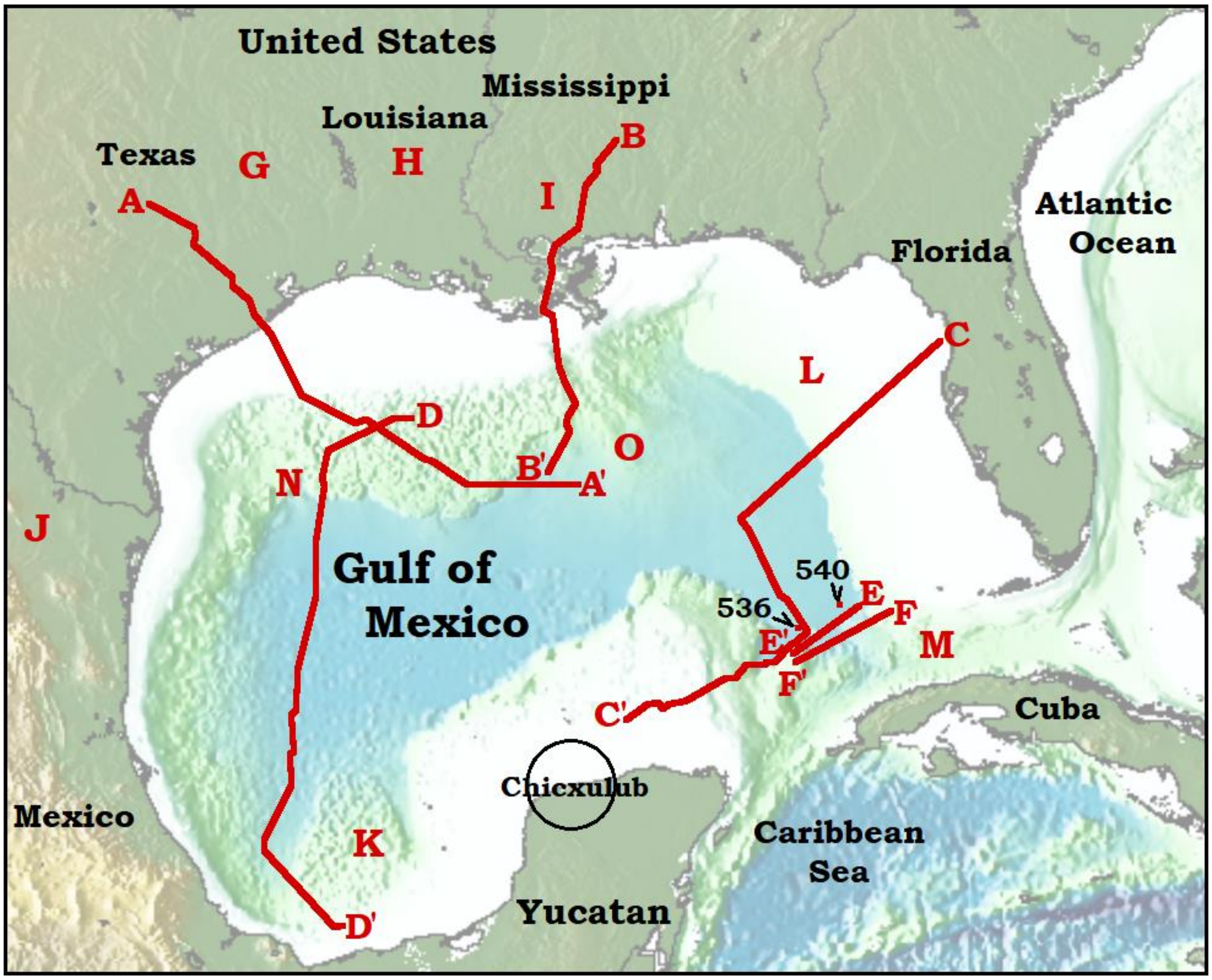

Figure 1: Locations of the seismic transects shown in Figure 2. (Map from BGI 2012.)

Hudec et al (2013, page 1684) questions the value of a model that needs to keep changing to accommodate new information. “The Gulf of Mexico Basin began forming during the Triassic-Early Cretaceous rifting between the Yucatan microplate and the North American plate…. However, despite more than 60 years of study, thousands of boreholes, and one of the most intensive seismic acquisition and processing efforts in the world, many fundamental aspects of the geologic evolution of the basin remain speculative. This uncertainty is especially true of the Jurassic, during [which] Louann Salt was deposited and most crustal extension occurred.…”

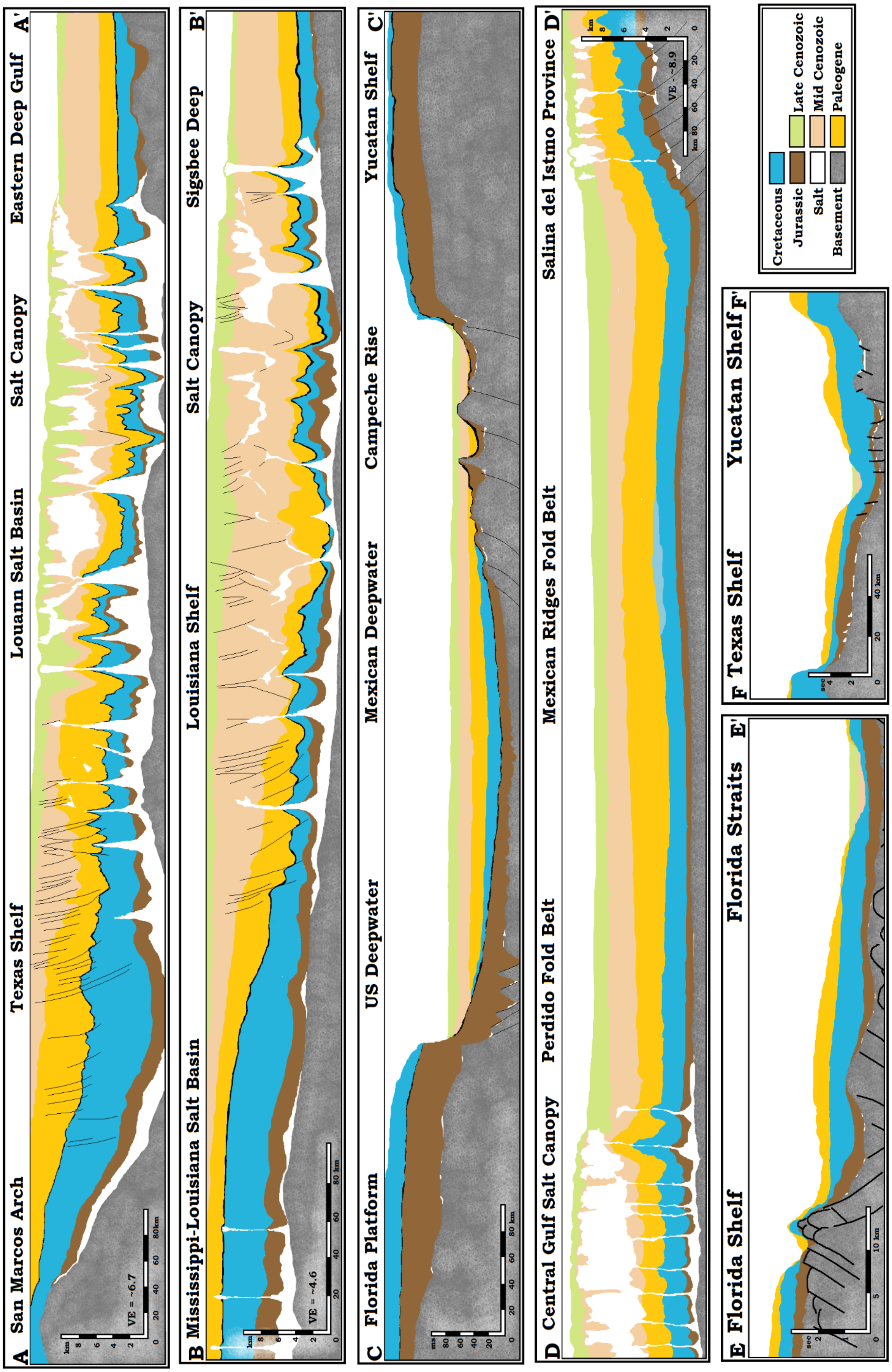

Figure 2: Seismic transects through the Gulf of Mexico; the location of each shown in Figure 1. Redrawn and simplified A-C from Sandford et al 2016, D from ION Geophysical 2019, and E-F from Schlager et al 1984.

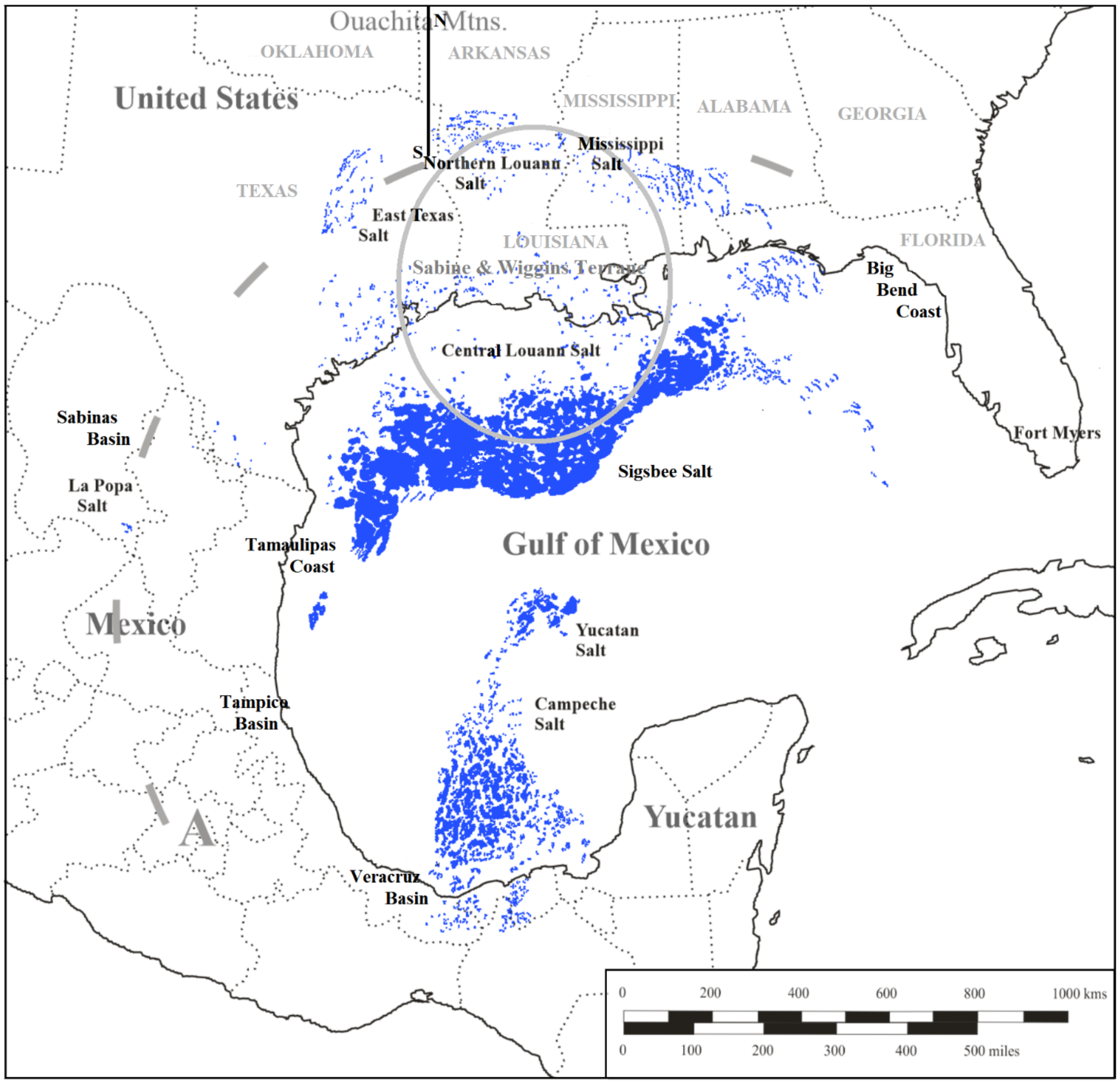

Figure 3: The mapped diapirs of the Louann Salts. Trend A represents a general northern limit to the salt. Modified from Reed et al 2004 and Hudec et al 2013.

The Louann Salt Distribution

The Louann Salt (NaCl or Halite, the mineral name) lines a bowl-shaped basin of between 1.6 - 1.8 million km^2 (0.6-0.7 million miles^2) as can be seen in Figure 2. The salt is primarily a thin layer (<100 m) in some places but forms 10 km tall pillars called diapirs in other places (Figure 3). Everyone agrees that nowhere an earth is a salt pan this large forming today.

Additionally, the Louann salt covers a terrane like none on the continents. Figure 4 compares two cross sections of the Gulf of Mexico with a typical section from the Rocky Mountain of Colorado to the Mississippi River in midcontinent, all at the same scale. While A-A' does not indicate the depth of sedimentary strata, it is not likely that it extends much below the visible bottom of the section. This is much thinner than all but the thinnest of gulf strata. In B-B' the high elevations of the Sabine-Wiggins Terrane, forming the ramp under the Mississippi Delta, is significantly higher and equally steep as the highest Rocky Mountains. In C-C' the ramp off the continent at the San Marcos Arch is even steeper and over 3 times the elevation change in the Rocky Mountains. This is not the terrane found in any of the continental basins, and does not resemble any shallow sea where salt pans are evaporating dry today.

The thinnest deposits of the Louann salt are consistently on the bottom at anyone point. That bottom is as much as 14-16 km below the present water level. Observing the slope of the Sabine-Wiggins terrane (B-B') and the San Marcos Arch, (C-C') the salt is not laid as a water born sediment, depositing layers between the highs, and the thickness does not vary appreciably dependent on slope. The place where the salt thins the most is near the edge and outside the basin, at the top of the San Marcos Arch, and around the highs towards the center of the gulf. This absence in the abyssal depths of the gulf is certainly because of no drilling to this depth and undisturbed layers of salt have low density and are transparent to seismic scans. The heavy occurrence of salt on central peaks and filling in between them suggest they were arrested while starting movement into diapirs, and would not expect it to border an area of no deposition.

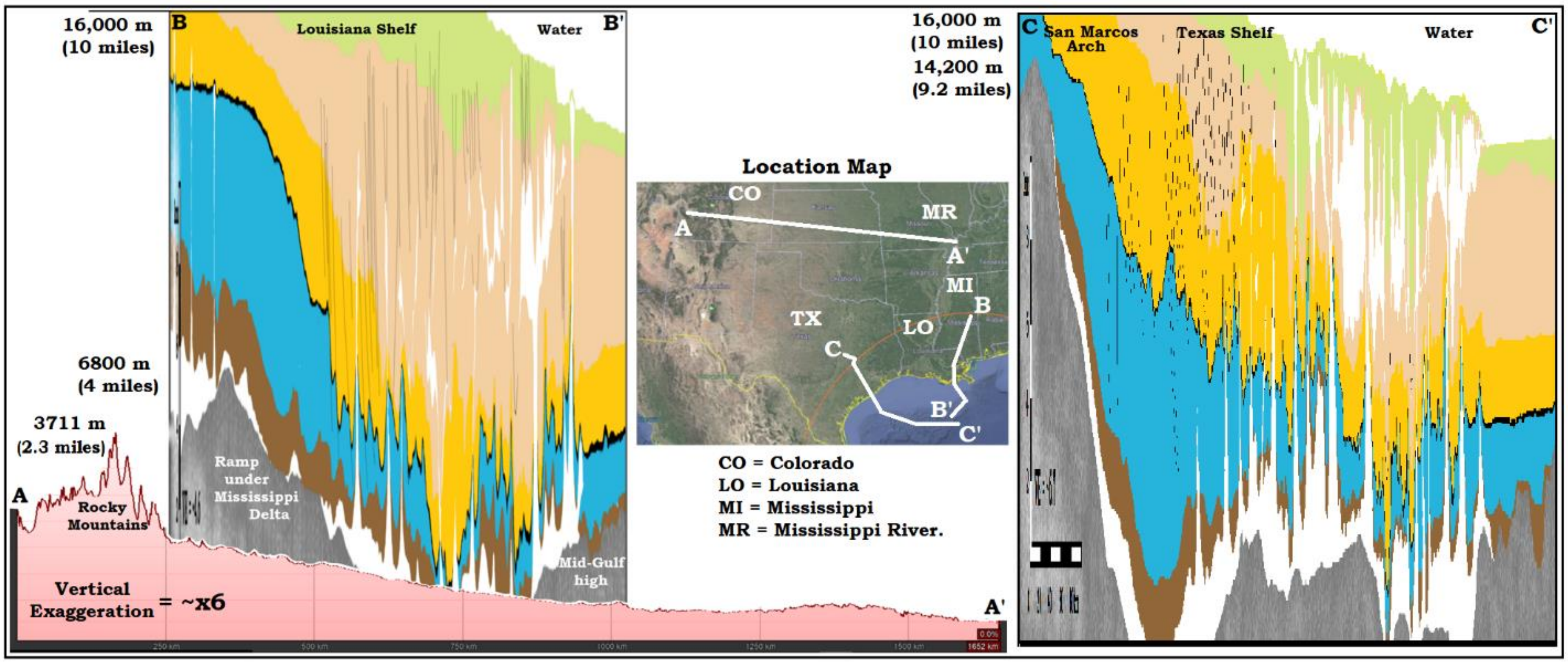

Figure 4: Cross sections showing the extreme difference in the terrane inside the Gulf of Mexico and the greatest extremes on the North American Continent. Section A-A' and location map from Google Earth. Sections B-B' and C-C' from Sanford et al 2016.

Problems with the Louann Salt deposition

Basement: The Plate Tectonics model for forming the gulf and salt involves stretching the crustal basement rocks while the salt was depositing. The Wiggins Terrane (Horton et al 1991) is identified as metamorphic core complex with a high occurrence of phyllite which is greatly foliated. Foliation involves elongating of the mineral crystals which is usually attributed to stretching of the rock. While sudden stretching might produce foliation, if the rock was heated to near the melting point of the crystals, subjecting the rock to high stress in a "kicking" motion would produce the heat from the sudden compression. The elongation of individual crystals would occur as they are moved in the direction of the thrusting stress. But, as this "kick" is produced by a sudden stress to generate that much heat, this event would apply a large quantity of stress and happen only once. Such a scenario would be impossible to fit in with a slowly forming basement.

Even salt layer: How did such an extensive relatively even layer of salt form if it formed in successive basins? Basins are by design deeper in the center and tapering to the sides. This would form a shallow crescent shape in cross section, but in seismic section this cross section is never seen. Instead, the salt looks like snow falling on the already foliated basement rock. An aerial source of the crystals would produce the relatively even layers over both slope and level surfaces.

Shape of crystals: Halite crystals, in the presence of gravity and fairly rapid growth, grow more rapidly on their edges than faces. This produces the distinctive "Berg effect" (Figure 5a) due to higher concentration of solute molecules in that area (Berg 1938). If slow growing NaCl crystals nucleate on the bottom, they grow as "hoppers" (Figure 5a & f), often intimately mixed in the fine mud. If they nucleate at the water-air interface, they form flotillas of "rafts" (Figure 5b & g). Rafts tend to sink with surface agitation and then grow as clumps of "hoppers" on the bottom. Rapid crystallization from super-concentration may lead to "teeth" (Figure 5e) forming at the surface as radial fingers from clusters of rafts. With continued bottom growth hoppers and rafts showing the Berg effect, cleave along chevron patterns (Figure 5c). Looking at samples from large salt formations around the world, Warren (2006) found "primary texture" of chevron patterns in less than 10-15% of the beds in salt formations worldwide, and few if any examples of hoppers grown in mud. Layers of mud do not appear within the salt.

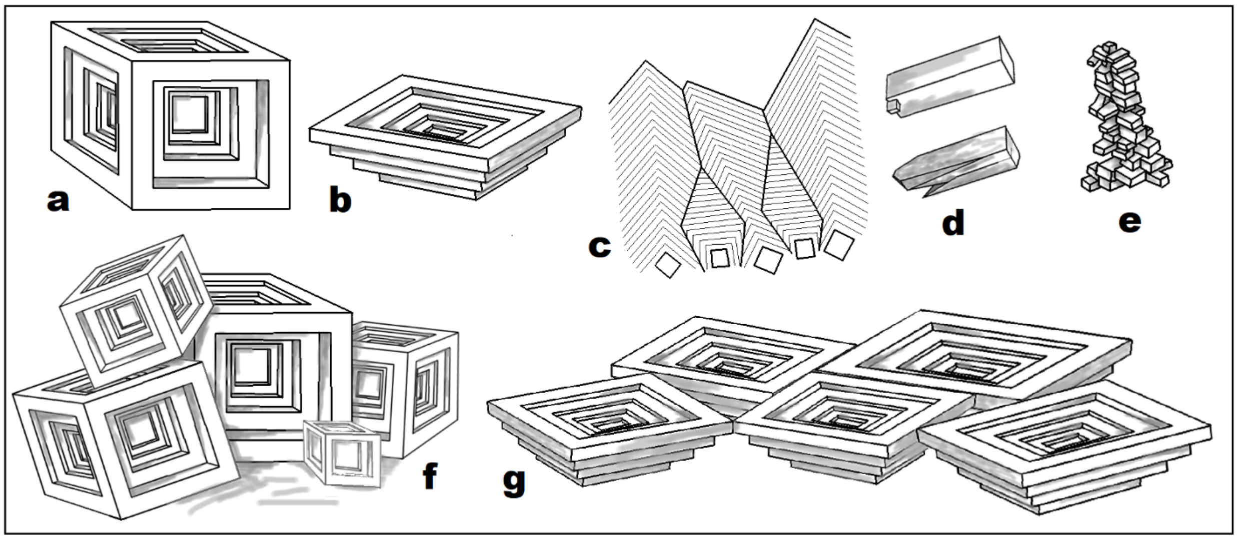

Figure 5: Forms of halite mineral crystals (a) Hoppers: steady unhindered growth (b) Rafts: growth at water-air interface (c) Chevron pattern showing Berg effect (d) Spar, upper; regular as it is believed to have formed, lower: irregular as it appears in specimen, (e) Tooth: rapid growth on surface. (f) Base of growth on bottom. (g) Base of growth on surface

Spar crystal orientation: The pervasive form of crystal Warren (2006) found in salt formations were 85-90% spar crystals. He assumes this high percentage reflected recrystallization of the halite while flowing into diapir and other movement caused by pressure. But, Scott et al (2014) found the flow pattern in the salt to be upwards while the flow pattern in the surrounding Wilcox was around the forming diapirs. Venus et al (2015) found the same relationship between the salt walls and Permian limestone in the Cutler Group of the Paradox Basin, Colorado, U.S.A. Both groups of authors illustrate this as a syndepositional process, so it happened while the halide was still mobile in saturated to supersaturated water while additional high temperature sediments were being deposited.

Solubility: Salt is highly soluble at every temperature, pressure, and up to several molality of HCl in water normally attainable on the earth's surface according to the phase diagram in Figure 6. While many phase diagrams stops at 400°C, this is the temperature range that Ballman (1967) used with dissolved NaCl in solution to transport amorphous quartz in growing crystals for piezoelectric resonators and transducers. This indicates the phase diagram could be extended to close to 600°C. The phase diagram is expanded by Chaplin (2020), but with a different configuration, up to the NaCl's vaporization temperature of 730°C.

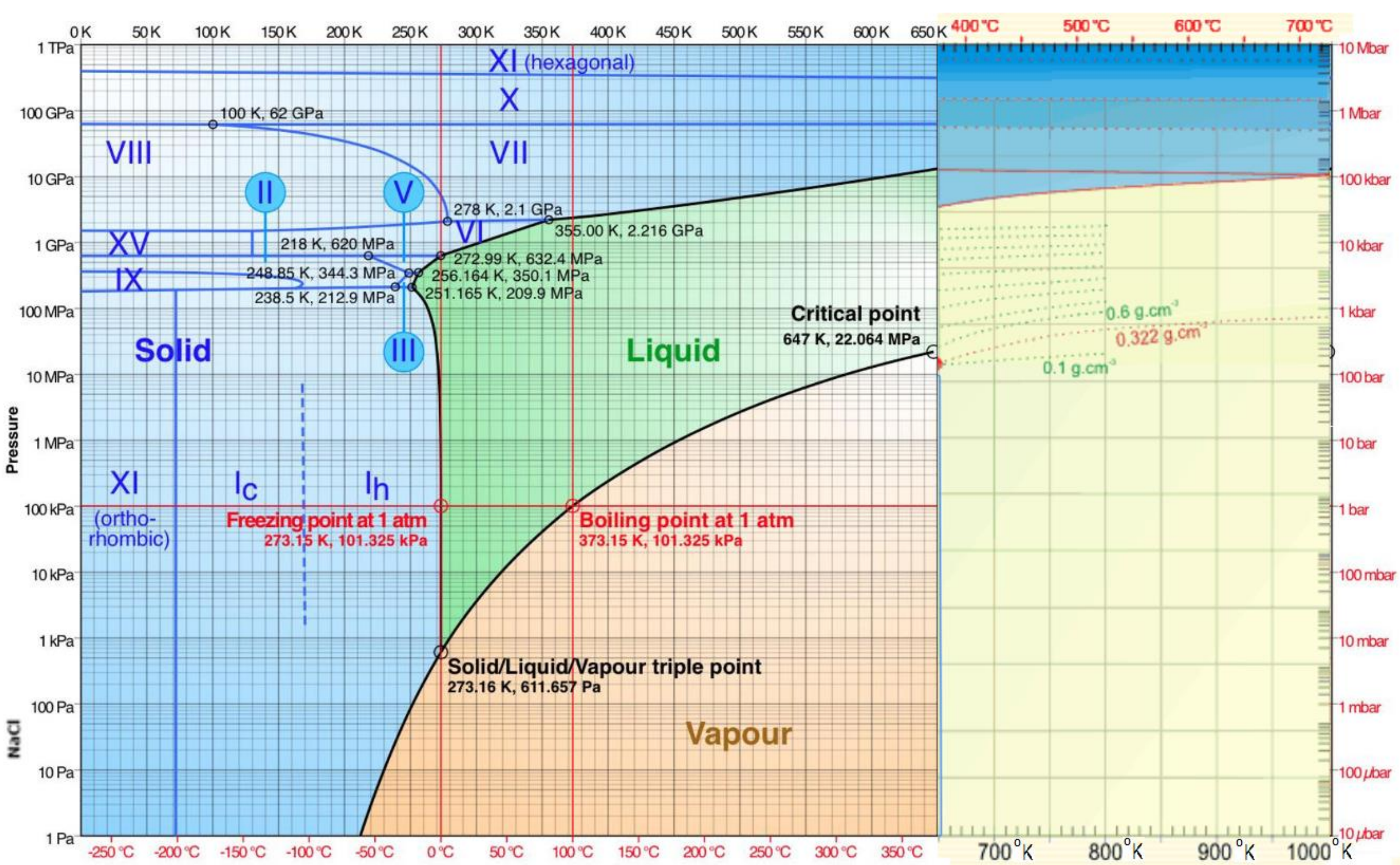

Figure 6: A log phase diagram of NaCl solubility in water continuing past the supercritical points of 100°C and 1atm (101 kPa). (CC Modified from Wikimedia and Chaplin (2020). Scales vary.)

Thus far, the only formation considered was the Louann Salt, but the salt always occurs within a suite of formations. The Werner Anhydrite and Eagle Mills red breccia below, and the Pine Hill Anhydrite and Norphlet Sandstone above (Figure 7).

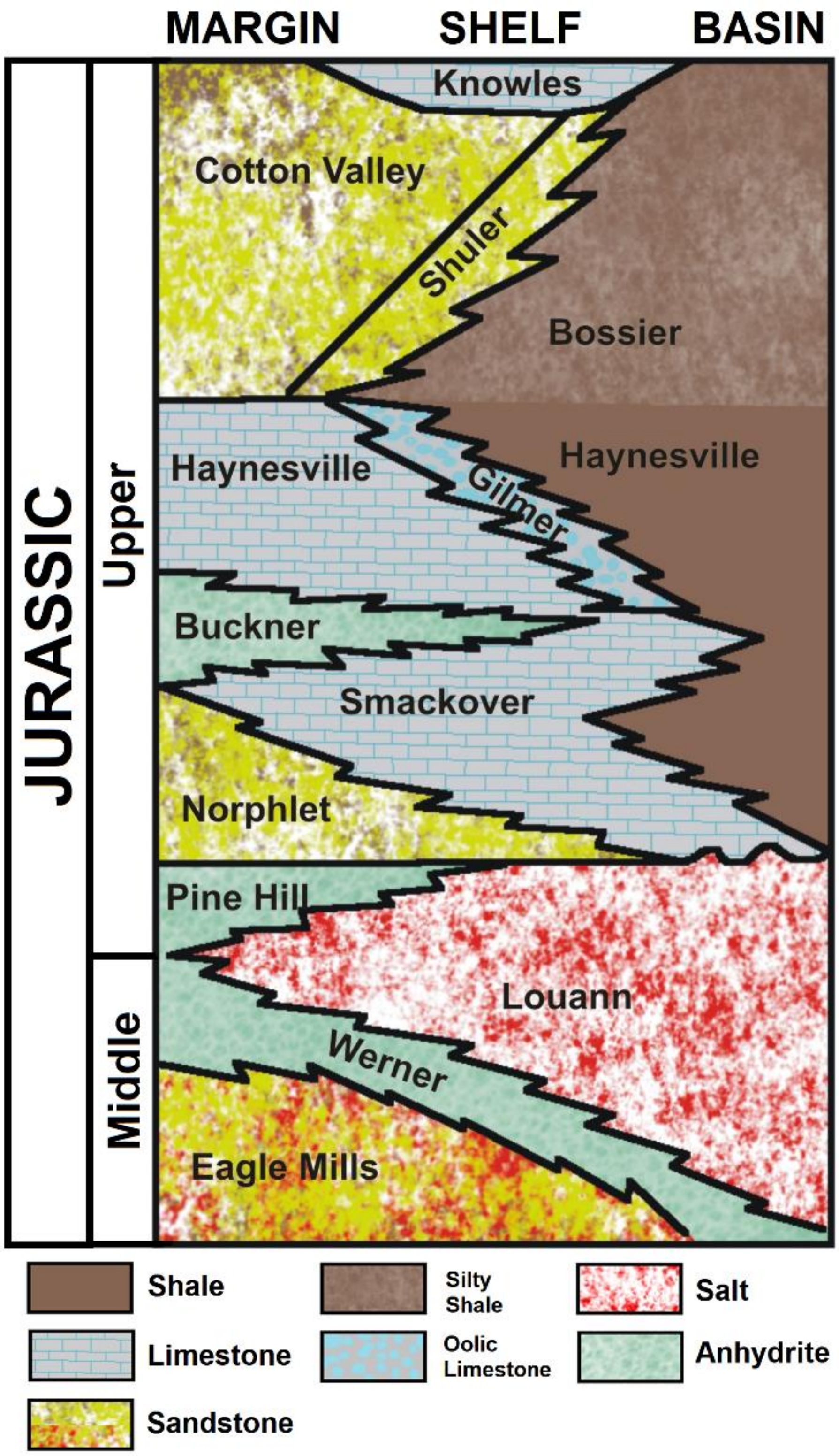

Figure 7: Generalized cross section of Gulf of Mexico sediments across the Gulf Coast Plain. (Modified from Goldhammer and Johnson 2001.)

Associated Strata

Eagle Mills

The sediment resting on the basement under the entire know gulf is fine angular breccia on the ramp-like surface (1973). The breccia of the Eagle Mills is so fine it is often referred to as a sandstone. It terminates in Ouachita County, Arkansas with a deposit that is 2124 m/ 6969 ft. (2.1 km / 1.3 miles) deep occurring less than 16 km/ 10 miles from its updip limit (Wade 1993). This location pierces down into deep deposits on the edge of the Gulf of Mexico sediments (EM on Figure 8).

The frosted particles include basalt, chert, quartzite, dolomite, and plagioclase feldspar in a matrix largely of red to green clay (Wade 1993, Mancini et al 2012). As clays are modeled to derive from degraded feldspar, it is unique that the feldspar particles are angular, showing little or no indication of degradation into the associated clays, suggesting both the feldspars and clay were formed in a simultaneous process.

The thickest Eagle Mills sits atop significant deposits of conglomerate and metasedimentary layers (Wade 1993) between the Sabine-Wiggins terrane and the Ouachita Mountains, which shows the Gulf of Mexico's sediments are part of a succession of similar sediment producing events. The composition and structure of the fine breccia is reminiscent of the fine breccia Shoemaker (1987) discovered in the Barringer Crater from the fallback of fragments of the Coconino Sandstone blasted out in the cratering event.

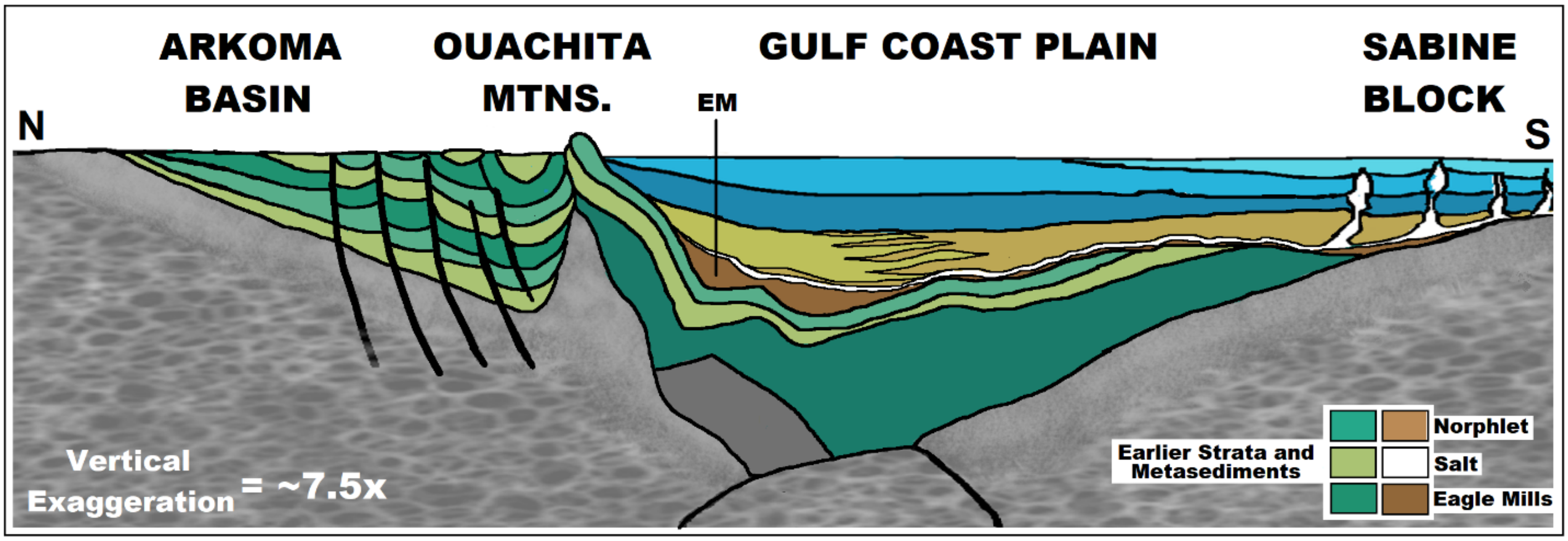

Figure 8: Strata structure from the Ouachita Mountains down to the Sabine Block (Sabine-Wiggins Terrane). (Location shown in Figure 3). After seismic section of Arben 2009, Steinhoff et al 2011, and Mickus and Keller 1992.

Anhydrite with the salt

The Werner Anhydrite below the salt and Pine Hill Anhydrite above is an anhydrate-salt-anhydrite sandwich which is seldom considered when the Louann salt's origin is modeled. Anhydrite, $CaSO_4$, is a regular accompanying rock for salt deposits where hot salt draws away the needed water to form Gypsum, $CaSO_4 \cdot 2H_2O$. Luhr (2008) places the temperature around 800ºC, and requires protection from cold seawater during its deposition. Anhydrites exhibit retrograde thermal solubility, which means it is more soluble in cold water, preventing its deposition by cold oceans. (Cryst of anhydride did not last a year in specimens exposed on the earth's surface.) The forced use of very hot water to deposit the anhydrite both above and below the salt suggest the salt origin was also a heat event.

Norphlet Sandstone

The Norphlet Formation which tops the Pine Hill Anhydrite, consist of a thin bed of black shale then a much thicker bed of arkose. Arkose is sand size particle contains more than 25% feldspar and often mica, is usually mostly quartz but may contain none. The arkose beds in the Norphlet are liberally sprinkled with hematite. Hunt (2013) describes it as being basement-derived clastics. Africano et al (2002) gives the condensation temperature for hematite in the presence of adequate oxygen from 850-550ºC. Arkose beds change in the upper Norphlet to frosted grains forming aeolian dunes. Individual dunes are over a mile/ 1.6 km wide, and liberally mixed with patches of salt grains. The longitudinal dunes are indicative of high wind speed and low sediment movement. This would be the wave form expected with moving sand size grains heavy with water. The dunes generally radiate into the central gulf, but suddenly change direction with little or no transition of smaller dune forms (Hunt 2013), suggesting sudden change of wind direction with no loss of force.

The top of the Norphlet shows considerable reprecipitated quartz suggesting a high temperature in very shallow moving water (multiple puddles of several hundreds of square kilometers each). There is no mechanism for low temperature reprecipitation of quartz, but at supercritical temperatures and pressure (Ballman 1967) it is possible. If deposition of these strata had occurred inside a shock bubble, superheating would keep the NaCl saturated water liquid, with superheated convection currents moving the water-salt-sand mixture with dissolved quartz.

Alternative models for salt precipitation

Recognizing difficulties with the evaporation model for deriving the Louann and other large salt formations of the world, four alternate models have been proposed. A couple models use a hydrothermal brine brought up from great depth by juvenile or enrichment recirculated ground water. One model proposes a pycnocline (Nutting 1984) and sees support in the salt sediments produced occasionally when the stratified waters of Dead Sea turnover.

The Dead Sea occurs in the Jordon Rift Valley between Jordon, on the east and Israel on the west. The sea is bordered by Mount Sedom, a salt diapir, on its southern end, and is entirely underlain at depth with the Sedom Formation (halite). The pycnocline develops when constant environmental conditions allow the Dead Sea's water to stratify by temperature and density[17]. When the waters do turn over a temporary shower of salt crystals does results as saturated brine becomes temporarily supersaturated. With the constant availability of salt from the diapir, salt concentration in the Dead Sea is always saturated and supersaturated conditions are often effected by weather, causing such temporary salt sediments on the bottom to be transitory.

A second model using hydrothermal brine (Hovland et al 2006) at 430-720^{o}C and 250 bars of pressure, finds an area where solid halite remains. Figure 4 in the supercritical range shows that NaCl does remain soluble when greater pressure than 250 bars is used. The experimental data for this model was too restrictive to fully test NaCl solubility. But, they did recognize a very important prerequisite; if solid NaCl is produced there needs to be an environment that separates the salt from water before cooling so that it does not redissolve.

A third model uses pH as a NaCl precipitator (Walker 2019). When acid is added to water, the ionic bonds of the water disassociate the anions and cations of the acid. When NaCl dissolves in water it also depends on the ionic bonds to disassociate the salt's ions. If the water's ionic charges are already tied up with the acid, the acid is acting like an anti-solvent preventing the salt staying in solution. Experimental results (Pettit and Fontana 2019) with HCl showed only 10-11.3 mol/l allowed the NaCL to crystallize in hopper form. At molals below that, 3-4 mm cubic crystals were formed, and above 11.3 mol/l only dendritic crystals would form. As only hoppers will form the chevron pattern in cleavage and molals greater than ten are very hard to imagine naturally occurring, this model seems inadequate.

The fourth model proposes molten NaCl, possibly in the form of a natrocarbonate (ultra-alkaline) lava (Heerema and van Heugten 2018). With the right mineral mixing, the lava shows a reduced eutectic melting point at 725^{o}C. However a eutectic mixture would crystallize as a mix of cryptocrystalline forms, not the pure salt covered and underlain by the anhydrite as found in the Werner-Louann-Pine Hill sequence of the gulf. Additionally, it is hard to imagine a lava being spread-out in a relatively thin layer over 1.6-1.8 million km^2. And, while this model assumes the liquid lave could mix with water born sediments, they provide no means of preventing the NaCl from dissolving in the water, as the phase diagram shows.

Warren (2006) sums-up the situation when he concludes that no comparable environmental condition exist today that would produce these large salt beds. This is certainly one area where the present is not the key to the past.

A new model for salt deposition

Making the assumption that the Gulf of Mexico is the result of a large astral-impact, has been suggested in Chapter 11 and would provide a shock bubble of superheated air above the excavated gulf. This provides a new model for the Louann Salt. Trend A, Figure 3 suggest a general extent of such a bubble and impact crater.

Africano and Bernard (2000) and Africano et al (2003) shows that from a cooling volcanic vapor pure crystal of the various minerals form according to their temperature of crystallization. The quantity of various minerals will varies by the composition of the magma. If the magma was alkaline as the occurrence of Smackover Limestone suggest (Figure 7), the cations may substitute and CaCl becomes more prominent than NaCl. At a few percent it acts as a desiccant and help control NaCl dissolution.

Africano and Bernard (2000) cite vapors that exit Japan's Satsuma-Iwojima Volcano at 850^{o}C / 1560^{o}F immediately start condensing iron and quartz oxides, in the form of Magnetite and Cristobalite, and then halite and sylvite, with all of the micro crystals elongated in the direction of gas movement. This could account for the predominance of the spar form of the halite crystals as Warren (2006) recognized, but as movement in the air column rather than movement into diapirs. If the elongated spar crystals were already formed, movement in saturated water would cause them to remain aligned in flow direction. If 85% of the halite is in the spar form, then 85% of the time the salt was depositing the winds were rapidly moving. This would be the expected condition in the early portion of cratering when winds first move out in the cratering event, then rush back in to fill the vacuum.

As the vaporized gases cooled slightly forming supersaturated conditions, results of Aficano and Bernard (2000) show first spherical crystals of Cristobalite and octahedrons of Magnetite form, then well-formed crystals of both Halite and Sylvite, KCl. I propose the spar crystals of NaCl production was extended as the cloud slowly cooled towards crystallizing the Ca ions. The prominent red color in clay and many of the layers is often identified as rust or limonite but probably is hematite, the high temperature oxide of iron. Hematite forms at the same temperature as magnetite if abundant oxygen is available and it does not break-down or become mobile under regular environmental conditions as rust does. The quartz oxide stopped deposition and the iron mineralization changed from Magnetite to Pyrite ($Fe^{+2}2Fe^{+3}$ = Magnetite to Fe^{+2} = Pyrite) at 510^{o}C. Between 850-650^{o}C sodium and potassium form sulfates, but Halite, NaCl, is the most prominent condensate between 650-550^{o}C. Sylvite, KCl, becomes the most prominent below 550^{o}C continues to be deposited in a broad range of temperatures depending on available of the ions. This variety of condensates seems to encompass every mineral and combinations of minerals found associated with the various anhydrite beds (Nutting 1984 and Block 1961).

I would propose the Louanne Salt condensed predominantly as fine spar crystals, in supersaturated water also produced by the event. Condensates from this crater probably continued through the Bossier Shale and Cotton Valley Sandstone, which would form a fairly good water excluding seal before the general Flood water had access. This depth would represent a single impact condensates, and a significant unconformity is recognized at this point. But the Louann Salt remained mobile through at least two additional impact events which deposited the "Cretaceous" strata, suggesting these additional event were very close in time sequence.

Conclusion

Multiple lines of reasoning associated with the Louann salts support the possibility that they are deposited from an impact cratering event.

1) The slope of the crystalline basement which the salt is clinging to would be consistent with the crater bowl excavated by an impact.

2) The original distribution of the NaCl as an even layer over that slope like fallen snow, indicates "falling", not waterborne sediments.

3) The occurrence and composition of the Eagle Mills Formation below the salts would be consistent as the rubble left on that surface striated by the cratering blast.

4) The occurrence of the salt low in the condensate is what volcanic vapor sequence suggest.

5) The composition of the salt and anhydrite sandwich supports differential crystallization from extremely high temperature source and deposition sequentially.

6) The cooling vapor cloud is consistent with the sequence oxidized iron, hematite, at high temperatures, and reduced iron, magnetite and pyrite at slightly lower temperatures.

7) The direction of form of longitudinal dunes in the Norphlet sandstone and spar crystal form in the Louann salt is consistent with air movements associated with cratering.

8) Foliation in metamorphic core complex is better explained by kicking, a sudden large stress pushing the minerals outward and producing melting by compressional stress.

9) Saturated to supersaturated water available at temperatures higher than 100^{o}C available surrounding NaCl to prevent dissolution of salt.

10) Interfingering up through the Smackover limestone and Haynesville shale show deposition was in one gulf wide event; big enough to be an impact crater.

This is enough evidence that impacts need to be considered as a possibility. The work of the Creator is visible in the details.

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