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**Depositional and Diagenetic History of the Triassic Redbeds and Evaporites
from the Mercia Mudstone Group in the Carnduff 02 Core of County Antrim,
Northern Ireland**

Anna Sofia Andeskie

**Thesis submitted to the
Eberly College of Arts and Sciences
at West Virginia University**

**in partial fulfillment of the requirements
for the degree of**

**Master of Science
in
Geology**

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**Morgantown, West Virginia
2016**

Keywords: Triassic, Mercia Mudstone Group, redbeds, evaporites, lake, Northern Ireland

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ABSTRACT

Depositional and Diagenetic History of the Triassic Redbeds and Evaporites from the Mercia Mudstone Group in the Carnduff 02 Core of County Antrim, Northern Ireland

Anna Sofia Andeskie

The Triassic Mercia Mudstone Group from the Carnduff 02 core from County Antrim, Northern Ireland was deposited by shallow perennial saline lakes and associated environments such as saline mudflats, dry mudflats, siltflats, sandflats, and desert soils. This setting contained shallow acid brines that underwent flooding and evapoconcentration cycles in an arid climate. The redbeds and evaporites of the group have a complicated diagenetic history.

The Mercia Mudstone Group is composed of five main lithologies: mudstone, siltstone, displacive halite, bedded halite, and bedded gypsum. Other less abundant lithologies include sandstone, mud/halite conglomerate, and igneous intrusive rocks. The mudstone and siltstone are composed of quartz, hematite, kaolinite, and halite. Some mudstone and siltstone contain evidence of sheetfloods, including ripple cross-bedding and dewatering structures, as well as evidence of subaerial exposure, such as mudcracks and rip-up clasts. Other mudstones and siltstones are massive and may have been deposited by wind. Later pedogenesis developed soil slickensides, blocky peds, and circumgranular cracks. In areas where these mudstones and siltstones are saturated with saline groundwater, randomly oriented displacive halite crystals formed, leading to the displacive halite lithology. Red mudstones without displacive halite crystals formed in dry mudflats where the groundwater table was low. Likewise, displacive halite crystals formed in saline mudflats, adjacent to saline lakes where saline water table was high. Saline lakes are represented by bedded halite and bedded gypsum. Most bedded halite contains chevron crystals indicating bottom-growth from a shallow surface brine. Bedded gypsum consists of swallow-tailed bottom-growth crystals, also indicative of surface brines. Bedded halite and bedded gypsum both contain dissolution pits/pipes and dissolution surfaces that are commonly covered by mud drapes. The saline lakes underwent cycles of flooding and evapoconcentration.

The diagenetic history of the Mercia Mudstone Group is complex. Mudstones and siltstones contain early reduction spots, early rare displacive halite crystals, and late sylvite veins. Displacive halite units contain abundant early halite grown in shallow groundwater and also host rare late sylvite veins. Bedded halite and bedded gypsum contain early diagenetic features such as dissolution pipes/pits. Another late diagenetic feature is gypsum replaced by halite. Tertiary intrusive rocks cross cut all Mercia Mudstone Group lithologies.

The saline nature of the Mercia Mudstone Group is interpreted based on high abundance of evaporites throughout the group such as bedded halite, bedded gypsum, and displacive halite. Lack of carbonates, as well as abundance of hematite and kaolinite in lake facies, suggests acidity. In summary, the early Triassic of Northern Ireland was characterized by shallow acid perennial saline lakes and red desert siliciclastics.

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Introduction

Research goal

The Permo-Triassic was an extremely unusual time for Earth. At this time, the supercontinent Pangea and the superocean Panthalassa dominated the surface. Earth's flora and fauna underwent one of the largest mass extinction events known. Earth was recovering from glaciation events with increasing atmospheric greenhouse conditions. Environments reflected these extremes. Some environments from this time are interpreted as highly acidic and saline continental lake settings. These interpretations are made from redbed and evaporite deposits in equatorial Pangea (now North Dakota through Oklahoma). These environmental interpretations are based on sedimentological and geochemical work (Foster et al., 2014; Sweet et al., 2013; Zambito and Benison, 2013; Benison and Goldstein, 2000, 2001; Benison et al., 1998). The worldwide spatial and temporal extent of these Permo-Triassic extreme continental environments is currently not well known.

The research goal is to determine the detailed depositional environment and diagenetic history of the early Triassic redbeds and evaporites in County Antrim, Northern Ireland (Fig. 1). My thesis focuses on the Mercia Mudstone Group from the Carnduff 02 core. This thesis tests three hypotheses: (1) this was once a continental environment with saline lake-saline mudflat-soil systems, (2) these environments had acid brines in an arid setting, and (3) the redbeds and evaporites have a complex diagenetic history. The first hypothesis tests if these redbeds and evaporites formed in continental environments including mudflats, lakes, and desert soils. An alternative hypothesis is that these redbeds and evaporites formed in marginal

marine settings, such as tidal flats or lagoons. The second hypothesis tests the extremities of these environments in regard to acidity, salinity, and aridity. An alternative hypothesis is that this was once a humid environment with neutral pH or alkaline waters and low salinity. The third hypothesis describes diagenetic history of the redbeds and evaporites of the Mercia Mudstone Group.

Global Importance

This research project has many implications of global importance. Most significantly, this project will contribute to a wider understanding of global Pangean environment and climate. There are recorded highly acidic and saline Permian environments in Kansas, North Dakota, Wyoming, and Oklahoma, but the global extent of these environments not well defined (Fig. 2; Foster et al., 2014; Sweet et al., 2013; Benison and Goldstein, 2000 and 2001; Benison et al., 1998). These environments are recorded to have pH's as low as -1 and air and shallow surface water temperatures ranging from 21°C to 50°C. The spatial and temporal limits of these environments can be found by expanding study locations and ages focusing on depositional environments.

Redbeds and evaporites can be used as an analog for martian sedimentary rocks. Modern and ancient redbed and evaporite sequences on Earth have properties similar to features seen on Mars. Minerals, sedimentary textures, sedimentary structures, and diagenetic features on Mars (Squyres et al., 2012) are consistent with those observed in the Permian Nippewalla Group (Benison, 2006) and modern acid saline lakes and groundwater systems in Australia (Benison and Bowen, 2006; Benison and LaClair, 2002). Both of these systems are dominated by redbeds and evaporites. It is important to continue research on new redbed and evaporite units on Earth to use an analog for the study of Mars.

Figure 1: Map of Pangea and Panthalassa during the Early-Middle Triassic. Location of Carnduff 02 core in County Antrim, Northern Ireland is designated by the gold star Courtesy of Ron Blakey and Colorado Plateau Geosystems, Inc.

Figure 2: Permian red beds and evaporites in the USA. Results from this proposed research on the Triassic red beds and evaporites of Northern Ireland will be compared and contrasted to these U.S. deposits to test lateral extent of extreme continental environments during Pangean time. Modified after Walker, 1967; Benison and Goldstein, 2000 and 2001.

The chemical composition of groundwater plays an important role in regard to early and late diagenesis in the subsurface, affecting porosity and permeability of rocks. Acid brine groundwaters can syndepositionally enhance or occlude the porosity or permeability of the rocks, influencing the potential of using the formation as a seal and/or trap. This can have an important lasting effect on the hydrocarbon potential of a formation.

The Mercia Mudstone Group has numerous implications for the petroleum industry. Evaporites, such as gypsum and halite, are easy to identify within well logs due to their well-defined densities. Halite has a specific gravity of 2.17 g/cm^3 and gypsum has a specific gravity of 2.32 g/cm^3 (Majithia, 1994). The average specific gravity of most other sedimentary rocks is $\sim 2.7 \text{ g/cm}^3$. The low specific gravity of halite, gypsum, and anhydrite makes them easy to distinguish on density logs. Utilizing these properties, evaporites (especially anhydrite) are commonly used as marker beds on well logs.

Locations of evaporites and redbeds in the subsurface are very important. Saltiness can cause drilling equipment to rust and break. Malfunctions can occur when drilling with fresh/dilute waters. This process will dissolve subsurface halite and cause drilling equipment to break within the subsurface. For this reason, it's important to have a strong understanding of the quality and location of evaporites within the subsurface.

In summary, studies focusing on red siliciclastics and evaporites are important for multiple reasons. These lithologies have implications with the petroleum industry, extraterrestrial studies, and paleoclimate studies. It is important to expand the knowledge on redbeds and evaporites spatially and temporally on Earth.

Background

Structural Setting and Basin Context

There are prominent Permo-Triassic rift basins in the western United Kingdom that are easily identified and composed of 1-4 km thick sequences of red beds and evaporites. The Carnduff 02 core is located within the Lough Neagh-Larne Basin (Fig. 3 and 4), which was likely formed in an early phase of extension from the splitting of Pangea (Benton et al., 2002). Based on boreholes, the Mercia Mudstone Group is twice as thick on the eastern side of the Lough Neagh-Larne Basin than in the west (Benton et al., 2002; Griffith and Wilson, 1982). The beds within the Sherwood Sandstone, Mercia Mudstone, and Penarth groups all gently dip to the north-west, but there is some small folding seen in the Mercia Mudstone Group slightly east of the Kilroot Salt Mine (Ruffell and Shelton, 1999). Strike-slip faults are present within the Lough Neagh-Larne Basin and are interpreted to have reactivated during the Permian, Mesozoic, and Cenozoic (Ziegler, 1990; Lake and Karner, 1987). Studies focusing on the thickening of strata near faults interpreted from seismic data suggest that the Mercia Mudstone Group was deposited during rifting (Ruffell and Shelton, 1999). Most faults post-date the group. Tertiary-aged igneous intrusions crosscut the Sherwood Sandstone Group, the Mercia Mudstone Group, and the Penarth Group (Griffith and Wilson, 1982).

Mercia Mudstone Group in England

In England, the stratigraphy of the Mercia Mudstone and Sherwood Sandstone groups has been well described (Fig. 3). The underlying Sherwood Sandstone Group is estimated to range from Late Permian/Late Early Triassic (late Olenekian) to Mid Triassic (Anisian; Warrington,

2005). The Permian/Triassic boundary has yet to be resolved, resulting in the uncertainty of the Sherwood Sandstone Group ages. The best method for dating these rocks is through biostratigraphy using multiple age-diagnostic fossils and magnetostratigraphy. The lower formations within the Sherwood Sandstone Group contain vertebrate footprints such as the *Chirotherium* and *Rhynchosauroides* (Tresise and Sarjeant, 1997) and crustaceans (*Euestheria*; Warrington et al., 1999). In upper formations within the Sherwood Sandstone Group in England, fossils such as conifers and horsetails plants, brachiopods, bivalves, crustaceans (*Euestheria* and ostracods), scorpions, fishes (*Gyrolepis*, *Dipteronotus*, and *Ceratodus*), and *Mastodonsarus* have been identified (Benton et al., 1994; Old et al., 1991; Walker, 1969).

Based on magnetostratigraphy, the Mercia in England is estimated to range from Middle Triassic (Anisian) to middle Late Triassic (Norian; Warrington, 2005), in agreement with macrofossil evidence from the Otter Sandstone Formation of the Mercia.

The overlying Penarth Group is dated to be Late Triassic (Rhaetian in age) from biostratigraphic and magnetostratigraphic evidence. Biostratigraphic evidence includes marine fossils such as dinoflagellate cysts, corals, brachiopods, bivalves, echinoderm debris, and ichthyosaur bones (Warrington, 2005; Warrington et al., 1981). In England, the Penarth Group overlies the Mercia Mudstone Group unconformably (Benton et al., 2002).

In the Cheshire Basin of England, the Mercia is composed of the Blue Anchor Formation, the Branscombe Mudstone Formation, the Arden Sandstone Formation, and the Sidmouth Mudstone Formation. The group is divided differently within the Lough Neagh-Larne Basin of Northern Ireland (Fig. 3 and 4).

Figure 3: Stratigraphic column of the formation within the Mercia Mudstone Group in the Cheshire Basin of England (modified from Arthurton, 1973) and the Lough Neagh-Larne Basin of Northern Ireland (modified from Griffith and Wilson, 1982).

The Mercia Mudstone Group has a potential industrial purpose in Nottingham, England within the Cheshire Basin (Fig. 4). In this location, the Mercia has been evaluated for a potential caprock for CO₂ sequestration in the Sherwood Sandstone Group to help lower greenhouse gas emissions.

The caprock quality of the Mercia Mudstone Group of the Cheshire Basin was assessed through studies on the Willow Farm borehole (Fig. 4). This study focused on mineralogy, petrology, and mercury injection porosimetry of six samples between the depths of 300-310 m (Armitage et al., 2015). It was found that the Mercia Mudstone has detrital minerals of quartz, K-feldspar, illite, and chlorite and diagenetic pore-filling minerals of calcite, dolomite, and gypsum. There is a very low overall porosity and a permeability of 10^{-20} and 10^{-19} m². Armitage et al (2015) interpreted that leakage of CO₂ will only occur over long periods of time (assuming that the samples observed represent the entire group). Armitage et al (2015) concluded that “because caprock quality correlates with illite content and illite will be relatively immune to elevated partial pressures of CO₂, the Mercia Mudstone probably represents a durable caprock for future Lower Triassic sandstone CCS projects”.

Few other studies have been completed on Permo-Triassic evaporites in England. Arthurton (1973) conducted petrographic analyses of bedded halite in the Cheshire Basin and concluded it was bedded halite with some detrital halite. Smith (1971) described the displacive halite in the Permian Upper Evaporite Group of northeast Yorkshire, England, noting that is dominated by fine grain-size red siliciclastics with syndepositional displacive halite growth.

Mercia Mudstone Group in Northern Ireland

The Mercia Mudstone Group is found between the depths of 387.24 m to 970 m in the Carnduff 02 core from County Antrim, Northern Ireland (Fig. 5). As discussed earlier, it is estimated to be early Triassic in age (Warrington, 2005; Benton et al., 2002) based on the biostratigraphy and magnetostratigraphy of the Mercia in England. The Mercia is bounded by the underlain Permo-Triassic Sherwood Sandstone Group and overlain by the Late Triassic Penarth Group (Fig. 7). Until now, detailed stratigraphy, petrography, and sedimentary geochemistry have not been undertaken on the Mercia Mudstone Group in Northern Ireland.

The few outcrops of the Mercia Mudstone Group in Northern Ireland are located on the coastline, are of low relief/extremely poor quality, and not amenable to section measurement (personal communication, K. Benison and J. Knapp). The official generalized geologic map of northeastern Northern Ireland (Fig. 6) is overly generalized. The mapped geology does not correspond to known Mercia outcrop locations. The Sherwood Sandstone is only located in the subsurface in Northern Ireland and can be seen in cores and the Irish Salt Mining and Exploration Company's Kilroot salt mine (R. Raine, personal communication). The Mercia Mudstone Group in Northern Ireland is reported to be composed of multiple formations: Glenstaghey Formation, Knocksoghey Formation (containing the Larne Halite Member), Pore More Formation, and Collin Glen Formation (Fig. 3; Griffith and Wilson, 1982).

No detailed petrographic and geochemical study on the Mercia Mudstone Group in the Lough Neagh-Basin of Northern Ireland has been undertaken to date. This thesis represents the first detailed description of lithology, interpreted depositional environments, and diagenetic history for these rocks.

Figure 4: Map displaying location of previous study on the Mercia Mudstone group in England (Willow Farm Borehole) compared with location of Carnduff 02 core (Lough Neagh-Larne Basin). Modified from Armitage et al., 2015.

Figure 5: Map of Northern Ireland and Ireland. Star represents research location.

Figure 6: Portion of the 1:200000 scale map of Northern Ireland, showing location of the core. Modified from Geologic Survey of Northern Ireland Geoindex, 2015.

Figure 7: General stratigraphic column of late Permian- mid Triassic of the United Kingdom. Modified from Benton et al., 2002.

Methods

The research plan was divided into two components: core repository and laboratory work. observations in hand sample and thin section of the Mercia Mudstone Group. The Geological Survey of Northern Ireland (GSNI) granted permission to use a core, Carnduff 02, drilled by Gaelectric company in 2014 near Larne, Northern Ireland. The drilling fluids were fully saturated in halite before the evaporite units were reached. The core has a recovery rate of 92.7%. The original purpose in drilling the core was to observe locations to use compressed air energy storage (CAES) technology. CAES is a renewable energy storage concept in which fresh air is trapped, compressed in the subsurface using the salt as a seal, and released to generate electricity. To complete an assessment for CAES, Gaelectric company only made a gross measured section, simply estimating abundance of halite and mud, without slabbing the core or making any detailed measured section describing sedimentary structures or diagenetic features.

Core Repository Work

The Carnduff 02 core is currently stored at the GSNI core repository in Belfast, Northern Ireland (Fig. 8). Dr. Kathleen Benison, Lynnette Eichenlaub, and I spent four weeks in Belfast during the summer of 2015. We slabbed the core, made a detailed measured section, scanned core slabs for digital photographs, and collected samples, which is 591.6 m thick in its entirety in this core.

The core had been stored in plastic. This prevented the evaporites from dissolving in the humid climate of Northern Ireland. Some thick, mudstone and siltstone units remained unbagged.

The plastic bags were sliced open with box cutters for observations and later sealed with packing tape to preserve the core.

The Carnduff 02 core was slabbed using a DeWalt D24000S Wet Tile Saw (Fig. 9) modified to employ a small, focused water stream onto the back of the saw blade to minimize salt dissolution. Water was used when cutting, rather than a light oil, because it was a less expensive option that provided an easier clean up. The slabbed core was scanned (Appendix 1) and measured/described based on sedimentary textures, mineral composition, color, sedimentary structures, any fossils present, diagenetic features, and bedding/contacts. Unit contacts were defined by a change in mineralogy. Mineralogy was determined by visual identification, HCl acid test, and taste test (specifically for halite). Sedimentary structures observed include discontinuous horizontal lamina, ripple cross-bedding, mudcracks, peds, and rip-up clasts.

The measured section was then used to create two stratigraphic columns of the Mercia Mudstone Group. A detailed stratigraphic column was created from the measured section and a generalized stratigraphic column was based on the detailed stratigraphic column. Selected representative samples were carefully sealed in plastic, packed, and mailed to West Virginia University for further work

Figure 8: Location of drilling for the Carnduff 02 core in Northern Ireland.

Figure 9: Photos from the GSNI core repository work (A) Mercia Mudstone Group in core boxes organized at the GSNI core repository and (B) the saw used to cut the core. Courtesy of K. Benison.

Laboratory Work

Once back at West Virginia University, detailed petrography was performed. The color of various lithologies were analyzed using the Konica Minolta Chroma Meter CR-400 (Appendix 5). This allowed exact colors to be recorded and compared with the Munsell color readings in the core repository. Representative lithologies samples were selected throughout the Mercia Mudstone Group and sent to Spectrum Petrographics Inc. for thin section preparation. A total of 33 thin sections were made and observed. There were 12 thick sections (approximately 4 mm thick) and 21 thin sections (standard thickness of 0.03 mm) made. Out of the 33 thin sections, 27 were large format and 6 were small format. All were made without use of water or heat and in vertical orientation. The petrography of the thin sections included examination of sedimentary textures, mineral composition, color, sedimentary structures, identification of any fossils present, diagenetic features, and bedding/contacts. Thin sections were observed in plane transmitted, reflective, polarized, and UV-vis light. Two microscopes were used: Olympus SZX10 (6.3-2000x magnification) and Olympus BX53 (6.3-63x magnification). Photomicrographs were taken with a digital camera and SPOT digital imaging system to record important sedimentary textures, sedimentary structures, and mineralogy.

Results

General stratigraphy and sedimentology

The Mercia Mudstone Group in the Carnduff 02 core is 591.6 m thick and has an excellent recovery rate of 92.7%. The group begins at 378.4 m and ends at 970 m deep. Only 45.4 m from

this depth range were missing. A cm-scale measured section was created and used to make both a generalized (Fig. 12) and detailed stratigraphic column (Fig. 13). Five main lithologies were identified throughout the group: mudstone, siltstone, displacive halite, bedded halite, and bedded gypsum (Appendix 2). Although the Mercia is relatively thick, the five main lithologies were repeatedly seen throughout the group. Other less abundant lithologies include sandstone, mud-halite conglomerate, and igneous intrusion. Sandstone was observed in shallow depths with a total thickness of 1.7 m and was interbedded with the siltstone. Two igneous intrusions were seen: one at depth 460 m, cross cutting siliciclastics and another at depth 790 m, cross cutting bedded evaporites. Mud/halite conglomerate was seen at the bottom-most depth of the measured section. The distribution of thickness for various lithologies is presented in Figure 10. This table shows that, respectively, mudstone, displacive halite, bedded halite, and bedded gypsum were the most common lithologies. Some units of evaporites were unable to be differentiated between halite and gypsum, therefore labeled “undifferentiated evaporites”. The undifferentiated evaporites comprised a total of 47.58 m of the Mercia Mudstone Group within the core (approximately 8%). The abundance of siliciclastics and evaporites is also compared in Figure 11. The most abundant lithology is mudstone, which comprises 203.65 m or 34% of the group. The second most prevalent lithology was displacive halite at 150.72 m or 25%. Bedded gypsum, bedded halite, and undifferentiated evaporites together composed 23%. Representative thin sections of the main lithologies were made to make observations of microscopic features. Thin sections were also made with the intention of documenting the entire core and not missing large areas. Thin sections depths and billets images are recorded in Appendices 3 and 4.

Multiple trends in lithology were seen throughout the Mercia Mudstone Group. Based on the acid test, there are no carbonates. The uppermost bedded halite members are found at

approximately 627 m, correlative with the top of the Larne Halite Member (Appendix 5). At this point, displacive halite and mudstone lithologies dominated from 627 m to 581.1 m depth. Mudstone and siltstone lithologies are prevalent between 581.1 m and 492.7 m depth. From 492.7 m to 378.4 m depth in the upper core, sandstone and siltstone lithologies dominate.

Figure 10: Bar graph illustrating the distribution of total thickness for various lithologies throughout the Mercia Mudstone Group.

Figure 11: Pie charts comparing the distribution of siliciclastics and evaporites within the Mercia Mudstone Group in the Carnduff 02 core. The top chart compares relative abundance of mudstone, siltstone, and sandstone. The bottom chart compares relative abundance of bedded halite, undifferentiated evaporites, and bedded gypsum. Displacive halite is the second most abundant lithology, but is not represented throughout these graphs because it contains both siliciclastics and evaporites.

Figure 12: Generalized stratigraphic column of the Mercia Mudstone Group in Carnduff 02 core. Stars representing thin section depths.

Carnduff 02 Core

Figure 13: Stratigraphic column of the Mercia Mudstone Group within the Carnduff 02 Core of County Antrim, Northern Ireland.

Mudstones

Observation of depositional features

Mudstone is the most common lithology in the core. It makes up approximately 203.65 m out of 591.7 m, approximately 34% of the Mercia Mudstone Group. The mudstone characteristics are very consistent. According to the Udden-Wentworth size class, the term mudstone incorporates grains that are coarse clay to silt sized. Most grains within the mudstone lithology are dominated by clay-sized grains with some occasional silt-sized grains. If the unit is dominated by silt-sized grains, then it is considered to be within the siltstone lithology. The color of the mudstone varies from a brick/chocolate red (Munsell color reading: 2.5YR 3/2) to a blue-ish gray (Munsell color reading: GLEY2 4/10B). Occasionally, the mudstone can appear purple, bright red, or dull green (Fig. 14). Color changes within the core can be abrupt or gradational. Most grains within the mudstone are smaller than 0.0020 mm and rare grain sizes reach 0.0625 mm. All mudstone had a high clay mineral content. When cutting the mudstone, a thick, tan mineral accumulated on the saw. This mineral was interpreted as and was observed throughout all mudstone units.

Multiple sedimentary textures and structures were observed within the mudstone. Some units of mudstone were relatively massive. In the massive units, some mudstone varied in color but did not have any other distinctive features. There was no bedding noted in most sections and grain size was very well sorted. There were rare laminae present within the mudstone. The laminae tend to be thin (1-3 mm in size) and discontinuous (Fig. 15). One of the most common sedimentary structures within the mudstone were blocky peds. The peds are two to three centimeters in width and height. The peds are well sorted, consistent in size, and prismatic angular to prismatic subangular. Soil slickensides are also common within the mudstone. Soil slickensides are made from shear planes when clays shrink and swell from repeated wetting and drying of mud. In hand

sample, they appear to be smooth surfaces with some long grooves. Other structures produced from wetting and drying were observed such as mudcracks. The mudcracks have disturbed lamina on the sides of a “V” shaped crack. The “V” shape cracked is filled in with later sediment (Fig. 16). Soft sediment deformation was found throughout the mudstone, once again indicating episodic wet environments. Typically, soft sediment deformation was found near mudcracks. Another sedimentary structure that was identified that indicates repetitive wetting and drying was dewatering structures (also known as pillar structures). These structures are thin, clay lenses that are vertically oriented with silt-sized sediment in the center due to water escaping. This was observed in multiple thin sections (Fig. 17). Rip-up clasts were also common within mudstone lithology. Typically, the rip-up clast itself is composed of mud-sized grains and the surrounding grains were silt due to the velocity needed to carry the clast itself (Fig. 19 and 20).

Observations of diagenetic features

Diagenetic features are also found within mudstones. An early diagenetic feature that can also be considered syndepositional are displacive halite crystals (Fig. 21C). The crystals are square, clear/pink halite crystals within the core and were very rare. Reduction spots are commonly found throughout mudstone and vary in size and are circular in shape and were observed in both hand sample and thin section (Fig. 21A, 21B, and 22). The outside circle tends to be a lighter grey with an inner circle that is a dark grey. Another extremely common diagenetic feature was the presence to sylvite veins. Sylvite veins were only found within mudstone and siltstone lithologies. The veins varied in size and length and occasionally branched throughout the rock. Gypsum stringers and gypsum efflorescent crusts were present as well. The gypsum efflorescent crust was identified on the outside of the core on the sections that weren't plastic bagged.

Figure 14: Core slab scans featuring various colored mudstone in the Larne Halite Member
A) 955.2 m B) 867 m.

Figure 15: Core slab scans featuring various colored mudstone in the Larne Halite Member at a depth of 959.3 m.

Figure 16: Core slab scan featuring a multi-colored mudstone in the Larne Halite Member at a depth of 965.9 m. The illustration on the right shows detailed laminations and a mudcrack. The laminae are disrupted from the mudcrack.

Figure 17: Thin section photomicrographs of mudstone in the Larne Halite Member at a depth 965.9 m showing: A) Dewatering structures and associated mudclasts B) Dewatering structure in plane light C) Dewatering structure in reflected and plane light D) Rip-up clast and dewatering structures in plane and reflected light.

Figure 18: Core slab scan featuring a multi-colored mudstone in the Larne Halite Member at a depth of 966.1 m. Image on the left is the core with full resolution of color. Image on the right shows the slightly transparent core with outline of important textures and structures. There are multiple mudcracks present varying in size throughout the slab. Rip-up clasts, horizontal laminae, and potential concretion or roots are present as well.

Figure 19: Thin section photomicrographs focusing on rip up clasts in the Larne Halite Member at a depth of 844.8 m
 A) Evaporites truncated by mud drapes in plane light B) Mud drapes with associated rip-up clasts C) Mud drapes with associated rip-up clasts in reflected and plane light D) Rip up clast in plane and reflected light.

Figure 20: Thin section photomicrographs of mudstone in the Larne Halite Member at a depth of 966.2 m A) Contact of color change within the mudstone B) Left-hand side shows brick-red concretion with large mudcrack on right-hand side C) Mudcrack on right and disrupted lamina on right D) Various colored mudclasts.

Figure 21: Core slab scans featuring various colored mudstone. A) Knocksoghey Formation at a depth of 509.1 m B) Knocksoghey Formation at a depth of 569.6 m C) Larne Halite Member at a depth of 899.6 m.

Figure 22: Thin section photomicrographs in the Knocksoghey Formation at a depth of 441.8 m A) Mudstone with reduction spots viewed in plane, reflected, and polarized light B) Mudstone with reduction spots viewed in plane, reflected, and polarized light.

Siltstone

Observations of depositional features

Siltstone is another fairly common lithology in the Mercia Mudstone Group. Units are considered to fall into the siltstone lithology when they are dominated by silt-sized grains (0.0039-0.0625 mm) with occasional rare clay-sized grains. If the unit is mainly composed (>20%) by clay-sized grains, then it is considered to be a mudstone. The grains within the siltstone lithology tend to vary between well sorted to moderately sorted and are mainly spherical and subrounded in shape. The siltstone lithology is never poorly sorted, the grain size and shape is very consistent (Fig. 23). The siltstone color varies slightly more than the mudstone, ranging from orange-ish red (Munsell Color chart reading of 2.5 YR 4/3) to blue-ish grey (GLE Y1 7/10Y, GLE Y2 6/10B). Usually, the siltstone units appeared to be fairly massive with no bedding and little sedimentary structures observed. In the massive units, the grains were extremely well sorted and many composed of quartz. Wavy discontinuous lamina was found in multiple units. The lamina vary with the color of the host rock and were noted in brick-red and dark grey. Soil slickensides were also found. There were potentially small climbing ripples observed as well.

Observations of diagenetic features

A variety of diagenetic features are found within the siltstone lithology. The most common diagenetic feature is circular reduction spots (Fig. 24). A very recent diagenetic feature includes gypsum efflorescence on the surface of unbagged samples. This feature is tiny gypsum crystals on the cut, unbagged core samples. and rare veins filled with quartz.

Figure 23: Thin section photomicrographs of siltstone in the Knocksoghey Formation at a depth of 486.6 A) Siltstone in polarized light B) Siltstone in plane light.

Figure 24: Thin section photomicrograph of brick-red siltstone with gray reduction spots in the Knocksoghey Formation at a depth of 413.45 m.

Displacive halite

Observations of depositional features

Displacive halite is the most common lithology seen throughout the Mercia, composing 150.72 m out of 591.7 m, approximately 25% of the Mercia. Displacive halite, easily recognized due to its distinct textures and crystal structures, is interpreted to have formed in very early diagenesis, essentially syndepositional. Displacive halite crystals were found within a mud (combination of clay- and silt-sized grains) matrix. The displacive halite crystals were subrounded-subangular in shape, typically in a cubic form (Fig. 25) and would vary greatly in size from a few mm to 2-3 cm. They grew at irregular angles and therefore had a chaotic structure within the core. Figure 26 illustrates different displacive halite crystals. There is no bedding within displacive halite. The largest variation in the displacive halite lithology was the amount of displacive halite crystals within the mud matrix. In the core lab, displacive halite lithology was divided into two groups: displacive halite that's mud rich and displacive halite. The groups were divided due to their mud composition. If the core appeared to have less than 20% mud and more than 80% displacive halite crystals, it was called "displacive halite". If the core appeared to be more than 20% mud and less than 80% displacive halite, it was called "mud-rich displacive halite". The differences in the two sub- lithologies are illustrated in Figure 26 and Figure 27. There is no relationship between mudrock color and displacive halite. It is present in brick-red, grey colors, and gradients as well. Since halite is relatively clear, the crystals reflect the color of the mudrock surrounding it. Therefore, displacive halite crystals within brick-red mudstone look like a dark, glassy brick-red color (Fig. 27).

In thin section, displacive halite continues to have many of the same features present (Fig. 28). The displacive halite crystals have cubic forms with subrounded to subangular crystals edges. It is evident that the crystals are more broken apart around the crystal edges. This could be the process in which displacive halite grows. Halite prefers to grow off previously present halite (treating the crystal as a nucleation site). Therefore, the smaller crystals surrounding the large crystals could be beginning to form. The cracks within the mud in are product of thin-section making and are not interpreted to be veins.

Observations of diagenetic features

Another form of diagenesis present throughout the displacive halite lithology was sylvite veins. The sylvite veins were noted to only exist in mud-rich areas. Therefore, mud-rich displacive halite commonly had sylvite veins cross cutting the mud and rarely around a displacive halite crystal. Displacive halite that had less mud within composition did not have sylvite veins present. The sylvite veins tend to be a lighter orange color and have a pungent, tangy taste in comparison to salt.

Figure 25: Displacive halite from the Larne Halite Member showing different shapes of displacive halite crystals.

Figure 26: Core slab scans featuring varying amounts of displacive halite in the Larne Halite Member A) 781.4 m B) 723.7 m.

Figure 27: Core slab scans of varying amounts of displacive halite in the Larne Halite Member A) 728.6 m B) 831.3 m.

Figure 28: Thin section photomicrographs at a depth 764 m in the Larne Halite Member A) Displacive halite B) Displacive halite crystals with plane light C) Displacive halite in reflected and plane light D) Displacive halite crystals in plane and reflected light.

Bedded halite

Observations of depositional features

The core had 49.25 m of bedded halite, approximately 8.3% of the Mercia. The bedded halite was typically a glassy pink/dark orange color and reflected color of nearby muds (Fig. 29). The bedded halite had some sedimentary characteristics and textures present. The most evident and defining feature within the lithology was the bottom growth crystal structures. Bottom growth halite crystals oriented in the upwards direction were observed with the naked eye. These crystals tended to be 0.25 to 2 cm in length (the average size is approximately 2 cm) and subangular-subrounded in shape. The crystals were normally widest at the bottom and grew into a point (similar to an upside down “V” shape). Chevrons were identified within these bottom growth crystals under the microscope. Chevrons were observed being terminated by dissolution surfaces in thin section as well (Fig. 30). Chevrons were observed in both thick and thin sections. The chevrons would have primary fluid inclusions present forming growth bands on the halite crystal boundaries (Fig. 31, 32, 33). The chevrons were always pointing in the “up” direction, indicated that they were not reworked and are currently still in the original direction. The bottom-growth crystals would form distinct horizontal beds within the core. The composition of this lithology is approximately 90-95% bedded halite and 5-10% mud. Mud clasts were occasionally seen throughout the bedded halite. Some mud appeared to drape across dissolution surfaces in bedded halite. These mud drapes tend to be very thin (0.1-0.3 cm thick), wavy, discontinuous lamina. Occasionally, the mud clasts would have displacive halite crystals suspended within. Kaolinite clay was present when the bedded halite was cut with the rock saw.

Dissolution truncated bedded halite growth can be seen in Figure 34. This thin section provides a contact of mudstone and bedded halite lithologies. The bedded halite has a 90-degree point at the top of the crystal growth. Then mud was transported in, truncating the bedded halite crystals, and creating a change in lithology. This can be seen on the edges of the crystal exposed to the mudstone lithology. Overall, there is not a significant amount of dissolution of the halite crystal, allowing the original crystal shape to still be observed.

Figure 29: Core slab scans of bedded halite in the Larne Halite Member. A) 906.1 m B) 928.5 m.

Figure 30: Thin section photomicrograph of bedded halite with chevrons being terminated by a dissolution surface in the Larne Halite Member at a depth 843.3 m.

Figure 31: Thin section photomicrographs of chevrons in bedded halite in the Larne Halite Member at a depth of 906.2 m.

Figure 32: Thin section photomicrographs of different chevrons in bedded halite in the Larne Halite Member at a depth 919.1 m.

Figure 33: Thin section photomicrographs of chevrons in bedded halite in the Larne Halite Member at a of depth 906.1 m.

Figure 34: Thin section photomicrograph at a depth of 844.4 m of dissolution on bedded halite with mud drapes and clasts in the Larne Halite Member. Note that the subangular quartz grains hosted within the tan cement is the epoxy used for thin section making.

Observations of diagenetic features

Diagenetic features were apparent throughout the bedded halite. An early form of dissolution pipes and pits were found with the core. Typically, the dissolution pipes are filled with a blocky halite cement. The later stage halite is very clear due to slow crystal growth, whereas bedded halite is cloudy from fluid inclusions.

Bedded Gypsum

Observations of depositional features

The bedded gypsum lithology comprised approximately 39.1 m of the Mercia Mudstone Group, approximately 6.6%. The bedded gypsum lithology is a crystal pseudomorph that is now composed of halite that has replaced gypsum. The bedded gypsum pseudomorphs have a single swallowtail- or splayed-shape but are now composed of halite. The gypsum crystals are oriented in an upward “V” shape, whereas halite crystals increase in width as they grow upward. The gypsum pseudomorphs vary in size from 0.5 to 2.5 cm in length. Bedded gypsum was typically reddish brown in color.

In core slabs, there are multiple well-defined beds of gypsum with interbedded layers of other evaporites and mud (Fig 35). Figure 36 is an image of a core slab aligned with an illustration to identify bedded gypsum and interbedded red muds. This shows the contacts between various lithology well too. For example, there is a sharp contact between bottom growth bedded gypsum and displacive halite.

Figure 37 shows bedded gypsum and other lithologies contacts. Figure 37A is a core slab with alternating with bedded gypsum and bedded halite. Figure 37B has bedded gypsum on the bottom of the core slab and a change in lithology into mudstone. Both contacts are sharp, providing an obvious change in lithology. Figure 38 illustrates bottom growth gypsum crystal growing upwards. Growth was terminated due to an influx of mud and the gypsum crystal was slightly dissolved. There was not enough to mud to create a new lithology. The mud tended to be just enough for a small lens (approximately 0.25-3 mm in thickness). After the mud lens, there was nucleation of another gypsum bed and new growth began.

Figure 35: Core slab scans featuring bedded bottom-growth gypsum in the Larne Halite Member at a depth of 910.3 m.

Figure 36: Core slab scans featuring bedded bottom-growth gypsum that is now composed of halite in the Larne Halite Member at a depth of 841.55 m on the right with an annotated slab illustrating bottom growth bedded gypsum, displacive halite, and mudstone.

Figure 37: Core slab scans featuring bedded gypsum in the Larne Halite Member. A) Alternating bedded gypsum and bedded halite at 658 m B) Contact of bedded gypsum and mudstone at a depth of 766.9 m.

Figure 38: Thin section photomicrographs of mud clasts trapped by dissolution surface and nucleation of new crystals in the Larne Halite Member A) Depth of 844.5 m B) Depth of 844.5 m.

Observations of diagenetic features

The main diagenetic feature found within the bedded gypsum pseudomorphs was the pseudomorph crystal themselves. The crystal shape suggests a different mineralogy than the current mineralogy, halite. There are potentially few dissolution pipes and pits found within the bedded gypsum lithology, but they are minor and not as distinct as dissolution in bedded halite.

Other lithologies

There were several lithologies identified throughout the Mercia Mudstone Group that were rare. These lithologies were sandstone, igneous intrusion, and the mud/halite conglomerate sample. Together, these lithologies only composed 24.3 m out of 591.7 m (approximately 4%).

The mud/halite conglomerate was 6 m thick and is only seen at the base of the core at a depth of 939 to 945 m. The halite crystals (60% total composition) were a glassy brown color, subrounded to subangular in shape, and mainly appeared to be a cement that formed around the mud clasts (Fig. 39). The mud (40% total composition) varied between a brick red color and dark grey color. The mud clasts have laminations present within from the previous depositional environment. (Fig. 40).

The sandstone lithologies composed 1.7 m and is only seen in the shallowest sections (486 and 492 m depth) of the Mercia. The fine-grained sandstone was gray (GEY2 8/5PB) and composed of ~90% quartz, plus minor feldspar. The massive, well-cemented sandstone displayed occasional climbing ripple cross-bedding and potential root features.

The igneous intrusion was the largest of the rare lithologies, composing approximately 16.6 m of the Mercia. It was a very dark grey color (GEY1 7/N and GEY1 2.5/N). It was composed of 60% stringy, crystalline, black mineral (potentially hornblende) and 40% white, chalk-like mineral. The igneous intrusion is identified as basalt (H. Lang, personal communication). The weathered sections of the core took on a green color (GEY1 5/5GY).

Figure 39: Halite cemented mud conglomerate core slab in the Larne Halite Member at a depth 943.9 m.

Figure 40: Thin section photomicrographs of halite-cemented conglomerate in the Larne Halite Member at a depth of 943.9 m. Note that the subangular quartz grains hosted within the tan cement is the epoxy used for thin section making
A) Halite cemented mud conglomerate B) Halite cemented mud conglomerate rip-up clasts with reflected and plane light.

Interpretations

Interpreted Depositional Environment

The lithologies of the Mercia Mudstone Group are interpreted as continental sedimentary deposits. The mudstone/siltstone formed in dry mudflats. The displacive halite lithology formed in saline mudflats. The bedded halite and bedded bottom-growth gypsum lithologies formed in shallow saline lakes.

Mudstone and siltstone lithologies are interpreted as dry mudflats and siltflats lithofacies (Fig. 42). The mudflats and siltflats were repetitively wet and dried from flooding events. This process is interpreted through various sedimentary structures. Rare ripple cross-bedding and discontinuous wavy lamina are interpreted as having formed by rapid subaqueous deposition due to an increase in energy from a flood. Massive units of mudstone and siltstone were most likely deposited by wind. Mudcracks, rip-up clasts, and dewatering structures are indicative of desiccation of the mudflat and siltflat after flooding within a previously wet environment (Benison et al., 2007).

Displacive halite lithologies are interpreted as saline mudflat lithofacies (Fig. 42). Displacive halite strictly forms in the unconsolidated shallow subsurface sediment that is saturated with saline groundwater (Smoot and Lowenstein, 1991; Smith, 1971; Benison et al., 2007). The groundwater must be supersaturated in Na and Cl ions for the precipitation of halite to occur. The displacive halite found within the Mercia Mudstone Group in the core only occurs in clay- and silt-sized grains. Therefore, displacive halite in mudstone and siltstone are interpreted as deposits of saline mudflats.

Bedded halite and bedded gypsum lithologies are interpreted to have formed in shallow saline lakes, so they are both considered saline lake lithofacies (Fig. 42). Saline water bottom growth is indicated by chevrons and bedded bottom-growth gypsum. Pseudomorph gypsum crystals were interpreted as bedded due to multiple crystals nucleating from the same surface. Bedded bottom-growth gypsum will grow on the sediment-water interface in surface water that is saturated in Ca and SO₄ ions. Bedded halite with chevrons can only form in surface waters that are less than 0.5 m deep and saturated with Na and Cl ions (Hardie, 1984). The chemical composition of the lake can be determined through the primary mineralogy. Due to the presence of primary halite and gypsum, the surface water must have been rich in Na, Cl, Ca, and SO₄ ions. The surface water could have been much more complex, but further geochemical analyses are needed to determine the complete chemical composition.

The rare sandstone lithology is interpreted as sandflats lithofacies (Fig. 42). This lithofacies has sedimentary structures such as rare climbing ripple cross stratification and potential root trace fossils. Climbing ripple cross stratification are formed from waning energy carrying overload of sediments. The climbing ripple cross stratifications are deposits of sheet floods. Winds could have moved fine-grain sediment such as clay and mud into the lake as well, creating mud drapes and fine-grained laminations.

Figure 41: Schematic illustration of three main sedimentological processes that occurred during time of deposition of the Mercia Mudstone Group (A) pedogenesis, (B) evapoconcentration, and (C) flooding.

Figure 42: Schematic illustration of the Mercia Mudstone Group saline lake and associated facies from (A) map view and (B) cross-sectional view. Modified from Benison et al., 2007.

Flooding and evapoconcentration cycles are interpreted by sedimentary structures, including evaporite crystal shapes and structures. Flooding events occur from influx of meteoric surface water. The meteoric water is considered to be relatively fresh water in comparison to the saline system, creating dissolution of some of the previously precipitated evaporites. This will increase groundwater table height, therefore increasing the surface water depth within the lake. Dissolution is indicative of flooding events. This is observed within the rock record through dissolution surfaces, pits, and pipes on/within the bedded evaporites. These flooding events can also bring an influx of siliciclastics from sheetfloods. The siliciclastics are deposited and form mud drapes on the surface of bedded evaporites. Surrounding facies will have ripples from the sheetfloods/winds which can form climbing ripples cross-bedding (Fig. 41C; Lowenstein and Hardie, 1985).

Evapoconcentration is represented by the precipitation of bedded halite and gypsum. The bedded halite and gypsum will precipitate on the sediment-water interface of surface waters. The surface water table will be lowered from the evaporation. The groundwater table will lower as well. Displacive halite will form in the surrounding siliciclastics (mudflats) that are saturated in saline groundwaters (Fig. 41B; Lowenstein and Hardie, 1985). The ground water table presence can be interpreted by lithofacies containing displacive halite. Displacive halite and mud-rich bedded evaporites also had kaolinite present within the mineralogy. At this point, areas of higher elevation (sandflats surrounding the lake) will become dry more quickly and the early signs of desiccation will begin to be seen.

Other mudstone and siltstone lithologies can be interpreted as paleosols. Paleosols will surround the saline lake, mudflat, and siltflat. Paleosols are identified within the mudstone lithology based on sedimentary textures and structures. The mudstone units that contain soil

slickensides, blocky peds, circumgranular cracks, and small rare root features are interpreted as paleosols (Fig. 41A). Soil slickensides are directly associated to clays shrinking and swelling due to repetitive wetting and drying within the soils (Retallack, 2001). The repetitive drying also provides evidence for an arid climate that caused evapoconcentration to occur. It is interpreted that the paleosols were more of a desert soil than a moist, organic-rich soil (Benison et al., 2007). The lack of roots, bioturbation, and fossils is not exclusive criteria but can indicate that these soils were uninhabitable to plants and animals, potentially due to the acidity and aridity of the environment.

The depositional environment of the Mercia Mudstone Group is controlled by four distinct characteristics: (1) the depositional environment needs to precipitate bedded halite and gypsum, (2) the depositional environment needs to have extremely saline groundwater for displacive halite growth, (3) there cannot be any carbonates present, (4) there cannot be any grain sizes larger than fine sand.

The depositional environment of the Mercia within the core is interpreted as a continental lakes and not a marine-sourced environment due to the lack of carbonates and lack of marine fossils. If this was once a marine-sourced water, there would be carbonates present within the rock record. If the original composition of a brine is seawater ($\text{Na-Cl-Ca-Mg-K-SO}_4\text{-HCO}_3$), the first mineral to precipitate will be calcite or aragonite (CaCO_3), followed by gypsum (CaSO_4), halite (NaCl), and sylvite (KCl). There was no sign of carbonates throughout the entirety of the 591.6 m thick Mercia Mudstone Group. The water must have had a paucity of carbonate ions, and therefore couldn't have been composed of an oceanic brine. The Mercia also lacks fossils. If this was a marine environment, some few or rare marine fossils would be expected within the core.

The Mercia Mudstone Group can be interpreted as being a saline, acid, and arid lacustrine environment. The salinity is interpreted due to the presence of bedded halite, displacive halite, and

bedded bottom-growth gypsum for 40.4% and associated mudflats, siltflats, and desert paleosols for 40.1% of the Mercia. Acidity is qualitatively interpreted due to the presence of minerals like kaolinite ($\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$), hematite (Fe_2O_3), and gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), all typical in modern acid saline environment, and the lack of carbonates. Lastly, aridity is determined from the multiple sedimentary structures that are indicative of wetting and drying events such as mudcracks, rip-up clasts, dewatering structures, and blocky peds.

In summary, the Mercia Mudstone Group from the core was once shallow acidic saline lake environment surrounded by desert paleosols and mudflats with saline groundwaters. The bedded halite and bedded gypsum are interpreted as the saline lake, the displacive halite is interpreted as a saline mudflat, the mudstone and siltstone are interpreted as the mudflats and desert paleosols, and the scarce amount of sandstone are interpreted as a sandflat. This environment underwent multiple flooding and evapoconcentration cycles.

Diagenesis

Early Stage Diagenesis

Diagenesis played a major role throughout the Mercia and was seen in many different forms. Most importantly, the syndepositional feature of displacive halite was so prominent within the core that it was treated as its' own lithology. Displacive halite forms within 10's of centimeters from the sediment surface and before lithification (Casas and Lowenstein, 1989) from saline groundwater and forms extremely early (Benison et al., 2015). It is a diagenetic feature because the sediment interface was already deposited before the growth of the displacive halite crystals.

Another early syndepositional event is the formation of dissolution features. Dissolution textures and features form at the Earth's surface (Fig. 43; Casas and Lowenstein, 1989). Dissolution features within evaporites form from dilution of the brine caused by flood events and is recorded by dissolution surfaces, pits, and pipes. The dissolution pipes and pits vary in size but are rather consistent in shape. Occasionally, dissolution surfaces correlate with adjacent mud drapes due to an influx of siliciclastics during the flood.

Later, but still early in the shallow subsurface, the dissolution pipes and pits are filled with a late-stage halite cement or mud. This occurs from the surface to 10 m burial depth (Casas and Lowenstein, 1989). The dissolution pipes and pits are cemented with blocky halite. This halite precipitates relatively slowly, making the halite cement extremely clear in comparison to bedded halite. This cement also greatly reduces the porosity of the rock (Casas and Lowenstein, 1989).

Moderate Stage Diagenesis

Reduction spots are seen within the mudstone and siltstone lithology as small, circular gray spot on the rocks. Occasionally, there is a black bullseye center, surrounded by an gray-ish circle (Fig. 44), suggesting localized reduction surrounding decaying and reducing within the sediment in an overall oxidized setting (Benison and Goldstein 2000). Often, there are multiple reduction spots. Reduction spots are mainly found in massive areas of mudstone and siltstone. Reduction spots have been observed cross-cutting discontinuous lamina, indicating that the reduction spots came after deposition. Sedimentary structures do not cross-cut the reduction spots.

Figure 43: Dissolution pit at the bottom of a core slab arrow from the Larne Halite Member at a depth of 928 m.

Figure 44: Reduction spots within mudstone in the Knocksoghey Formation at a depth of 478.1 m

Late Stage Diagenesis

Once buried, the bedded gypsum was replaced with halite. Currently, the bedded gypsum is completely halite. The gypsum could have been recrystallized to anhydrite and switched back and forth in the past 200-250 million years but the original bottom-growth crystal structure is clear within the samples. Therefore, the primary gypsum could not have been dramatically altered. Gypsum (a less soluble mineral ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)) can be replaced by halite (a more soluble mineral (NaCl)) under certain pressure and temperature conditions. Multiple studies around the world have recognized similar halite-replaced gypsum pseudomorphs (Hovorka, 1992; Hardie, 1967). Previous studies have estimated that gypsum can be replaced by halite at a burial depth of approximately 600 m. This occurs as a result of elevated temperatures and pressures (Hovorka, 1992). The bottom-growth buried between 627 m and 970 m, meeting this 600 m depth at which replacement occurs. Igneous intrusions, which cross cut siliciclastics at 460 m and bedded evaporites at 790 m, must have increased the temperatures at these depths. However, the maximum temperature and distance away from intrusions it was felt, is unknown. Under these conditions, it is possible for the gypsum to have been replaced by halite.

Sylvite veins were found cross cutting displacive halite, mudstones, and siltstones lithologies (Fig. 45). Sylvite veins were never found cross cutting bedded halite or bedded gypsum. The sylvite veins were bright orange in color with a tangy taste (different than halite). Sylvite veins bifurcate in various directions.

Figure 45: Mudstone with large sylvite veins in the Larne Halite Member at a depth of 629.75 m.

Summary of Diagenetic Interpretations

In summary, some diagenetic features occur extremely early and can be considered syndepositional. Other diagenetic features occurred much later. This can be interpreted from cross cutting relationships within the core. The chart below discusses the diagenetic sequence of the various diagenetic features. It is unclear in what order the displacive halite and dissolution surface, pipes, and pits, happened in. They were never found in a cross cutting relationship. It is safe to interpret that they were fairly early processes and occurred slightly before the reduction spots. The blocky halite cements in dissolution pipes and pits could still have occurred early but this needed to occur post dissolution. Therefore, this is an early-middle event. It is unclear if the gypsum replaced with halite happened before or after the sylvite veins. There are no cross cutting relationships to assist in interpreting the timing. Sylvite veins are only found within the mudstone and siltstone lithologies whereas the gypsum replaced by halite only occurred in the bedded gypsum lithology. Therefore, both of these diagenetic sequences can be interpreted as the latest events within the sequence.

Diagenesis Event	early → late
dissolution surfaces/pipes/pits	_____
displacive halite in clay/silt	_____
reduction spots in clay/silt	_____
blocky halite cement in pipes/pits	_____
halite cement siliciclastics	_____
most gypsum replaced with halite	_____
sylvite veins in clay/silt stone	_____

Figure 46: Diagenetic sequence of the Triassic Mercia Mudstone Group from the Carnduff 02 core.

Stratigraphic Trends

Throughout the Mercia Mudstone Group, the relationship between different lithofacies and their changes in the core is well defined. The bottom half of the group is mainly dominated by alternating rock units of bedded halite, bedded gypsum, and displacive halite. The depth of 627 m marks the top of the bedded halite and gypsum lithologies. Overlying this bedded halite and bedded gypsum units, the Mercia consists of an alternating series of displacive halite and mudstone units. The top most displacive halite lithology is at 581.1 m. From this point on, the remainder of the Mercia Mudstone Group is composed of mudstone units, siltstone units, and eventually sandstone units. This transition from bedded evaporites, to displacive halite, to very fine grained siliciclastics, to fine/medium grained siliciclastics is a coarsening upwards sequence (Fig. 17).

Mercia Mudstone Group contains distinct trends in lithology. The most logical interpretation of these trends is that the depositional environments featured within these lithofacies were slowly moving laterally across the surface (in an unknown direction). This would cause a gradual shift from one depositional environment to another. The beginning of the Mercia was mainly composed of bedded evaporites and is interpreted as a shallow saline lake. This lake was moved laterally across the Earth's surface due to differences in elevation. The elevation change can be related back to the current rifting of Pangea. Once the shallow saline lake laterally moved location on the surface, saline mudflats dominated the land. At this point, the displacive halite lithology formed. Eventually, the displacive halite growth stopped. This could have been a product of either from a fresher groundwater source, a significant drop in saline ground water table height, or the lateral movement of the saline groundwaters. Coarser siliciclastic grains became more abundant over time. These lithologies would slightly alternate between one another, potentially representing the facies pinching out. Overall, this provided a relative constant coarsening upwards

grade. This is representative of a mudflat, pinching out into a siltflat, and eventually into a sand flat. Meanwhile, the depositional environments are still consistently moving away, following the movement of the saline lake. The sand units at the end could be the beginning of dunes. Utilizing Walther's Law, the upward changes in lithofacies within the Mercia Mudstone Group in the core are interpreted as lateral changes displaying associated facies of the shallow saline lakes.

Discussion

Analogs

Ancient and modern analogs are useful in comparing and contrasting potential depositional environments for the Mercia Mudstone Group within the Carnduff 02 core. Multiple depositional systems will be considered such as saline pans, tidal flats, saline lagoons, and paleosols. These analogs were selected because they are known for depositing small grain-sized siliciclastics, like mudstone and siltstone, and precipitating evaporites, such as halite and gypsum. With consideration of Walther's law, these analogs were also selected because they are known to be laterally adjacent to one another on the Earth's surface. The analogs focused on are both from modern and Permo-Triassic times. Comparing and contrasting these environments with the observations made of the Mercia will provide the most accurate interpretation of depositional environment. It is first important to accurately understand each environment and highlight the differences of each.

Acid saline lakes

The first depositional environment that is important to discuss is a modern acid saline pan system. The best analog for this environment are the well-studied and observed acid saline lakes in southern Western Australia (Benison et al., 2007). These environments are extreme due to their highly acidic, saline groundwater, and surface waters and deposits dominated by redbed siliciclastic and chemical sediments. These lakes have been recorded with pH's as low as 1.4 and salinities as high as 32% TDS (Benison and Bowen, 2015). Regional acid saline groundwater has an average pH of 3 (Bowen et al., 2012; Benison et al., 2007). The waters are rich in Na-Cl-Mg-SO₄, lack HCO₃, and have high concentrations of Al, Si, Fe, and Br (Benison and Bowen, 2015). Sedimentological, mineralogical, geochemical, and petrographic analyses were performed on acid saline lake systems for their chemistry, spatial and temporal variability, and arid climate (e.g., Zambito and Benison, 2013; Bowen and Benison, 2009; Mormile et al., 2009).

Multiple facies are observed within these systems including shallow acid saline lakes, mudflats, sandflats, dunes, and desert soils (Benison et al., 2007; Benison and Goldstein, 2002). These subfacies can be seen in Figures 42 and 47. Figure 42 is a generalized illustration of the lakes and their subfacies. These subfacies have unusual mineral compositions, sedimentary textures, sedimentary structures, and diagenetic features.

The Western Australia lakes have well-defined cycles of flooding, evapoconcentration, and desiccation (Fig. 48). Short-lived rain events flood the surface areas with storm-generated water and the lakes fill from meteoric run off called sheetfloods. At this point, some of the more soluble evaporite minerals (such as halite) will dissolve or partially dissolve within the lake. Dissolution is evident in the rock record in dissolution pipes, pits, and surfaces. Some dissolution surfaces are accompanied by mud drapes and climbing ripple cross-bedding from sheetfloods.

Figure 47: Acid saline lake in southern Western Australia with visible sandflat, mudflat, and lake facies.

Figure 48: Flooding, evapoconcentration, and desiccation cycle. Benison and Goldstein, 2001.

After the flooding event, the lake water evaporates and concentrates ions. This causes precipitation of chemical sediments like bedded halite, cumulate halite, and bedded gypsum (Fig. 50). Early diagenetic minerals, which are also considered syndepositional, will form from evapoconcentration of shallow groundwater in mudflats and sandflats. An example of these early diagenetic minerals are displacive halite and displacive gypsum. Clay-sized hematite and kaolinite can chemically precipitate from the lake waters. Early diagenetic minerals, such as jarosite and alunite, form in sediment in mudflats and sandflats (Bowen et al., 2012; Benison et al., 2007;).

Over time, the surface water within the lake will evaporate, allowing desiccation to occur within the lake. This is indicated by mudcracks and rip-up clasts. This cycle is summed up in Figure 49. These cycles can be seen in the rock record, which can be used for interpretations of depositional environments (Benison et al., 2007). The groundwater table is highly concentrated brine at this point and will continue to precipitate displacive halite (Benison et al., 2007).

Figure 49: Model of a modern natural acid lake and groundwater system in Australia (courtesy of K. Benison).

The mudflat and sandflat facies are relatively flat and vegetation free (Smoot and Lowenstein, 1991). Mudflats and sandflats in Western Australia range in composition and are dominated by quartz, gypsum, and hematite (Fig. 51). This composition and relative mineralogical abundances will vary from lake to lake. These grains can range from coarse to very fine and well sorted to very poorly sorted. The sandflats/mudflats will also change from the flooding, evapoconcentration, and desiccation cycles. During flood stage, ephemeral streams with quickly deposit siliciclastics into the lake (Fig. 51A, G). Sands will dominate the surface with sedimentary structures present such as sheet-flood deposits, interference ripples (Fig. 51B, C), raindrop impressions, and plant debris. During evapoconcentration, the sandflat/mudflat becomes dominated by silt-sized grains from eolian deposition. Some mudcracks and early diagenetic evaporite minerals, like needle-shaped gypsum and cubic halite crystals, are present. During desiccation, the sandflat, mudflat, and lacustrine facies consolidate into one. There surface is dominated by silt size grains and evaporites (precipitated and/or reworked crystals are both present). Eolian processes are distinctly present within these environments and form asymmetrical ripples. Another distinct sedimentary structure is the polygonal mudcracks (Fig. 51F) on the efflorescent evaporite crust (Fig. 51B; Smoot and Castens-Seidell, 1994).

Another significant subfacies within the southern Western Australian acid saline lakes are the sand dunes and channels surrounding the lake. The desert soils have mild vegetation within sand dunes. The dunes contain medium sand-size quartz/gypsum grains with some iron oxides present. The sand dunes themselves are rather massive with some rare cross-bedding. Animals (spiders, snakes, ants) live within the dunes and create burrows (Benison et al., 2007).

Figure 50: Photographs of acid saline lakes in southern Western Australia: A) Cubic halite crystals precipitating on the sediment-water interface. B) Overview of bedded halite-water interface with 1-2 cm of surface water. C) Cross-sectional view of halite and mud crust. D) 7-8 cm long gypsum crystals growing within mud with halite crust on surface. E) Efflorescent cracks in salt crust. F) Cumulate halite crystals floating on lakewater surface. G) Overview of yellow lakewater with many cumulate halite crystals floating.

Figure 51: Photographs of mudflats, sandflats, and dunes subfacies of acid saline lakes in southern Western Australia: A) Channel flowing through sandflat and mudflat to lake. B) Mudcracks in mudflat. C) Ripples in shallow lake water. D) Overview of mudflat: Red surface is interpreted to be hematite with a brown/gray mud underneath) Trees and organic matter within the dunes with channel flowing into sandflat. F) Mudcracks in mudflat. G) Sheetflood deposit into lake.

It is important to establish the differences within various non-marine saline systems. There are three systems in this category: saline pan/shallow ephemeral saline lake, shallow perennial saline lake, and deep perennial saline lake. A saline pan is mostly dry but occasionally has some surface water. An ephemeral saline lake typically has water within but can become completely dry. A shallow perennial saline lake always has water but relatively shallow surface water. A deep perennial saline lake always has relatively deep surface waters. Different sedimentary structures and textures can be found in the rock record for each of these environments:

	Cumulate evaporites	Flooding features (e.g., dissolution features)	Evapoconcentration features (e.g., bedded halite)	Desiccation features (e.g., efflorescent crust)
Saline pan/ephemeral saline lake	x	x	x	x
Shallow perennial saline lake	x	x	x	
Deep perennial saline lake	x			

Figure 52: Comparing saline pan/ephemeral saline lake, shallow perennial saline lake, and deep perennial saline lake by the sedimentary textures and sedimentary structures produced by flooding, evapoconcentration, and desiccation cycles.

Bedded halite with chevron can only form in water depths less than 0.5 m (Hardie, 1984), restricting this type of crystal growth to shallow waters. Cumulate evaporites can form in all lakes of all depths. Flooding features are only seen within saline pan/ephemeral saline lake and shallow perennial saline lake deposits because deep perennial saline lakes brines will not become diluted from small amounts of fresh water influx. Desiccation only occurs in saline pan/ephemeral saline lakes and therefore these environments record features such as efflorescent evaporite crusts. The mudcracks can form in lake facies, but also form in mudflats adjacent to non-desiccating salt lakes.

Permo-Triassic acid saline pan system

Sedimentological, mineralogical, geochemical, petrographic, and geochronological studies have been completed on Permo-Triassic saline pan systems. This research extends from. The mid Permian Nippewalla Group of Kansas, USA is very well studied and interpreted to have been halite-dominated and gypsum-dominated ephemeral saline lakes surrounding by mudflats, sandflats, sand dunes, and desert soils (Benison and Goldstein, 2001). The group is composed of bedded evaporites, displacive evaporites, redbed siliciclastics, and rare grey siliciclastics. Saline lakes are interpreted from observations of bedded halites (halite containing chevrons and cumulate crystals), gypsum-crystal pseudomorphs, clastic anhydrite grains, dissolution surfaces and pipes, red mud drapes, and efflorescent crusts (Fig. 53). The sedimentary textures and structures observed indicate flooding, evapoconcentration, and desiccation cycles as well. Saline mudflats are interpreted through red mudstone and siltstone, displacive halite crystals, mudcracks, root and plant features. Eolian and shallow water deposition is seen within the sandstone lithology with well-sorted and well-rounded quartz grains with bimodal grain size distribution (Benison and Goldstein, 2001).

Another well studied analog is the Permian Opeche Shale of North Dakota, USA. Overall, this formation has many similarities to the Nippewalla Group. It is composed of bedded and displacive evaporites and redbed siliciclastics and is interpreted to have been an acid saline pan system. The formation contains sedimentary structures identified as bedded halite with chevrons, cumulate crystals, dissolution surfaces and pipes, and mudcracks, that indicate flooding, evapoconcentration, and desiccation cycles (Fig. 54; Benison and Goldstein, 2000).

Figure 53: Thin section photomicrographs A) Beds of bottom-growth gypsum crystals (now halite and anhydrite) B) Beds of bottom-growth gypsum crystals (now anhydrite) C) Two chevron halite crystals oriented in the up direction Scale bar = 1 cm D) Chevron crystal truncated by dissolution pipe and capped by efflorescent crust. Scale bar = 2.5 mm. (Benison and Goldstein, 2001).

Figure 54: Hand sample and thin section photomicrographs. A) Chevron bands in halite crystal. B) Displacive halite in red mudstone. C) Mudcracks in red mudstone. D) Displacive halite in mudstone in thin section. (Benison and Goldstein, 2000).

Modern tidal flat system

There are many well-documented modern tidal flats around the world. Tidal systems are energy-dynamic environments located in the intertidal zone on coasts and beaches. These systems are defined by high tides and low tides. Tides are caused from gravitational interaction between the Earth and the Moon. High tides are produced from swelling in the ocean in the direction of the Moon. Low tides occur when the Moon is on the other side of the earth, causing the water level to drop. Spring and neap tides are more accentuated high and low tides. Spring tides are stronger high tides that occur when the Sun, the Moon, and the Earth are aligned. Neap tides are weaker low tides that occur when the Sun and the Moon are perpendicular to one another with respect to the Earth (Fig. 55). The change in tides cause specific sedimentary textures and structures that are characteristic of tidal flats.

Figure 55: Illustrates different alignments in the Earth, the Moon, and the Sun to cause spring and neap tides (Col, 1996).

Tidal flats have very consistent sedimentary textures and structures present due to the predictable change in high and low tide. This allows for tidal flats to have definite diagnostic

properties, including tidal bundles. Tidal flats can precipitate diagenetic evaporites between the high and low tides in arid climates (in the intratidal and supratidal zones, Fig. 56). Typically, these are early diagenetic evaporites like gypsum nodules. Due to the chemical composition of seawater (Cl, Na, Ca, SO₄, Mg, K, CO₃-rich), minerals are typically precipitate in this order: calcite/aragonite, gypsum, halite, and sylvite.

Figure 56: Schematic map showing the cross profile of tidal flats and highlighting supratidal, intertidal, and subtidal zones (Daidu, 2013).

Tidal bundles are very common in tidal flat deposits, regardless of climate. Tidal bundles are fine-grained laminae that have sedimentary alternations of mud, silt, and fine sand due to the energy change in tides (Walker, 1984). One tidal bundle is representative of one single, dominant tide. They can vary in overall thickness depending on the strength of the tide.

Some sedimentary structures are seen in both tidal flats and saline pan systems such as mud drapes, mudcracks, thin laminations, microbial laminites, and intraclasts. One distinct sedimentary structure are mud drapes. A mud drape is a single, layer of mud/silt that forms a lense in the surrounding sediment that forms when the current speed of the tide is close to zero causing “slack-water”, causing fine-grain suspended sediment will settle to the bottom (Dalrymple, 2005).

Mudcracks occur during times of desiccation caused by low tides in the mudflat subfacies or desiccation of a lake. Thin laminations can be deposited both from slackwater and/or eolian processes. Microbial laminites are caused from microbial mats within and/or on the sediment interface. Finally, intraclasts are formed by erosion of partially lithified sediment that are eroded, transported, and later deposited in other environments.

Permo-Triassic tidal flat system

One documented analog of a Permo-Triassic tidal flat system in a coastal paleoenvironmental setting is the Permian San Andres Formation of Texas Panhandle, USA. The depositional environment was interpreted through petrographical studies and geochemical data (Hovorka, 1987). Hovorka bases her criteria on concepts presented in Hardies (1984).

Hovorka (1987) describes four events that she interpreted within the San Andres Formations depositional environment: (1) flooding by marine-derived water, (2) evaporation and precipitation of evaporites, (3) karstification, and (4) deposition of clastics. She describes flooding, evaporation, and precipitation of chemical sediment stages of brine pool deposition, like the beginning of saline pan systems with flooding and evapoconcentration. Hovorka (1987) interprets flooding stages by presence of dissolution and truncation of deposited crystals. San Andres anhydrite and carbonates beds have a downdip direction, indicating the marine source. Halite crystals with chevrons provide an up direction. This is interpreted as deposition occurring in a shallow brine pool (Hovorka, 1987). Cumulate halite is also observed. Hovorka (1987) notes that there is “repetition of the sequence: (1) truncation surface (2) anhydrite parting (after gypsum), and (3) brine pool halite precipitation resulted in accumulation of the intervals of anhydrite and halite”.

Hovorka mainly uses geochemical evidence to confirm marine origin. There are many carbonates present through the San Andres Formations (Hovorka, 1987). Hovorka states that the brine pool was supplied by marine water due to the consistent moderate bromide concentrations (50-100 ppm) within the halite (Hovorka, 1987). This paper was written before it was confirmed that acid saline lakes could also have high bromide concentrations and before it was accepted that halite could form in low pH waters. This field area should be revisited with the new scientific findings in mind.

Saline lagoon

Another depositional environment of evaporites is a saline lagoon. A saline lagoon is a saline body of water connected to the ocean through an ephemeral stream. If the ephemeral stream is cut off from the ocean (which can occur through various means such as dune movement or lateral drift), then it is considered to be a marginal marine “lake” (Fig. 57). Marginal marine “lakes” can be recharged through oceanic groundwater and floods of seawater into the system by storms or breaching of dunes that might separate lake from ocean.

An analog for an evaporite-dominated saline lagoon is a study completed by Taj and Aref (2015) focusing on the ephemeral halite pan of South Jeddah on the Red Sea Coast, Saudi Arabia. This study focused on two saline (halite and gypsum-dominated) pans that developed as result of road construction. These modern pans are recharged by seawater seepage in groundwater but are not directly connected to the Red Sea water flow. This is known through field and petrographic studies along with major element geochemistry of the brine. This system is very different than the saline pans of southern Western Australia. The saline pan systems in southern Western Australia

are recharged through meteoric water and groundwater, whereas these saline lagoons are recharged through the ocean water, causing mineralogical differences such as the presence of carbonates.

Figure 57: Illustration defining the differences between saline lagoon and marginal marine “lake” environments.

The seawater seepage and occasional rainfall recharge the ephemeral halite pan system of South Jeddah and begins a new cycle of flooding, evaporative concentration, and desiccation (Taj and Aref, 2015). The flooding stage has textures and structures such as truncation surfaces, microkarst pits, pipes, and vugs. These are formed due to partial dissolution of halite crusts. Microbial mats will also form during flooding surfaces. Evaporative concentration stage is recorded by the formation of thick, flat chevron-structured halite crust and cumulate rafts. Halite can also form in isolated masses referred to as “cauliflowers, mushrooms, and platforms” (Fig. 12). These are large dome shapes composed of halite. The surface water can be agitated by wind which will create waves and currents. These waves and currents deposit sand and gravel-sized broken halite crystals. This can cause the halite to be rippled. The desiccation stage is recorded by polygonal fractures, displacive halite filling microkarst pits and pipes, overgrowths, and efflorescent halite crystals. Bioclastic sediments are also found within the ephemeral halite pan

system such as gastropods (Taj and Aref, 2015). In summary, the saline lagoon has flooding, evapoconcentration, and desiccation cycles seen within the evaporites with marine source.

Figure 58: Image showing gypsum and halite formations. (A) A thin gypsum crust with a microbial mat composed of cyanobacteria underneath. (B) Gypsum stromatolites forming dome-shaped surficial structure. (C) Cauliflower shaped halite formations subaqueously. (D) Subaerial mushroom shaped halite formations (Taj and Aref, 2015).

Paleosols

Paleosols are another distinct facies that was observed in the Mercia Mudstone Group. Paleosols are lithified soils and are vital to understand continental paleoenvironments. Like bedded

evaporites, they are a direct record of Earth's past surface conditions (Retallack, 1997, 2001, 2003). Paleosols have many distinct features within the rock record for interpretation of depositional environments.

Paleosols typically contain root fossils. Roots can be found in most (but not all) post-Silurian environments. This is a non-exclusive criterion. Roots can be identified by their truncated tops that taper and bifurcate (split) downward. In some parts of the rock record, roots leave organic matter behind as well. Roots can also cause rhizoliths, calcified roots features, to form in the rock record (Retallack, 2003).

Many paleosols also contain peds. Peds are soil material structures, such as columns or blocky textures that form from the swelling and shrinking of clays (Retallack, 2003). Peds can vary in shape and size depending on which horizon they form within, the extent of shrinking and swelling, and the type of clay. Some peds are granular with angular to rounded, nonconformable faces. Another type of ped is called a block which is moderate sized, angular to subangular, equidimensional aggregate with conformable facies. The third type of ped is called prismatic. These are moderate to large, elongated, and vertically orientated aggregates. There are also platy peds that are small to moderate tabular aggregates that are oriented parallel to the earth's surface and wedge-shaped peds that are bounded by concave upward fractures that form from shrinking and swelling smectitic clays (Retallack, 1998 and 1990; Gustavson, 1991; Birkleand, 1984).

Paleosols can also contain nodules and concretions. Nodules are a small, irregular mineral mass within the paleosol. The minerals are typically composed of calcite, iron, silica, or opal (Retallack, 1992). Paleosols can also have "desert roses" or displacive evaporites within the mud when located near environments such as a saline lake. Displacive evaporites (such as halite and gypsum) can have a variety of structures. For example, displacive halite tends to be cubic in

shape. Displacive gypsum can have a needle-like shape (Benison and Goldstein, 2001; Retallack, 1992).

A dominate process within soils is called eluviation. This is a leaching process in which material within the soil is moved downward into an underlying horizon. Illuviation is the deposition of cutans which can be composed of clay, calcite, organic matter, silica, and iron oxides (Mack et al., 1993).

Burrows may also be present within Phanerozoic soils and survive the transition into paleosols. Burrows are created by a variety of organisms that dig into the soil for food or safety. Burrows can also act as trace fossils, allowing the organisms to be identified and potentially confirmation of the paleoenvironment (Retallack, 1992).

An important component of paleosols is the overall color. Different colors are indicative of different conditions of the soil. For example, yellow-red paleosols may mean the soil was once under oxidizing conditions and green-gray paleosols may mean the soil was under anoxic conditions (Mack et al., 1993). It is also possible that the minerals were yellow or green when first deposited. Colors of soil and paleosols are typically quantified using the Munsell Color chart.

Paleosols can also be classified into different types. Modern soils are classified as well but the same system cannot be used because features in modern soils (like bulk density, cation exchange capacity, and moisture content) do not survive lithification (Mack et al., 1993). A classification system that focuses on clay type, colors, and minerals present within the paleosol has been proposed (Mack et al., 1993).

peds	granular	1 mm-1 cm
	blocky	1 cm
	prismatic	1 cm-10 cm
	platy	1 mm-1 cm
	wedge	10 cm-100 cm
roots	10 cm-100 cm	
nodules/ concretions	1 cm-10 cm	
burrows	1 cm Schlirf and Uchman, 2005	
displacive evaporites	1 cm	

Figure 59: Structures found within paleosols. Modified from Retallack, 2001; Schlirf and Uchman, 2005.

Eolian system

Eolian systems are very common in arid climates resulting in deserts. Desert environments have arid climates and can be divided into three facies: alluvial fans and ephemeral streams, inland sabkhas or playas, and sandy deserts (Goudie et al., 2000). Alluvial fans are a fan-like structure that are dominated by sheetfloods and/or debris flow. The deposited sediment is coarse, poorly sorted sand, gravel, and boulder deposits sorted into reverse graded bedding structure. This is not representative of the mud/silt and evaporites in the Mercia Mudstone Group. Ephemeral streams deposit fining-upward sandstone sheets with assemblages of cross-bedding and ripples from flash floods (Miall, 1996). The finest sediment can be a mud/silt but the entire sequence is needed for interpretation. Sandy deserts will not be discussed because there is rarely sand present within the Mercia Mudstone Group.

Fluvial and alluvial systems

Rivers are a major contributor to sediment transfer and deposition. Rivers include a wide variety in style from type, velocity, and size and contain many sub environments such as active and inactive channels, point bars, floodplains, and levees. These extreme varieties can cause many different types of deposits. Alluvial deposits are typically classified by grain size, texture, sedimentary structures, and bedding. Occasionally, biogenic structures, fossils, and chemical sediments can be used for classification too except these are relatively minor components. The Mercia rarely has grains larger than silt-sized, therefore any alluvial deposits larger than silt, such as sand and gravel, will be ignored. Combination of silt and mud deposits can form fine laminations and small ripples. These can be interpreted by overbank, abandoned channel, or waning flood

deposits. Silt and/or mud deposits can also be massive from back-swamp or abandoned channel deposits, have desiccation cracks from abandoned channel deposits, and/or have roots and bioturbation from fauna and flora (Miall, 1978). These sedimentary textures and structures will normally be accompanied by other textures dominated by sand to gravel.

Using Analogs to Determine the Depositional Environment of the Mercia Mudstone Group

Due to distinct characteristics of the Mercia, it is possible to interpret an accurate depositional environment. A marginal marine, saline lagoon, or tidal flat environment interpretation has been discounted due to the lack of carbonates, lack of marine fossils, and the different types of evaporites. Tidal flats typically precipitate gypsum nodules and deposit tidal bundles, but neither of these are present within the Mercia Mudstone Group. This group was also not dominated by a fluvial system due to the absence of erosional channel boundaries, abundance of small grain sizes, lack of plant fossils, and low energy level needed to precipitate bedded evaporites.

The Mercia Mudstone Group within the core was once a shallow saline lake system. This interpretation is supporting by observed mineralogy, sedimentary textures, sedimentary structures, and crystal shapes throughout the core. The saline lake system was most likely a perennial shallow saline lake. In addition, bottom-growth gypsum and halite attest to saline surface waters. More specifically, chevrons and dissolution features indicate shallow saline waters. The lack of efflorescent crusts suggests that these lakes did not dry up. When saline lakes fully desiccate, efflorescent crusts, composed of tiny evaporite crystals, form. These efflorescent crusts are recognized in the rock record as an opaque, white microcrystalline thin bed or thick lamina situated

on top of chevron and/or cumulate bedded halite or bedded gypsum (Schubel and Lowenstein, 1997; Smoot and Castens-Seidell, 1994; Lowenstein and Hardie, 1985). It is possible that there could have been efflorescent crust at some point during deposition but it might not have been preserved. Efflorescent crust was not observed throughout the 591.6 m-thick group, making the most accurate interpretation a shallow perennial saline lake system.

The interpretation of the depositional environment of the Mercia Mudstone Group is also confirmed through the similarities with the Permian Opeche Shale and the Middle Permian Nippewalla Group. The Opeche Shale, Nippewalla Group, and Mercia Mudstone Group are mainly composed of bedded evaporites and redbed siliciclastics. The bedded evaporites all contain dissolution features indicating flooding events. The bedded evaporites include bedded halite with chevrons, cumulate halite crystals, and gypsum-crystal pseudomorphs indicating evapoconcentration. All three rock groups have similar subfacies as well including saline mudflats, mudflats, and sandflats. In addition, displacive halite is abundant in all redbed units.

The North American Permian redbeds and evaporites contain efflorescent crusts, indicating desiccation. There is no evidence of desiccation of the lakes from efflorescent crusts within the Mercia Mudstone Group. The possibilities for this could be due to (1) climate, (2) groundwater availability, (3) elevation differences, (4) tectonic settings. (1) The climate in North America could have been slightly drier, allowing the lake to fully desiccate. Likewise, the climate in Northern Ireland could have been slightly wetter, allowing the lake to consistently have surface waters from meteoric waters. (2) Another possibility is that there could have been more groundwater in the system in Northern Ireland than North America. This would allow surface water to be retained in the lake. (3) The topography during the Triassic is also unknown in Northern Ireland. The area of the core could have been at a lower elevation than North America, forcing the groundwater table

to be higher. (4) Tectonically, rifting could have been occurring at this time. If rifting was happening during deposition, then the basin floor would continually be lowering. This would result in higher flood waters and groundwaters than the Nippewalla Group and Opeche Shale.

Lack of efflorescent crusts and abundance of bottom growth evaporites and dissection features indicates that the Mercia only underwent cycles of evapoconcentration and flooding. The Nippewalla Group, Opeche Shale, and some modern analogs, such as the saline lakes in Western Australia, undergo flooding, evapoconcentration, and desiccation cycles. Other than desiccation, similar mineralogies, sedimentary textures, and sedimentary structures can be found in all three analogs. Therefore, the Opeche Shale and Nippewalla Group serve as a very good ancient analog and the ephemeral saline lakes of southern Western Australia serve as a modern analog for the Mercia Mudstone Group. The saline lakes of China in Schubel and Lowenstein (1997) are a good physical processes modern analog but the Permian Nippewalla Group is a good chemical analog.

Recognizing acidity, salinity, and aridity in the rock record

Acidity, salinity, and aridity are evident in the rock record in multiple features. These characteristics can be defined quantitatively or qualitatively. Acidity and salinity are dependent on the chemical composition of the surface and groundwater. Acidity within an acid saline lake can be indicated by bisulfate and high concentrations of Al, Fe and Si within the rock and fluid inclusions (Benison et al., 1998). In the Mercia, kaolinite ($\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$) and hematite (Fe_2O_3) were abundant throughout the bedded evaporite lithofacies. These minerals could have been transported into the lake, by wind or water, or have been chemically precipitated from the lake surface waters. If these minerals chemically precipitated from the lake, then the lake waters must

have been acid due to the Al, Si, and Fe found in the mineral composition. (Benison and Goldstein, 2002). This is very similar to the mineralogy found in the mudflats surrounding the acid saline lakes of Western Australia (Benison et al., 2007). The absence of carbonates is another indicator of acidity. If once present, the carbonates could have been dissolved to buffer the acidity. If never present, the acidity would never be buffered and would be easily maintained, especially in an arid climate. Lack of carbonates cannot be used as diagnostic criteria, but it can help assist in interpretation (Benison and Goldstein, 2002).

Figure 60: Trench dug in mudflats in Lake Aerodrome, WA. Sediments are composed of quartz and gypsum clastic grains, cemented by hematite, jarosite, alunite, and kaolinite.

Salinity within depositional environment can be traced qualitatively through the presence of saline minerals such as halite and gypsum/anhydrite (Fig. 61). Due to a high abundance of bedded halite and bedded gypsum throughout the Mercia Mudstone Group, it is interpreted that the surface waters of the lake were enriched in respect to Na, Cl, Ca, and SO_4 ions. The surface waters within the lake could have alternated between being supersaturated in Na-Cl and Ca- SO_4 due to varying beds of halite and gypsum. Bedded evaporites indicate shallow saline surface waters

(< 0.5 m) such as saline lake waters. The groundwaters were more saturated in Na and Cl ions because of the large abundance of displacive halite. No displacive gypsum crystals are found from groundwater precipitation.

Figure 61: Displacive halite lithology from the Opeche Shale, Gulf-Romanysyn 2-33-4B core, Williston Basin, D. Displacive halite indicates saline environments. Image courtesy of K. Benison.

Arid environments can be qualitatively seen through sedimentological features. Circumgranular cracks in mudflats and soils are evidence of wetting and drying. Eolian deposition such as small-scale ripples, bimodal grain size distribution, and mud drapes are also indicative of a dry environment. Lack of plant fossils such as roots can also suggest an arid setting. This cannot

be used as diagnostic criteria but it can suggest an environment that is unfavorable to plants such as too arid, acidic, or hypersaline.

In summary, most environments that precipitate evaporites will have similar crystal mineralogy, structures, shapes, and feature signs of flooding, evapoconcentration, and desiccation cycles. It is important to consider the five major criteria created by Hardie (1984) and focus on “(1) kinds of fossils, (2) sedimentology of the associated non-saline facies, (3) kinds of primary saline minerals, (4) association of such saline minerals, both in qualitative and quantitative terms, (5) trace element, isotope, and fluid inclusion geochemistry of such saline minerals” (Hardie, 1984). The best way to determine the depositional environment is to consider the five criteria together.

Using Hardie’s (1984) criteria, it is interpreted that the Mercia Mudstone Group was a continental lake environment, therefore nonmarine. The criteria include fossils, lithologic, mineralogic, stratigraphic, and geochemical characteristics. There are no fossils found within the group. Paucity of fossils for 591.6 m is indicative of a nonmarine environment with extreme water and/or climate conditions. Marine environments typically deposit some marine fossil such as brachiopods or forams. The siliciclastic lithologies, such as mudstone, siltstone, and sandstone, have a saline aspect because the majority of the units are cemented with halite. The rare units that are not cemented with halite are typically massive mudstone units, indicating paleosols. The primary saline minerals found within the group include bedded halite, bedded bottom-growth gypsum, and displacive halite. Both of the bedded evaporites can form in marine and nonmarine aspects. Displacive halite lithology is suspected to be more common in nonmarine environments, rather than marine environments. Association of these saline minerals have been observed in qualitative terms. Bedded halite and bedded bottom-growth gypsum lithologies are vertically

adjacent to one another throughout the core. Displacive halite lithologies are found near mudflats and siltflats. These environments would be laterally adjacent to one another on the Earth's surface. Trace element and isotope work has not yet been completed on the Mercia. My research partner completed fluid inclusion geochemistry.

My research partner, Lynnette Eichenlaub, has been using fluid inclusion studies to quantitatively determine the salinity, chemical composition, and acidity of the lake waters which precipitated the bedded halite in the Larne Halite Member in the Carnduff 02 core (Master's Thesis, in Progress). Eichenlaub performed freezing/melting runs and laser Raman spectroscopy. Inclusions failed to freeze. Laser Raman spectroscopy showed the presence of bisulfate and/or hydronium in some fluid inclusions. This data strongly suggests that perennial saline lake waters during deposition of the Mercia Mudstone were acidic (Eichenlaub et al., 2016).

Multiple diagenetic interpretations

Diagenetic processes played a major role in the Mercia Mudstone Group. Since the Triassic, the evaporites and siliciclastics within the group have undergone diagenetic changes. Some of these diagenetic features were difficult to interpret as well. There are multiple diagenetic features within the group that could be interpreted in a variety of ways.

Diagenetic processes are apparent in the undifferentiated evaporite lithology. In core slab and thin section, it is difficult to determine the primary mineralogy of the undifferentiated evaporites. Currently, the undifferentiated evaporites lithology is dominated by halite mineralogy but the primary texture is unknown. There are no identifiable primary structures to assist in determining primary mineralogy but it was most likely originally halite or gypsum. The original

evaporite (most likely halite or gypsum) could have been recrystallized back and forth over time. For example, if it was original bedded gypsum, the mineralogy could have recrystallized from gypsum to anhydrite and vice versa within the subsurface. Multiple diagenetic processes of neomorphism would destroy the original crystal shapes. This process could potentially create the lithology called “undifferentiated evaporites” identified within the Mercia Mudstone Group of the core.

The sylvite veins were a very interesting diagenetic feature. The veins were found in mudstone, siltstone, and mud-rich displacive halite units. These sylvite veins could be filling preexisting weak faces within the units. Mudcracks, soil slickensides, and blocky ped edges would all provide a weaker zone for the sylvite veins to form. Once nucleated, the sylvite veins compacted the mud and silt grains to create more space for growth, altering the original weak zone within the lithology.

The mud/halite conglomerate lithology is diagenetically complicated. The paragenetic sequence of this lithology is unknown and can be interpreted in multiple ways. One explanation is that there was laminated mud that dried and formed rip-up clasts. The rip-up clasts were transported from wind or water into a saline environment. Once in the saline environment, blocky halite cement slowly precipitated around the rip-up clasts, lithifying the rock. Another interpretation is that this lithology is the remnant of a large evaporitic karst feature. There could have been a large dissolution event of the primary evaporites within the subsurface. Then halite recrystallized and formed the blocky cement around the mudclasts. Another interpretation is that this lithology is a fault breccia. The Mercia Mudstone Group in the core is located in the Lough Neagh-Larne rift Basin. Multiple faults cross cut the group surrounding the Carnduff 02 core. During rifting, faults could have formed near/cross cutting the core and the pressure could have

dissolved the evaporites. Later, the blocky halite cement would form surrounding the mud clasts. These interpretations are all geologically possible and would result in the mud-halite conglomerate lithology.

Problematic stratigraphic classification of the Mercia Mudstone Group

Multiple formations have been named within the Mercia Mudstone Group. These formations include the Glenstaghey Formation (including the Larne Halite Member), Knocksoghey Formation, Pore More Formation, and Collin Glen Formation. In Figure 63, the formations and their depth are compared to a summarized stratigraphic column of the Mercia Mudstone Group in the Carnduff 02 core. This created an easier comparison for the two competing interpretations.

It is apparent that many of the previously used formation names and contacts are not distinct in the stratigraphic column (Fig. 62). The only formation that is recognizable within the group is the Larne Halite Member. The Larne Halite Member is composed of bedded halite and bedded bottom-growth gypsum. The Glenstaghey Formation (undifferentiated) is questionably passable due to the amount of displacive halite found within those depths. The overlying formations are not distinct from one another. The Collin Glen Formation, the Pore Form Formation, and the Knocksoghey Formation (Coolmaghera Skerry Member and undifferentiated) are not viable names for the Mercia Mudstone Group for this location and should not be used when discussing this core.

Figure 62: Measured stratigraphic column for the Mercia Mudstone Group in the Carnduff 02 core (on left) compared to stratigraphic nomenclature for the Mercia Mudstone of the Lough Neagh-Larne Basin (as described by Griffith and Wilson, 1982).

Can a sedimentology study resolve if this was a tectonically active basin?

It is still debated if rifting of Northern Ireland occurred during deposition of the Triassic Mercia Mudstone Group. Some papers (Ruffell and Shelton, 1999) suggest that deposition of the group occurred synrifting, but this is still questionable. This sedimentological study of the Mercia can provide assistance in determining if the Lough Neagh-Larne Basin was tectonically active at this time. There were no faults seen throughout the 591.6 m of observed core. This is not diagnostic criteria because it is highly possible that no faults crossed the core itself. The Mercia follows Walther's Law, meaning facies transitions are more likely due to lateral environmental changes. The stratigraphic column (Fig. 13) illustrates detailed lateral facies change. Vertical changes in facies are expected by faulting. There is also no evidence of alluvial "clastic wedge" deposition. This is expected in a tectonically active rift basin. For example, Death Valley is actively rifting today. In Death Valley, there are large-grained deposits from alluvial fans. Within the group, there are no grains larger than fine-sand. Therefore, there was no alluvial "clastic wedge" deposition that you would expect to see from the modern analog. Finally, the Tertiary igneous intrusions that cross cut the Triassic Mercia are much younger than the group itself. Together, these four criteria indicate that rifting potentially occurred after deposition of the Mercia Mudstone Group.

How extensive were extreme acid saline environments in Pangea?

Past studies indicate that during the Middle (Guadalupian) Permian (272.3 to 259.9 Ma), areas of North America were dominated by shallow acid saline lakes (Benison and Goldstein, 2000 and 2001). Based on the position of North Dakota and Kansas at this time, these lakes were located from the equator to ~5°S latitude. It is now suggested that Northern Ireland was also dominated by

similar shallow acid saline lakes during the Middle Triassic (247.2 to 235.0 Ma). Based on the position of Pangea at this time, this area was located at ~30°N (Benton et al., 2002). Therefore, these extreme terrestrial environments could have dominated Pangea for as long as ~30-40 million years. These extreme environments may have ranged over a distance of ~8,000 kilometers and potentially from the equator to 30°N latitude. This spatial and temporal extent of these extreme environments would have majorly affected the Permo-Triassic paleoclimate and potentially the mass extinction.

Conclusions

The Triassic Mercia Mudstone Group of the Carnduff 02 core from County Antrim, Northern Ireland is composed of five main lithologies: mudstone, displacive halite, bedded halite, bedded gypsum, and siltstone. Other lithologies were rare and include sandstone, mud/halite conglomerate, and igneous intrusions. Detailed hand sample and thin section observations were used to identify sedimentary textures and structures, which later assisted depositional environment interpretations.

The depositional environment of this group is interpreted to be shallow perennial saline lakes with adjacent environments such as saline mudflats and paleosols. Bedded halite and bedded gypsum are interpreted to be the shallow saline lake environments. These lakes underwent flooding, evapoconcentration, and desiccation cycles. Flooding was interpreted from dissolution surface, halite-filled dissolution pipes/pits, climbing ripple cross-bedding, mud drapes. Evapoconcentration and salinity, driven by aridity, is interpreted from bedded pseudomorph gypsum crystals, bedded halite crystals with primary growth bands creating chevrons, and

displacive halite crystals. Aridity is interpreted from mudcracks and rip-up clasts. Displacive halite is interpreted as saline mudflat deposits. Mudstone and siltstone are interpreted as massive deposits of mudflats and paleosols. Paleosols are interpreted from soil slickensides, blocky peds, circumgranular cracks, and suspected root features. Acidity was interpreted through the abundance of kaolinite and hematite, paucity of carbonates, and similarities in sedimentology and mineralogy to known acid saline systems.

The Mercia Mudstone Group also has a complicated diagenetic history. Diagenetic features were observed and interpreted as halite-filled dissolution pipes and pits, displacive halite crystal growth, bottom growth gypsum crystals replaced with halite, and sylvite vein growth. In summary, the Triassic group of Northern Ireland was a shallow ephemeral saline lake in an arid climate with associated facies including saline mudflats, dry mudflats, and paleosols.

Acid saline lakes and groundwater systems were widespread in Pangea. Previously documented acid saline lake systems, with pH's as low as -1, are known from the mid Permian of Kansas and North Dakota. The Triassic Mercia Mudstone Group is similar to these Permian North American redbeds and evaporites in regard to mineralogy, sedimentology, and geochemistry. Therefore, these extreme environments may have ranged over a distance of ~8,000 kilometers and potentially from the equator to 30°N latitude. These terrestrial environments could have dominated Pangea for as long as ~30-40 million years.

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Appendices

Appendix 1: Core Slab Photos

509.1 m

590.5 m

604.6 m

629.75 m

658.0 m

675.4 m

707.7 m

723.7 m

713.4 m

728.6 m

740.1 m

107

741.95 m

746.6 m

762.3 m

766.9 m

769.6 m

1 cm

778.3 m

1 cm

781.4 m

787.5 m

793.5 m

804.8 m

813.7 m

814.4 m

819.6 m

831 m

1 cm

831.3 m

1 cm

841.55 m

867 m

1 cm

871.3 m

1 cm

878.6 m

886.7 m

1 cm

897.6 m

1 cm

870.6 m

899.6 m

900.8 m

906.1 m

910.3 m

928.2 m

940.6 m

928.5 m

943 m

955.2 m

121

959.3 m

965.9 m

969.2 m

970 m

Appendix 2: Measured Section of the Carnduff 02 Core in County Antrim, Northern Ireland

Unit #	Depth (m)	Description
1	970-966.25	Mudstone <ul style="list-style-type: none">• color: 2.5YR 3/2• sedimentary characteristics: high clay content, rare discontinuous wavy laminae, rare cubic displacive halite crystals• gradual contacts with surrounding units• Minor HCL reaction• diagenetic features: anhydrite nodules/clasts?, rare reduction spots, burrows?
2	966.25-965.3	Mudstone <ul style="list-style-type: none">• color: 2.5 YR 3/3• sedimentary characteristics: low clay content, rip up clasts, discontinuous wavy lamina• conformable contact• reaction to HCl• diagenetic features: reduction spots, disruption from mudcracks
3	965.3-964.2	Mudstone <ul style="list-style-type: none">• color: 2.5 YR 3/2• sedimentary characteristics: large (~3 cm) cubic displacive halite, discontinuous wavy lamina• well-defined bedding• minor HCl reaction• diagenetic features: rare iron oxide concretions that are approximately 2-3 cm in length
4	964.2-945	Mudstone <ul style="list-style-type: none">• color: 2.5 YR 3/2, sylvite veins: 5 YR 3/4• sedimentary characteristics: mica sparkles, pink displacive halite, salt content increases as you move up in unit, wavy lamina, rip up clasts, variations in content between silt and clay• gradual contacts with other units• well-defined bedding• reaction to HCl• diagenetic features: common reduction spots shown by circular spots, rare soft sediment deformation, rare mudcracks, rare roots?, uncommon anhydrite nodules, sylvite veins

5	945-939	Mud/halite Conglomerate <ul style="list-style-type: none"> • color: halite 2.5 YR 5/2, mud 2.5 YR 3/2 and GLEY 2 4/5B • sedimentary characteristics: very common angular rip-up clasts, halite crystals are subrounded to subangular, the amount of halite increases as you move up in section, halite cement • no HCl reaction beyond this point • diagenetic features: halite cement
6	939-937.9	Bedded Halite <ul style="list-style-type: none"> • color: halite 5 YR 6/4 and mud GLEY 2 4/10B • sedimentary characteristics: rare mud clasts, rare displacive halite in clasts, kaolinite clay, difficult to see bedding, but can definitely identify bottom growth crystal structure • diagenetic features: recrystallization of halite?
7	937.9-936	Missing Core
8	936-933.4	Displacive Halite that is Mud Rich <ul style="list-style-type: none"> • color: halite 5 YR 6/6 mud 2.5 YR 3/3 • sedimentary characteristics: subangular to subrounded halite crystals, mud content= 30%, no bedding seen
9	933.4-932.2	Displacive Halite that is Mud Rich <ul style="list-style-type: none"> • color: halite 5 YR 6/6 mud 2.5 YR 3/3 • sedimentary characteristics: 60% mud, 40% halite, mud is relatively massive and well sorted, no bedding is seen, sharp angular contacts between salt and mud • diagenetic features: reduction spots?
10	932.2-929.6	Displacive Halite <ul style="list-style-type: none"> • not bagged, salt dissolved and core is in pieces • color: mud 2.5 YR 3/3, halite same as unit 8, sylvite 10 YR 5/8 • massive and well sorted mud clasts
11	929.6-928.7	Displacive Halite <ul style="list-style-type: none"> • color: halite 7.5 YR 5/1 mud Gley 2 5/5BG

		<ul style="list-style-type: none"> ● sedimentary characteristics: 85% halite, 15% mud, mud clasts are ~2-3 cm wide, mud is well sorted and relatively massive, abundance of salt increases as you move up in section ● diagenetic features: sylvite veins
12	928.7-927.2	<p>Bedded Halite</p> <ul style="list-style-type: none"> ● color: clear and cloudy white ● no sedimentary characteristics ● sharp contact with units 11 and 13 ● small fractures within the salt
13	927.2-925.9	<p>Displacive Halite</p> <ul style="list-style-type: none"> ● color: halite is dark brown and clear and cloudy and mud 2.5 YR 3/3 (chocolate brown) ● sedimentary characteristics: 90% halite, 10% mud, cubic halite crystals are subrounded in shape, rare mud clasts, no bedding is seen, some reduction of mud (?), color change creates a gradient
14	925.9-925.5	<p>Bedded Halite</p> <ul style="list-style-type: none"> ● color: halite 2.5 YR 4/4 and mud (Gley 2 5/10BG) ● sedimentary characteristics: clear halite at the bottom and it gets progressively muddier up section ● bedding and contacts: ½ cm thick lamina of mud, some bedding?, muddiness of halite makes it difficult to identify distinct beds ● diagenetic features: pseudomorph gypsum crystal texture?, reduction gradient?, mud lamina
15	925.5-925.2	<p>Mudstone</p> <ul style="list-style-type: none"> ● color: mud is chocolate brown ● sedimentary characteristics: climbing ripples ~1 cm thick at the bottom of the unit, no contacts in bedding ● diagenetic features: gypsum stringers 10R 5/8, few reduction spots, gypsum efflorescence on the core due to not being wrapped in plastic
16	925.2-925	<p>Mudstone</p> <ul style="list-style-type: none"> ● color: GLEY 2 3/10G, distinct blue-ish gray color ● high clay content, potentially kaolinite? ● diagenetic features: reduction gradient?, gypsum stringers, same color as unit 15

17	925-923.8	Displacive Halite <ul style="list-style-type: none"> • color: halite is brown and glassy and mud is chocolate brown • sedimentary characteristics: 10% mud, high clay content, relatively massive mud
18	923.8-920	Missing Core
19	920-919.5	Displacive Halite <ul style="list-style-type: none"> • color: halite is brown and glassy, mud is chocolate brown • sedimentary characteristics: 90% halite, 10% mud, cubic displacive halite crystals
20	919.5-918.3	Bedded Halite <ul style="list-style-type: none"> • color: halite glassy and chocolate brown in color, mud is chocolate brown • sedimentary characteristics: large bottom growth halite crystals and common mud clasts • bedding and contacts: distinct bedding from crystal shape and mud drapes • diagenetic features: pseudomorph gypsum splays?
21	918.5-916.4	Missing Core
22	916.4-915	Mixed Displacive and Bedded Halite <ul style="list-style-type: none"> • color: mud is chocolate brown, halite is a pink (5 YR 7/6) and brown color (2.5 YR 4/2 and 2.5 YR 3/2) • sedimentary characteristics: displacive halite is composed of small crystals with very rare mud, ~7 cm thick displacive halite region, bedded halite with large bottom growth crystals, 90-95% halite, 5-10% mud • bedding and contacts: bedded halite beds are 2 cm thick • diagenetic features: potentially recrystallized gypsum
23	915-914.7	Bedded Halite <ul style="list-style-type: none"> • color: mud is a blueish green (Gley 2 5/10 GB), halite is pink (5 YR 7/6) and brown color (2.5 YR 4/2 and 2.5 YR 3/2). • sedimentary characteristics: varying halite crystal size, all crystals are subrounded in shape, mud is wavy discontinuous lamina

- bedding and contacts: distinct beds with layers of mud draped over beds, bed layers are composed of varying sized halite crystals and mud
 - diagenetic features: dissolution pipes filled with clear halite
- 24 914.7-914.4 Bedded Halite
- color: mud is a blueish green (Gley 2 5/10 GB), halite is pink (5 YR 7/6) and brown color (2.5 YR 4/2 and 2.5 YR 3/2).
 - sedimentary characteristics: upward growing, needle-shaped crystals, rare mud drapes, beds alternate dark and light in color
 - diagenetic features: bottom growth gypsum pseudomorphs creating needle-shaped crystals
- 25 914.4-912.5 Displacive Halite
- color: mud is a blueish green (Gley 2 5/10 GB), halite is pink (5 YR 7/6) and brown color (2.5 YR 4/2 and 2.5 YR 3/2).
 - sedimentary characteristics: subangular, displacive halite crystals surrounded by mud
 - bedding and contacts: layers of mud with sharp boundaries to the salt and uncommon bedded halite layers that ~2 cm thick
 - diagenetic features: dissolution pipes filled with clear halite and reduced mud? shown by a color gradient
- 26 912.5-911.3 Mixed Bedded and Displacive Halite
- color: mud is Gley 2 5/10GB, halite is glassy and brown
 - sedimentary characteristics: upward pointing bottom growth halite crystals and cubic, displacive halite crystals
 - bedding and contacts: rare mud drapes found with the displacive halite crystals and gradual contacts from displacive to bedded
 - diagenetic features: dissolution pipes filled with clear halite
- 27 911.3-910.9 Mudstone
- color: mud is Gley 2 4/5B and 10R 3/3
 - sedimentary characteristics: well sorted and relatively massive mud with one displacive halite cube in the middle of the mudstone
 - bedding and contacts: bedding is defined by color laminations
 - diagenetic features: ~4 fractures through the mudstone that could potentially be related the displacive halite cube
- 28 910.9-910.6 Bedded Halite
- color: mud is Gley 2 5/10GB and halite is 5YR 7/4

		<ul style="list-style-type: none"> ● sedimentary characteristics: upward bottom growth halite crystals, mud lamina, uncommon displacive halite cubes ● bedding and contacts: bedding is very well defined between the mud and the halite crystal shape ● diagenetic features: recrystallized gypsum pseudomorphs?
29	910.6-908.8	Missing Core
30	908.8-907.9	Mudstone <ul style="list-style-type: none"> ● color: 5 YR 4/3 ● sedimentary characteristics: ped-like structure, slickens on surface, no true bedding, relatively massive ● bedding and contacts: no bedding is seen ● diagenetic features: sylvite veins and reduction zones?
31	907.9-907.8	Bedded Halite <ul style="list-style-type: none"> ● color: glassy pink 2.5 YR 7/6 ● sedimentary characteristics: chevrons ● bedding and contacts: beds from the crystal shape and very thin, discontinuous mud drapes
32	907.8-906.7	Mixed Bedded and Displacive Halite <ul style="list-style-type: none"> ● color: mud is Gley 2 5/10GB and halite is glassy and brown ● sedimentary characteristics: upward pointing bottom growth halite crystals and cubic, displacive halite crystals ● bedding and contacts: no bedding seen ● diagenetic features: gypsum pseudomorph needles growing upwards and dissolution pipes filled with clear halite
33	906.7-906.6	Bedded Halite <ul style="list-style-type: none"> ● color: glassy pink (2.5 YR 7/6) ● sedimentary characteristics: faint chevrons ● bedding and contacts: sharp contact with unit 32 and 34 ● diagenetic features: some pseudomorph gypsum textures at the bottom of the samples
34	906.6-905.4	Mixed Bedded and Displacive Halite <ul style="list-style-type: none"> ● color: mud is a blueish green (Gley 2 5/10 GB), halite is pink (5 YR 7/6) and brown color (2.5 YR 4/2 and 2.5 YR 3/2).

		<ul style="list-style-type: none"> ● sedimentary characteristics: subangular to subrounded, displacive halite crystals, bottom growth, bedded halite crystals ● bedding and contacts: no distinct bedding ● diagenetic features: large reduction spots in mud bleeding into one another, gypsum efflorescence on the core (not bagged), sylvite veins
35	905.4-902.6	<p>Mudstone</p> <ul style="list-style-type: none"> ● color: chocolate brown ● sedimentary characteristics: well sorted and relatively massive ● bedding and contacts: no bedding seen ● diagenetic features: sylvite veins and reduction zones?
36	902.6-901.7	<p>Displacive Halite</p> <ul style="list-style-type: none"> ● color: grey mud, glassy, brown halite ● sedimentary characteristics: subangular to subrounded crystals with mud clasts ● bedding and contacts: no bedding seen ● diagenetic features: sylvite veins and some reduction?
37	901.7-901.3	<p>Bedded Halite</p> <ul style="list-style-type: none"> ● color: brown to tan halite (2.5 YR 2.5/2 and 7 YR 6/4) and mud is a dark grey color ● sedimentary characteristics: chevrons? in the lower unit, as you move up in section, mud abundance increases, discontinuous mud drapes ● bedding and contacts: distinct halite beds from varying color and crystal shape ● diagenetic features: gypsum pseudomorphs?
38	901.3-901	<p>Displacive Halite</p> <ul style="list-style-type: none"> ● color: mud is a blueish green (Gley 2 5/10 GB), halite is pink (5 YR 7/6) and brown color (2.5 YR 4/2 and 2.5 YR 3/2). ● sedimentary characteristics: subangular crystals ● bedding and contacts: sharp contacts with units 37 and 39 ● diagenetic features: potentially some gypsum pseudomorphs
39	901-900.8	<p>Bedded Halite</p> <ul style="list-style-type: none"> ● color: brown to tan halite 2.5 YR 2.5/2 and 7 YR 6/4 and mud is a dark grey color ● sedimentary characteristics: chevrons

		<ul style="list-style-type: none"> • bedding and contacts: very distinct beds by color variation
40	900.8-899.6	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> • color: mud is chocolate brown, halite is a pink color (5 YR 7/6), a brown color (2.5 YR 4/2 and 2.5 YR 3/2) with a dark grey mud • sedimentary characteristics: discontinuous mud layers, distinctive cubic halite crystals • bedding and contacts: gradual change from bedding to displacive • diagenetic features: sylvite veins and gypsum pseudomorphs
41	899.6-899	<p>Mudstone</p> <ul style="list-style-type: none"> • color: Gley 2 5/10GB • sedimentary characteristics: relatively massive mud with a rare floating, displacive halite crystal • bedding and contacts: no bedding seen • diagenetic features: reduction spots?
42	899-890.6	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> • color: mud is chocolate brown, halite is a pink color (5 YR 7/6), a brown color (2.5 YR 4/2 and 2.5 YR 3/2) • sedimentary characteristics: rare mud drapes, subangular, displacive halite crystals that vary in size, bottom growth, bedded halite crystals • bedding and contacts: beds are defined by color variations and mud drapes • diagenetic features: sylvite veins and dissolution pipes filled with clear halite
43	890.6-887.7	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: mud is chocolate brown and grey • sedimentary characteristics: well sorted, relatively massive, high clay content • bedding and contacts: no bedding seen • diagenetic features: sylvite veins
44	887.7-884.7	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> • color: mud is chocolate brown and halite is glassy and brown • sedimentary characteristics: chevrons, rare mud drapes, halite crystals are smaller sized near the mud drapes, one bright red mud layer on a halite bed

		<ul style="list-style-type: none"> • bedding and contacts: bedding in the halite is from colors in the crystals and mud drapes
45	884.7-884.5	<p>Mudstone</p> <ul style="list-style-type: none"> • color: mud is chocolate brown • sedimentary characteristics: rare, very large, cubic, displacive halite crystals • bedding and contacts: no bedding seen • diagenetic features: sylvite veins
46	884.5-883.5	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: mud is Gley 2 5/10GB and halite is glassy and brown • sedimentary characteristics: large upward growing halite crystals and discontinuous mud drapes • bedding and contacts: light to dark colored beds of halite and mud drapes ~0.5 cm thick • diagenetic features: few fractures and dissolution pipes filled with halite
47	883.5-881.7	<p>Missing Core</p>
48	881.7-880.1	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> • color: mud is Gley 2 5/10GB and halite is glassy and brown • sedimentary characteristics: larger bottom growth crystals present • bedding and contacts: halite beds are evident due to color differences • diagenetic features: sylvite veins, dissolution pipes with clear halite. fractures
49	880.1-879.3	<p>Displacive Halite</p> <ul style="list-style-type: none"> • color: grey mud, same pink/brown salt • sedimentary characteristics: 10% mud, 90% halite, cubic displacive halite crystals • bedding and contacts: no bedding seen • diagenetic features: sylvite veins and fractures
50	879.3-878.6	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> • color: mud is Gley 2 5/10GB and halite is glassy and brown • sedimentary characteristics: 15-20% mud, large variation in crystal size, discontinuous mud drapes • bedding and contacts: varying bed thickness depending on crystal size

		<ul style="list-style-type: none"> • diagenetic features: reduction? in mud
51	878.6-878.3	<p>Mudstone</p> <ul style="list-style-type: none"> • color: chocolate brown and grey mud • sedimentary characteristics: ped-like texture, rare displacive halite crystals, high clay content • bedding and contacts: no true bedding • diagenetic features: sylvite veins and reduction? in the mud
52	878.3-874.5	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: mud is Gley 2 5/10GB and halite is glassy and brown • sedimentary characteristics: large (3 cm wide) cubic, displacive halite crystals, crystals are subangular in shape, 15-20% mud • bedding and contacts: no bedding seen • diagenetic features: sylvite veins and reduction? in mud
53	874.5-873.1	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: pink halite (2.5 YR 7/ 8) and grey mud • sedimentary characteristics: bottom growth halite crystals and kaolinite drapes seen in slab • bedding and contacts: distinct halite beds from color and the upward growth of crystals • diagenetic features: sylvite veins and reduction? in the mud
54	873.1-871.5	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> • color: grey mud, same pink/brown salt • sedimentary characteristics: mixed textures from crystal shape, cubic, small, displacive crystals, larger bottom growth crystals • bedding and contacts: bedding seen in crystal size • diagenetic features: sylvite veins and gypsum pseudomorph splays
55	871.5-869.6	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: mud is Gley 2 5/10GB and halite is glassy and brown • sedimentary characteristics crystal size varies, 15% mud, kaolinite? • bedding and contacts: bedded halite seen in crystals, mud drapes • diagenetic features: gypsum pseudomorphs in needle-like shape
56	869.6-869.5	<p>Bedded Halite</p>

		<ul style="list-style-type: none"> • color: glassy pink/orange 7.5 YR 7/8 • sedimentary characteristics: relatively clear halite with chocolate brown mud clasts suspended in halite • bedding and contacts: bedding in crystal shape
57	869.5-867.5	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: grey mud, same pink/brown salt • sedimentary characteristics: subrounded to subangular halite crystals • bedding and contacts: beds defined by color and rare mud laminations • diagenetic features: reduction? in mud
58	867.5-864	<p>Mudstone</p> <ul style="list-style-type: none"> • color: chocolate brown mud with mixed grey mud and grey colors are Gley 2 6/10GB and Gley 2 4/10B • sedimentary characteristics: rare displacive halite crystals and mud is well sorted and relatively massive • bedding and contacts: no bedding seen • diagenetic features: reduction? lamina
59	864-862	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: glassy pink/orange 7.5 YR 7/8 • sedimentary characteristics: 5% mud, upward growing halite crystals, very rare displacive halite crystals found in mud • bedding and contacts: well defined beds with some mud layers, clear halite, and muddy halite • diagenetic features: bedded gypsum pseudomorphs and halite-filled dissolution pits
60	862-861.3	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: Gley 2 4/10B • sedimentary characteristics: 90% mud, 10% displacive halite, abrupt change in color from brown to grey halfway through the unit • bedding and contacts: no bedding seen • diagenetic features: sylvite veins
61	861.3-857.6	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: grey and chocolate brown mud and glassy brown halite • sedimentary characteristics: 15-20% mud, kaolinite seen in mud, rare chevrons

		<ul style="list-style-type: none"> • bedding and contacts: clear bedding defined by crystal growth • diagenetic features: sylvite veins, reduction? in mud, pseudomorph, bottom growth gypsum
62	857.6-856.1	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: glassy pink/orange 7.5 YR 7/8 • sedimentary characteristics: abundance of mud increases as you move up unit, cubic, displacive halite crystals that are consistent in size • bedding and contacts: no bedding seen • diagenetic features: sylvite veins, clear halite in dissolution pipes, reduction? in mud
63	856.1-854.4	<p>Missing Core</p>
64	854.4-853.2	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> • color: pink halite (2.5 YR 7/ 8) and grey mud • sedimentary characteristics: 20% mud • bedding and contacts: evident bedding, but hard to see with so much mud • diagenetic features: reduction? in mud, dissolution pits filled with halite?
65	853.2-852.5	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: grey and chocolate brown mud and glassy brown halite • sedimentary characteristics: large, cubic, displacive halite crystals, mud is relatively massive, but breaks apart like peds • bedding and contacts: no bedding seen • diagenetic features: sylvite veins, reduced? Mud
66	852.5-848	<p>Missing Core</p>
67	848-846	<p>Displacive Halite</p> <ul style="list-style-type: none"> • color: grey and chocolate brown mud and glassy brown halite • sedimentary characteristics: the mud breaks apart like peds • bedding and contacts: no beds seen • diagenetic features: reduction? spots, sylvite veins
68	846-845.8	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: chocolate brown and grey mud and pink/brown halite

		<ul style="list-style-type: none"> ● sedimentary characteristics: 5-10% mud, moderately clear halite, large crystals interbedded with muddy halite and rare displacive halite crystals ● bedding and contacts: very well defined bedding by crystal size ● diagenetic features: potentially some halite dissolution
69	845.8-845.6	<p>Displacive Halite</p> <ul style="list-style-type: none"> ● color: chocolate brown and grey mud and pink/brown halite ● sedimentary characteristics: mud content increases as you move upward ● bedding and contacts: very faint bedding at the bottom of the unit ● diagenetic features: dissolution pits filled with clear halite
70	845.6-845.5	<p>Mudstone</p> <ul style="list-style-type: none"> ● color: chocolate brown ● sedimentary characteristics: rare displacive halite crystals and very massive ● bedding and contacts: no bedding seen ● diagenetic features: sylvite veins
71	845.5-844.5	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> ● color: chocolate brown rare spots of grey and glassy brown halite ● sedimentary characteristics: cubic, displacive halite crystals, 80% mud, formed in mud drapes with slicken features ● bedding and contacts: no bedding seen ● diagenetic features: abundant amount of sylvite veins, halite filled dissolution pits, reduction? in mud
72	844.5-844.3	<p>Bedded Halite</p> <ul style="list-style-type: none"> ● color: pink/brown halite and grey/chocolate brown mud ● sedimentary characteristics: rare mud clasts that are approximately 0.25 cm thick ● bedding and contacts: alternating light and dark colored beds of halite ● diagenetic features: gypsum pseudomorph needles ~1-2 cm long and reduction? in mud
73	844.3-843.5	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> ● color: chocolate brown mud and glassy pink and brown halite ● sedimentary characteristics: 0.5-1 cm wide cubic halite crystals, 15% mud

		<ul style="list-style-type: none"> • bedding and contacts: bedding of halite formed by upward growth crystals • diagenetic features: dissolution pits filled with clear halite
74	843.5-843.2	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: chocolate brown and grey mud and pink/brown halite • sedimentary characteristics: mud content increases as you move upward • bedding and contacts: very faint bedding at the bottom of the unit • diagenetic features: sylvite veins and reduction spots?
75	843.2-842.7	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: chocolate brown • sedimentary characteristics: rare displacive halite crystals and very massive, 5% mud • bedding and contacts: no bedding seen • diagenetic features: sylvite veins
76	842.7-842.1	<p>Displacive Halite</p> <ul style="list-style-type: none"> • color: chocolate brown and grey mud and pink/brown halite • sedimentary characteristics: 15% mud • bedding and contacts: very faint bedding at the bottom of the unit • diagenetic features: dissolution pits filled with clear halite
77	842.1-841.2	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: chocolate brown • sedimentary characteristics: rare displacive halite crystals and very massive, 5% mud • bedding and contacts: no bedding seen • diagenetic features: dissolution pipes filled with clear halite
78	841.2-841.1	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: chocolate brown and grey mud and glassy brown halite • sedimentary characteristics: some cubic, displacive halite crystals suspended in mud, mud is ~60% • bedding and contacts: no bedding is seen • diagenetic features: sylvite veins
79	841.1-839.6	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: chocolate brown

		<ul style="list-style-type: none"> ● sedimentary characteristics: rare displacive halite crystals and very massive, 15% mud ● bedding and contacts: no bedding seen ● diagenetic features: dissolution pipes filled with halite
80	839.6-839.4	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> ● color: chocolate brown and grey mud and glassy brown halite ● sedimentary characteristics: 70% mud, subrounded, displacive halite crystals ● bedding and contacts: no bedding seen ● diagenetic features: sylvite veins and reduction? in mud
81	839.4-837.8	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> ● color: glassy brown halite and chocolate brown mud ● sedimentary characteristics: 25% mud, mud drapes, bottom growth halite crystals, cubic, displacive halite crystals suspended in mud ● bedding and contacts: defined by the bottom growth crystals ● diagenetic features: some pseudomorph gypsum crystals
82	837.8-837.5	<p>Bedded Halite</p> <ul style="list-style-type: none"> ● color: glassy, dark brown halite and chocolate brown mud ● sedimentary characteristics: 10% mud, large halite bottom growth crystals with chevrons? ● bedding and contacts: very well defined by halite crystal size and shape ● diagenetic features: gypsum pseudomorph crystals
83	837.5-837.3	<p>Mudstone</p> <ul style="list-style-type: none"> ● color: chocolate brown mud ● sedimentary characteristics: extremely crumbly, breaks into peds, rare displacive halite crystals ● bedding and contacts: no bedding seen ● diagenetic features: sylvite veins
84	837.3-837	<p>Bedded Halite</p> <ul style="list-style-type: none"> ● color: glassy brown to pink halite and chocolate brown mud ● sedimentary characteristics: 15% mud found in mud drapes ● bedding and contacts: great bedding defined by bottom growth crystals ● diagenetic features: pseudomorph gypsum crystals

85	837-836.5	Mixed Bedded and Displacive Halite <ul style="list-style-type: none"> • color: glassy, dark brown halite and chocolate brown mud • sedimentary characteristics: bedded bottom growth halite and displacive halite crystals in muddier areas • bedding and contacts: some nicely defined beds throughout the unit • diagenetic features: sylvite veins and gypsum pseudomorph crystals
86	836.5-836	Displacive Halite <ul style="list-style-type: none"> • color: grey and chocolate brown mud and glassy brown halite • sedimentary characteristics: large displacive halite crystals ~2 cm in width and 15% mud • bedding and contacts: sharp contacts with unit 85 and 87 • diagenetic features: some sylvite veins and beginning of reduction zone?
87	836-835.9	Mudstone <ul style="list-style-type: none"> • color: chocolate brown mud to dark grey mud • sedimentary characteristics: rare displacive halite crystal and well sorted • bedding and contacts: bedding in the mudstone alternating from grey to brown • diagenetic features: grey gradient indicating reduction?
88	835.9-834.6	Displacive Halite that is Mud Rich <ul style="list-style-type: none"> • color: chocolate brown mud and glassy brown halite • sedimentary characteristics: large, displacive crystals and 70% mud • bedding and contacts: no bedding seen • diagenetic features: some reduction? in mud and dissolution pipes filled with clear halite
89	834.6-834.4	Mudstone <ul style="list-style-type: none"> • color: chocolate brown and grey mud • sedimentary characteristics: slickensides, crumbles into peds, relatively massive • bedding and contacts: no bedding seen • diagenetic features: reduction gradient? in mud
90	834.4-832.9	Mixed Bedded and Displacive Halite <ul style="list-style-type: none"> • color: chocolate brown to grey mud and glassy brown halite • sedimentary characteristics: cubic, displacive halite crystals, 40% mud, minor mud drapes • bedding and contacts: bedding in bottom growth crystals

		<ul style="list-style-type: none"> • diagenetic features: dissolution pipes filled with clear halite and reduction of mud?
91	832.9-832.6	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: chocolate brown mud and glassy brown halite • sedimentary characteristics: 60-80% mud and large displacive halite crystals • bedding and contacts: no bedding evident • diagenetic features: sylvite veins
92	832.6-831.4	<p>Displacive Halite</p> <ul style="list-style-type: none"> • color: grey and chocolate brown mud and glassy brown halite • sedimentary characteristics: 40% mud and large, cubic halite crystals • bedding and contacts: very minor and rare beds • diagenetic features: small sylvite veins and dissolution pipes filled with halite
93	831.4-830.9	<p>Mudstone</p> <ul style="list-style-type: none"> • color: mud is chocolate brown to grey • sedimentary characteristics: rare (2-3) displacive halite crystals • bedding and contacts: massive mud, no bedding • diagenetic features: thin sylvite veins and reduction spots?
94	830.9-829.9	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: mud is chocolate brown and halite is brown • sedimentary characteristics: 70-75% at bottom, 60% at top and small displacive crystals • bedding and contacts: no bedding, straight chaos • diagenetic features: very thin sylvite veins
95	829.9-829.3	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: mud is chocolate brown and halite is brown • sedimentary characteristics: 5-10% mud as drapes clasts and rare displacive crystals • bedding and contacts: beds defined by crystal shape • diagenetic features: minor reduction in mud
96	829.3-828.5	<p>Mixed Bedded and Displacive Halite</p>

		<ul style="list-style-type: none"> ● color: mud is chocolate brown and halite is brown ● sedimentary characteristics: 10-15% mud, cubic crystals, same mud content throughout ● bedding and contacts: very faint bedding, 1-2 cm thick bed of mud , ~1 sylvite vein ● diagenetic features: small reduction amount in mud
97	828.5-827.5	<p>Bedded Halite that is Mud Rich</p> <ul style="list-style-type: none"> ● color: mud is chocolate brown and grey and halite is brown ● sedimentary characteristics: some mud drapes and 5% mud ● bedding and contacts: distinct beds defined by mud drapes ● diagenetic features: potentially some pseudomorph gypsum splays
98	827.5-826.6	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> ● color: mud is grey and halite is brown ● sedimentary characteristics: cubic displacive crystals ● bedding and contacts: no evident bedding ● diagenetic features: sylvite veins
99	826.6-825.6	<p>Bedded Halite</p> <ul style="list-style-type: none"> ● color: mud is chocolate brown and brown clear halite ● sedimentary characteristics: repetitive texture from beds with crystal side up, as you go up from mud and then more mud ● bedding and contacts: great beds defined by both mud and crystals and clear contact ● diagenetic features: pseudomorph gypsum crystals
100	825.6-824.4	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> ● color: mud is dark chocolate brown to grey ● sedimentary characteristics: 15% mud and mixed crystal size ● bedding and contacts: distinct halite beds growing upward ● diagenetic features: pseudomorph gypsum crystals, reduction gradient in mud?, halite veins
101	824.4-823.7	<p>Bedded Halite</p> <ul style="list-style-type: none"> ● color: mud is chocolate brown and brown clear halite ● sedimentary characteristics: well bedded with clear and slightly muddy (10%) halite ● bedding and contacts: beds alternate in thickness and are very clear

		<ul style="list-style-type: none"> • diagenetic features: clear halite in dissolution pipes
102	823.7-819.9	Missing Core
103	819.9-818.2	Bedded Halite <ul style="list-style-type: none"> • color: mud is chocolate brown and halite is clear brown • sedimentary characteristics: some floating mud chips/clasts and 10% mud • bedding and contacts: bedding is very clear • diagenetic features: few dissolution pipes
104	818.2-818.05	Mudstone <ul style="list-style-type: none"> • color: mainly chocolate brown with hazes of grey • sedimentary characteristics: well sorted mud • bedding and contacts: massive, no bedding • diagenetic features: sylvite veins
105	818.05- 817.5	Mixed Bedded and Displacive Halite <ul style="list-style-type: none"> • color: mud is chocolate brown and halite is brown • sedimentary characteristics: 15% mud • bedding and contacts: gradual contacts with faint bedding • diagenetic features: dissolution pipes with halite
106	817.5-814.3	Bedded Halite <ul style="list-style-type: none"> • color: halite color is the same and mud is gray 10R 4/14 • sedimentary characteristics: kaolinite and new reddish color • bedding and contacts: very clear bedding • diagenetic features: dissolution pipes in halite and reduction in mud
107	814.3-814	Mudstone <ul style="list-style-type: none"> • color: purple brick 10 R 3/2 and Gley 2 3/5BG • sedimentary characteristics: rare displacive crystals and mud is fairly massive • bedding and contacts: no bedding • diagenetic features: reduction gradient?
108	814-813.6	Bedded Halite

		<ul style="list-style-type: none"> • color: dark brown halite and gray mud • sedimentary characteristics: some floating mud chips/clasts and 10% mud • bedding and contacts: clear contact between 107 and 108 • diagenetic features: gypsum pseudomorph splays
109	813.6-813.1	<p>Mudstone</p> <ul style="list-style-type: none"> • color: purple brick and grey mud • sedimentary characteristics: very rare displacive halite crystals • bedding and contacts: very sharp contacts between units 108 and 109 and no bedding seen • diagenetic features: reduction gradient?
110	813.1-812.6	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: mud is grey and chocolate brown and brown halite • sedimentary characteristics: rare displacive crystals • bedding and contacts: sharp contact with 109 and faint bedding • diagenetic features: pseudomorph gypsum needles
111	812.6-812.2	<p>Mudstone</p> <ul style="list-style-type: none"> • color: chocolate brown to grey mud • sedimentary characteristics: very rare displacive halite crystals • bedding and contacts: no bedding seen • diagenetic features: sylvite veins
112	812.2-811.4	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> • color: chocolate brown and gray mud and brown halite • sedimentary characteristics: mud drapes, mud is 10%, large variety in crystal size • bedding and contacts: well defined beds • diagenetic features: sylvite veins
113	811.4-810.4	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: chocolate brown mud and brown halite • sedimentary characteristics: 70-80% mud, large sized, cubic halite crystals, mud is massive • bedding and contacts: no bedding seen • diagenetic features: dissolution pipes filled with clear halite and sylvite veins

114	810.4-810.2	Bedded Halite <ul style="list-style-type: none"> • color: chocolate brown mud and dark brown halite • sedimentary characteristics: 5-10% mud • bedding and contacts: very well-defined beds and sharp contact with unit 115
115	810.2-809.6	Displacive Halite <ul style="list-style-type: none"> • color: grey and chocolate brown mud and brown halite • sedimentary characteristics: large displacive crystals • bedding and contacts: no evident bedding • diagenetic features: sylvite veins and dissolution pipes filled with clear halite
116	809.6-808.8	Mixed Bedded and Displacive Halite <ul style="list-style-type: none"> • color: chocolate brown mud and brown/pink halite • sedimentary characteristics: 25% mud, distinct upward growth halite crystals, and cubic displacive crystals • bedding and contacts: one bed 2-3 cm thick of mud • diagenetic features: sylvite veins and bottom growth gypsum pseudomorphs
117	808.8-807.6	Displacive Halite with Varying Amounts of Mud <ul style="list-style-type: none"> • color: chocolate brown mud and brown halite • sedimentary characteristics: 5-10% mud and small displacive crystals • bedding and contacts: no evident bedding • diagenetic features: small to medium sized sylvite veins and large dissolution pipes filled with clear halite
118	807.6-807	Mixed Bedded and Displacive Halite <ul style="list-style-type: none"> • color: chocolate brown and grey mud and dark brown halite • sedimentary characteristics: 30-35% mud mainly in mud drapes and cubic displacive halite crystals • bedding and contacts: small beds of crystals with mud drapes • diagenetic features: reduction? and mud drapes
119	807-801.6	Bedded Halite <ul style="list-style-type: none"> • color: chocolate brown/grey mud and brown halite

		<ul style="list-style-type: none"> ● sedimentary characteristics: 20% mud mainly found in mud drapes, rare displacive halite crystals, entire unit becomes slightly more orange as you move up ● bedding and contacts: beds are defined by crystal's bottom growth structure ● diagenetic features: dissolution pipes filled with clear halite and reduction? in mud drapes
120	801.6-801.4	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> ● color: mud 10 R 2.5/2 and grey and halite is brown to pink ● sedimentary characteristics: 80% mud, mud is massive, cubic displacive halite crystals ● bedding and contacts: no bedding seen ● diagenetic features: reduction? in the mud
121	801.4-799.8	<p>Bedded Halite</p> <ul style="list-style-type: none"> ● color: mixed chocolate brown and brown and pink halite ● sedimentary characteristics: the abundance of mud increases as you move up from 10-30% and mud is found in mud drapes ● bedding and contacts: beds defined by upward bottom growth crystals ● diagenetic features: reduction? in mud
122	799.8-799.3	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> ● color: warm chocolate brown mud and brown halite ● sedimentary characteristics: 70-80% mud and cubic displacive halite crystals ● bedding and contacts: no bedding seen ● diagenetic features: dissolution pipes filled with clear halite and sylvite veins
123	799.3-797	<p>Bedded Halite</p> <ul style="list-style-type: none"> ● color: mud is 10R 2.5/2 and grey and halite is dark brown ● sedimentary characteristics: 15-20% mud and mud drapes ● bedding and contacts: beds defined by upward bottom growth crystals ● diagenetic features: sylvite veins
124	797-796.4	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> ● color: warm chocolate brown mud and brown halite ● sedimentary characteristics: 50% mud

- bedding and contacts: no bedding seen
 - diagenetic features: sylvite veins and dissolution pipes filled with clear halite
- 125 796.4-795.3 Bedded Halite
- color: chocolate brown mud and dark brown halite
 - sedimentary characteristics: 10% mud found in small mud drapes and upward growth halite crystals
 - bedding and contacts: beds formed from crystal shape and color
 - diagenetic features: reduction? in mud
- 126 795.3-794.7 Displacive Halite
- color: chocolate brown mud and dark brown halite
 - sedimentary characteristics: well sorted mud and cubic displacive halite crystals
 - bedding and contacts: no bedding seen and sharp contact with unit 127
 - diagenetic features: large sylvite veins and dissolution pipes filled with clear halite
- 127 794.7-794.1 Bedded Halite
- color: chocolate brown mud and dark brown halite
 - sedimentary characteristics: 5-10% mud found in mud drapes and sharp contact with unit 126
 - bedding and contacts: well defined beds from halite growth
 - diagenetic features: large sylvite veins and dissolution pipes filled with clear halite
- 128 794.1-793.9 Displacive Halite
- color: chocolate brown mud and dark brown halite
 - sedimentary characteristics: well sorted mud and cubic displacive halite crystals
 - bedding and contacts: no bedding seen
 - diagenetic features: very large sylvite veins
- 129 793.9-791.6 Bedded Halite
- color: chocolate brown mud and dark brown halite
 - sedimentary characteristics: mud drapes and upward growth halite crystals
 - bedding and contacts: well defined beds from halite growth
 - diagenetic features: reduction? in mud

130	791.6-789.9	Missing Core
131	789.9-782	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: orangeish brown mud and brown halite • sedimentary characteristics: small to medium sized bottom growth halite crystals • bedding and contacts: sharp bedding boundaries with the other units • diagenetic features: sylvite veins, dissolution pipes filled with clear halite, pseudomorph gypsum splays
132	782-780.7	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: mud is 10R 2.5/1, 10 R 3/10 B and Gley 2 5/5RB and halite is brown • sedimentary characteristics: 60% mud and displacive halite crystals • bedding and contacts: some bedding seen in the mud and sharp contact with unit 131 • diagenetic features: reduction gradient? in mud and sylvite veins
133	780.7-780.2	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: bright orange color found in spots in the halite 10 R 6/8, brown halite, and brown mud • sedimentary characteristics: small to medium sized bottom growth halite crystals, 5-10% mud • bedding and contacts: sharp bedding boundaries with the other units • diagenetic features: reduction? in mud
134	780.2-779.5	<p>Displacive Halite</p> <ul style="list-style-type: none"> • color: mud is 10R 2.5/1, 10 R 3/10 B and Gley 2 5/5RB and halite is brown • sedimentary characteristics: 60% mud and displacive halite crystals • bedding and contacts: no bedding seen • diagenetic features: sylvite veins and reduction? in mud
135	779.5-778.5	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: bright orange color found in spots in the halite 10 R 6/8, brown halite, and brown mud • sedimentary characteristics: small to medium sized bottom growth halite crystals

		<ul style="list-style-type: none"> • bedding and contacts: sharp bedding boundaries with the other units • diagenetic features: sylvite veins, dissolution pipes filled with clear halite, pseudomorph gypsum splays
136	778.5-778.3	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> • color: bright orange color found in spots it he halite 10 R 6/8, brown halite, and brown mud • sedimentary characteristics: common displacive halite crystals and bottom growth halite crystals • bedding and contacts: bedding is evident in crystal shape • diagenetic features: dissolution pipes filled with clear halite, reduction? in mud, pseudomorph gypsum crystals
137	778.3-773.6	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> • color: bright orange color found in spots it he halite 10 R 6/8, brown halite, and brown mud • sedimentary characteristics: 10-15% mud and common halite displacive crystals found suspended in mud • bedding and contacts: defined beds from crystal size and shape • diagenetic features: reduction? in mud drapes, sylvite veins, gypsum pseudomorph splays
138	773.6-771.4	Missing Core
139	771.4-770.9	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> • color: mud is chocolate brown and halite is brown • sedimentary characteristics: 5-10% mud found in mud drapes • bedding and contacts: same as unit 137 • diagenetic features: reduction? in mud
140	770.9-769.8	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: chocolate brown mud and brown halite • sedimentary characteristics: 5-10% mud found in mud drapes and mud clasts • bedding and contacts: well defined beds from crystal shape and color • diagenetic features: rare reduction? found in mud
141	769.8-769.6	Displacive Halite that is Mud Rich

		<ul style="list-style-type: none"> • color: mud is purple chocolate 10R 3/2, red mud 10R 3/1, grey mud, and brown halite • sedimentary characteristics: some small, rare, 1cm in width displacive halite cubes • bedding and contacts: no bedding seen, sharp contact with unit 140 • diagenetic features: sylvite veins that are 10R 5/8 in color and reduction? in mud gradient
142	769.6-769.4	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: chocolate brown to brown halite • sedimentary characteristics: some mud and color difference • bedding and contacts: mud helps define beds and sharp contact with unit 141
143	769.4-769.3	<p>Mudstone</p> <ul style="list-style-type: none"> • color: Gley 2 3/5 BG • sedimentary characteristics: mud is well sorted and mud is massive • bedding and contacts: no bedding seen • diagenetic features: large sylvite veins (color: 10 R 5/8)
144	769.3- 769	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: chocolate brown mud halite is brown and red (10 R 4/8) • sedimentary characteristics: subrounded to subangular crystals and crystals are strictly bottom growth • bedding and contacts: beds are defined by color and crystal shape • diagenetic features: reduction? in mud and dissolution pipes filled with clear halite
145	769-768.7	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> • color: chocolate brown mud and brown halite • sedimentary characteristics: 10-15% mud and relatively smaller bottom growth halite crystals • bedding and contacts: faint bedding defined by crystal shape • diagenetic features: dissolution pipe filled by clear halite
146	768.7-768	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: chocolate brown mud and grey and brown halite • sedimentary characteristics: more mud as you move up in the unit, the amount of displacive halite cubes increases as you move up in section, the mud is massive • bedding and contacts: no bedding seen

		<ul style="list-style-type: none"> • diagenetic features: small and large sylvite veins and reduction in mud
147	768-766.8	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: chocolate brown mud and brown halite • sedimentary characteristics: 5% mud and large bottom growth halite crystals • bedding and contacts: sharp contact with unit 146 and well-defined beds from color and crystal shape • diagenetic features: dissolution pipes
148	766.8-766.6	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: chocolate brown mud and brown halite • sedimentary characteristics: some cubic, displacive halite and 80% mud • bedding and contacts: sharp contact with unit 147 and no bedding with mud or halite • diagenetic features: medium sized sylvite veins
149	766.6-766.1	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: chocolate brown and red mud and brown halite • sedimentary characteristics: 20% mud found in mud drapes and bottom growth halite crystals • bedding and contacts: very well-defined bedding from color and crystal shape • diagenetic features: reduction? in mud
150	766.1-766	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: grey and chocolate brown mud and brown halite • sedimentary characteristics: common displacive halite cubes and 80% mud • bedding and contacts: no bedding in the mud and layers of displacive cubes (would grow on a plane. Is this bedding?) • diagenetic features: medium sized sylvite veins and reduction? in mud
151	766-765.3	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: brown halite and chocolate brown and grey mud • sedimentary characteristics: 5-10% mud and bottom growth crystals are subrounded • bedding and contacts: bedding formed from crystal shape • diagenetic features: dissolution pipes and reduction? in mud

152	765.3-765	Mixed Bedded and Displacive Halite <ul style="list-style-type: none"> • color: grey mud and brown halite • sedimentary characteristics: 5-10% mud • bedding and contacts: faint bedding • diagenetic features: sylvite veins
153	765-764.3	Bedded Halite <ul style="list-style-type: none"> • color: grey mud and brown halite • sedimentary characteristics: 5-10% mud, large pink/brown colored halite crystals, and grey mud drapes • bedding and contacts: evident bedding and sharp contact boundary with unit 154 • diagenetic features: dissolution pipes and reduction? of mud
154	764.3-764.1	Displacive Halite that is Mud Rich <ul style="list-style-type: none"> • color: chocolate brown color of mud and brown clear halite • sedimentary characteristics: common displacive halite crystals and 80-90% mud • bedding and contacts: sharp lower contact with unit 153 • diagenetic features: large sylvite veins
155	764.1-762.5	Mixed Bedded and displacive Halite <ul style="list-style-type: none"> • color: chocolate brown and grey mud and brown and pink halite • sedimentary characteristics: 20% mud, distinct cubic halite crystals in mud, and bottom growth halite crystals • bedding and contacts: bedding formed from crystal shape and mud drapes • diagenetic features: reduction? in mud seen in color, dissolution pipes filled with halite, sylvite veins
156	762.5-762.45	Displacive Halite that is Mud Rich <ul style="list-style-type: none"> • color: chocolate brown and grey mud • sedimentary characteristics: 90% mud and rare displacive halite crystals • bedding and contacts: no bedding seen • diagenetic features: sylvite veins and reduction? in mud
157	762.45-760.9	Bedded Halite

		<ul style="list-style-type: none"> • color: chocolate brown and grey mud, brown halite • bedding and contacts: beds from color and shape and 2-3 cm thick beds of mud • diagenetic features: reduction in mud, thin sylvite veins, dissolution pipes
158	760.9-760	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> • color: chocolate brown and grey mud and brown/pink halite • sedimentary characteristics: displacive halite cubes mixed in with bedding and 30% mud • bedding and contacts: well-defined beds from bottom growth crystals • diagenetic features: reduction? in mud and large dissolution pipe
159	760-759.5	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: dark grey to chocolate brown mud and brown halite • sedimentary characteristics: cubic, displacive halite crystals • bedding and contacts: bedding evident from halite growth • diagenetic features: thick vein of sylvite and reduction? in mud
160	759.5-759.2	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: chocolate brown mud and clear brown halite • sedimentary characteristics: rare mud (5-10%) • bedding and contacts: bedding evident from halite color and crystal shape • diagenetic features: dissolution pits and grey mud, possible reduction?
161	759.2-758.2	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: chocolate brown mud and clear brown halite • sedimentary characteristics: high mud content and subrounded, cubic halite crystals • bedding and contacts: maybe some bedding in mud based on coloration • diagenetic features: thin sylvite veins and reduction? in mud
162	758.2-757.9	<p>Mixed Bedded and displacive Halite</p> <ul style="list-style-type: none"> • color: chocolate brown and grey mud and brown halite • sedimentary characteristics: subrounded, displacive, cubic halite and some mud • bedding and contacts: faint traces of bedding in coloration • diagenetic features: reduction? in mud and thin sylvite veins

163	757.9-756.9	Bedded Halite <ul style="list-style-type: none"> • color: chocolate brown and grey mud and brown halite • sedimentary characteristics: very large halite crystals and rare to some mud • bedding and contacts: bedding seen by color and crystal shape • diagenetic features: dissolution pipes filled by clear halite
164	756.9-756.2	Mixed Bedded and displacive Halite <ul style="list-style-type: none"> • color: chocolate brown and grey mud and brown halite • sedimentary characteristics: some mud • bedding and contacts: faint traces of beds • diagenetic features: a large amount of large dissolution pits and pipes and thin sylvite veins
165	756.2-755.9	Bedded Halite <ul style="list-style-type: none"> • color: chocolate brown and grey mud and brown halite • sedimentary characteristics: small to medium halite crystals that are subangular in shape and rare mud • bedding and contacts: bedding evident in crystal shape and color • diagenetic features: reduction? in mud
166	755.9-753.9	Bedded Halite <ul style="list-style-type: none"> • color: chocolate brown and grey mud and brown halite • sedimentary characteristics: some mud and mud content increases as you move up in the unit • bedding and contacts: faint bedding seen in color • diagenetic features: a large amount of large dissolution pits and pipes and thin sylvite veins
167	753.9-753.6	Bedded Halite <ul style="list-style-type: none"> • color: chocolate brown and grey mud and brown halite • sedimentary characteristics: rare mud content and large bottom growth halite crystals • bedding and contacts: beds evident in color • diagenetic features: dissolution pipes filled with clear halite and reduction in mud?

168	753.6-751.7	Missing Core
169	751.7-750.9	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: dark chocolate brown mud and brown halite • sedimentary characteristics: subrounded to subangular displacive halite crystals and mainly composed of mud • bedding and contacts: no bedding seen • diagenetic features: sylvite veins
170	750.9-749	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: pink and brown halite and chocolate brown mud • sedimentary characteristics: very large bottom growth halite crystals • bedding and contacts: halite crystals and color define the beds • diagenetic features: dissolution pipes filled with halite and reduction? in mud
171	749-748.8	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> • color: dark chocolate brown mud and brown halite • sedimentary characteristics: some mud and halite crystal size varies • bedding and contacts: faint bedding seen in color • diagenetic features: very large sylvite veins and dissolution pipes filled with halite
172	748.8-745.6	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> • color: chocolate brown mud and brown halite • sedimentary characteristics: some mud • bedding and contacts: bedding is shown by colors • diagenetic features: dissolution pits seen in halite
173	745.6-745.5	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: chocolate brown mud and brown halite • sedimentary characteristics: mud content increases as you move up in the unit • bedding and contacts: no bedding seen • diagenetic features: sylvite veins and dissolution pits filled with halite
174	745.5-743.9	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> • color: chocolate brown mud and brown halite

		<ul style="list-style-type: none"> ● sedimentary characteristics: pinkish halite in some spots and 10-15% mud ● bedding and contacts: bedding due to crystal size and shape ● diagenetic features: dissolution pits
175	743.9-743.1	<p>Bedded Halite</p> <ul style="list-style-type: none"> ● color: mainly chocolate brown mud with some grey mud and brown halite ● sedimentary characteristics: rare to some mud ● bedding and contacts: bedding defined by crystal color ● diagenetic features: dissolution pipes filled with halite and sylvite veins
176	743.1-742.5	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> ● color: Gley 2 4/5GB and brown/red mud and brown halite ● sedimentary characteristics: some mud and a mix of halite crystal sizes ● bedding and contacts: faint bedding beds found due to crystal type (ex. displacive or bedded) ● diagenetic features: dissolution pits filled with halite
177	742.5-741.8	<p>Bedded Halite</p> <ul style="list-style-type: none"> ● color: chocolate brown mud and brown halite ● sedimentary characteristics: rare mud ● bedding and contacts: bedding evident through color change ● diagenetic features: dissolution pits filled with halite
178	741.8-741.7	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> ● color: chocolate brown mud and brown halite ● sedimentary characteristics: mostly mud and some displacive, cubic halite crystals ● bedding and contacts: no distinct bedding seen ● diagenetic features: large sylvite veins
179	741.7-739.9	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> ● color: chocolate brown mud and brown halite ● sedimentary characteristics: varying crystal size, 30% mud, and mud content increases as you move up in section ● bedding and contacts: faint bedding from coloration ● diagenetic features: dissolution pipes filled with halite

180	739.9-739.2	Bedded Halite <ul style="list-style-type: none"> • color: chocolate brown and grey mud and pink and brown halite • sedimentary characteristics: very large bottom growth halite crystals with large mud clasts in the center of the crystals • bedding and contacts: evident bedding from crystal shape • diagenetic features: reduction? seen in mud
181	739.2-737.6	Mixed Bedded and Displacive Halite <ul style="list-style-type: none"> • color: chocolate brown mud and brown halite • sedimentary characteristics: 30-40% mud and subangular halite crystals • bedding and contacts: bedding defined by crystal shapes • diagenetic features: reduction? in mud and dissolution pits
182	737.6-735.9	Missing Core
183	735.9-734.3	Mudstone <ul style="list-style-type: none"> • color: mud is red/brown 2.5 Yr 3/3 and Gley 2 5/5B • sedimentary characteristics: well-sorted, rare displacive halite crystals, mud is massive • bedding and contacts: no bedding seen • diagenetic features: large sylvite veins that are 7cm thick and reduction spots? that could be roots?
184	734.3-733.4	Missing Core
185	733.4-732.4	Displacive Halite that is Mud Rich <ul style="list-style-type: none"> • color: chocolate brown mud and brown halite • sedimentary characteristics: 50-60% mud and cubic, displacive halite crystals • bedding and contacts: no bedding seen • diagenetic features: dissolution pipes filled with clear halite
186	732.4-727	Mudstone <ul style="list-style-type: none"> • color: mud is red/brown 2.5 YR 3/3 and 11 cm thick bed of grey mudstone • sedimentary characteristics: ped-like sed textures, soil slickensides, rare displacive halite crystals • bedding and contacts: no bedding seen

		<ul style="list-style-type: none"> • diagenetic features: sylvite veins and dissolution pipes filled with halite
187	727-725.2	Missing Core
188	725.2-723.3	Displacive Halite that is Mud Rich <ul style="list-style-type: none"> • color: chocolate brown mud and brown halite • sedimentary characteristics: cubic displacive halite crystals, very high clay content, 60% mud • bedding and contacts: no bedding seen • diagenetic features: reduction? seen in mud
189	723.2-722.6	Mudstone <ul style="list-style-type: none"> • color: warm, chocolate brown mud • sedimentary characteristics: mud is well sorted and massive • bedding and contacts: no bedding seen • diagenetic features: large dissolution pipes filled with halite and medium sized (thickness) sylvite veins that are 50cm long
190	722.6-722.3	Displacive Halite <ul style="list-style-type: none"> • color: chocolate brown mud and brown halite • sedimentary characteristics: 70% mud and cubic, displacive halite crystals • bedding and contacts: no bedding seen • diagenetic features: small sylvite veins
191	722.3-721.4	Mudstone <ul style="list-style-type: none"> • color: warm chocolate brown mud • sedimentary characteristics: mud is well sorted and massive • bedding and contacts: no bedding seen • diagenetic features: sylvite veins
192	721.4-719.4	Missing Core
193	719.4-718.9	Displacive Halite that is Mud Rich <ul style="list-style-type: none"> • color: warm, chocolate brown mud • sedimentary characteristics: 90% mud with some cubic displacive halite crystals

		<ul style="list-style-type: none"> • bedding and contacts: no bedding seen
194	718.9-699	<p>Displacive Halite</p> <ul style="list-style-type: none"> • color: chocolate brown and grey mud • sedimentary characteristics: very large displacive halite crystals with mud clasts and mud content decreases as you move up section • bedding and contacts: no bedding seen • diagenetic features: reduction? in mud and dissolution pits filled with clear halite
195	699-695.6	Missing Core
196	695.6-688.4	<p>Displacive Halite</p> <ul style="list-style-type: none"> • color: chocolate brown and grey mud • sedimentary characteristics: very large displacive halite crystals with mud clasts and mud content decreases as you move up section • bedding and contacts: no bedding seen • diagenetic features: reduction? in mud and dissolution pits filled with clear halite
197	688.4-688.2	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: chocolate brown mud and clear brown halite • sedimentary characteristics: large halite crystals and 15-20% mud • bedding and contacts: no bedding seen • diagenetic features: some grey reduction? spots and dissolution pits and pipes
198	688.2-686	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: chocolate brown mud and rare areas of grey mud • sedimentary characteristics: 10-15% mud and subangular displacive halite crystals • bedding and contacts: no bedding seen • diagenetic features: sylvite veins
199	686-682.1	<p>Igneous Rock</p> <ul style="list-style-type: none"> • color: black on fresh surface Gley 1 2.5/N and green on weathered surface Gley 1 5/5GY

		<ul style="list-style-type: none"> ● sedimentary characteristics: aphanitic and looks like basalt, but does not feel as dense ● diagenetic features: halite veins and green weathering
200	682.1-681.1	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> ● color: mud is Gley 1 2.5/N and dark brown and clear halite ● sedimentary characteristics: 20-30% mud and mud is found in clasts and beds ● bedding and contacts: sharp contact with unit 199 ● diagenetic features: dissolution pipes filled with clear halite
201	681.1-680	<p>Displacive Halite</p> <ul style="list-style-type: none"> ● color: chocolate brown mud and brown halite ● sedimentary characteristics: large cubic halite crystals ~1 cm in length ● bedding and contacts: no bedding seen ● diagenetic features: some dissolution pits filled with pink halite crystals and reduction? in mud
202	680-679	<p>Mudstone</p> <ul style="list-style-type: none"> ● color: Gley 2 4/10 G mud and chocolate brown mud ● sedimentary characteristics: high clay content, ped textures, soil slickensides ● bedding and contacts: no bedding seen ● diagenetic features: sylvite veins and reduction? in mud
203	679-678.6	<p>Displacive Halite</p> <ul style="list-style-type: none"> ● color: chocolate brown mud and brown halite ● sedimentary characteristics: large displacive halite crystals that are cubic and subangular and 20% mud ● bedding and contacts: no bedding seen ● diagenetic features: dissolution pits and sylvite veins
204	678.6-676.1	<p>Bedded Halite</p> <ul style="list-style-type: none"> ● color: chocolate brown mud and clear brown halite ● sedimentary characteristics: rare displacive halite crystals ● bedding and contacts: beds are defined by crystal shape ● diagenetic features: some dissolution pits and reddish color found underneath a salt bed

205	676.1-673.7	Mixed Bedded and Displacive Halite <ul style="list-style-type: none"> • color: chocolate brown mud and clear brown halite • sedimentary characteristics: subangular cubic halite crystals • bedding and contacts: bedding defined by crystal shape • diagenetic features: some dissolution pits
206	673.7-666.3	Displacive Halite that is Mud Rich <ul style="list-style-type: none"> • color: chocolate brown mud and grey mud and clear brown halite • sedimentary characteristics: large subangular, cubic halite crystals and 10-15% mud • bedding and contacts: no bedding seen • diagenetic features: sylvite veins and dissolution pits
207	666.3-662.3	Missing Core
208	662.3-660	Mixed Bedded and Displacive Halite <ul style="list-style-type: none"> • color: chocolate brown mud and clear brown halite • sedimentary characteristics: crystal size varies and 5-10% mud • bedding and contacts: some bedding from gypsum pseudomorph crystals • diagenetic features: gypsum pseudomorph crystals, dissolution pits filled with halite, and reduction in mud?
209	660-659.5	Bedded Halite <ul style="list-style-type: none"> • color: chocolate brown mud and brown halite • sedimentary characteristics: 5% mud • bedding and contacts: beds defined from crystal size and shape • diagenetic features: pseudomorph gypsum crystals and dissolution pipes filled with halite
210	659.5-658.2	Displacive Halite <ul style="list-style-type: none"> • color: chocolate brown mud and clear brown halite • sedimentary characteristics: 5% mud, large, subangular, displacive halite cubes, few mud drapes • bedding and contacts: no true bedding • diagenetic features: dissolution pipes filled with halite
211	658.2-658	Bedded Halite <ul style="list-style-type: none"> • color: chocolate brown mud and brown clear halite

		<ul style="list-style-type: none"> ● sedimentary characteristics: 5-10% mud and gorgeous salt crystals ● bedding and contacts: evident bedding defined by halite crystal size and shape and sharp contact with unit 210 ● diagenetic features: dissolution pipes filled with halite
212	658-656	Mixed Bedded and Displacive Halite <ul style="list-style-type: none"> ● color: chocolate brown mud and clear brown halite ● sedimentary characteristics: 15% mud, large mud clasts, subangular halite crystals ● bedding and contacts: beds formed from color and crystal shape ● diagenetic features: reduction? in mud
213	656-653.7	Mixed Bedded and Displacive Halite <ul style="list-style-type: none"> ● color: chocolate brown and grey mud ● sedimentary characteristics: large cubic halite crystals and 20-25% mud ● bedding and contacts: evident contact with unit 212 shown by a change of color and appearance of sylvite veins ● diagenetic features: sylvite veins and reduction? in mud
214	653.7-651.4	Mixed Bedded and Displacive Halite <ul style="list-style-type: none"> ● color: chocolate brown and grey mud and clear and brown halite ● sedimentary characteristics: subangular halite crystals and 5% mud ● bedding and contacts: bedding evident from crystal growth and color ● diagenetic features: dissolution pipes filled with clear halite
215	651.4-647.83	Displacive Halite <ul style="list-style-type: none"> ● color: chocolate brown and blue/grey mud and mud becomes more red as you move up section (2.5 YR 3/4) ● sedimentary characteristics: 10% mud, very small mud clasts with rare large mud clasts, large cubic displacive crystals, mud clasts become larger as you move up section ● bedding and contacts: no bedding seen ● diagenetic features: reduction of mud? And dissolution pipes filled with clear halite
216	647.83-646.8	Mixed Bedded and Displacive Halite <ul style="list-style-type: none"> ● color: Gley 2 2.5/5 GB mud and chocolate brown mud ● sedimentary characteristics: 5-10% mud and large cubic halite crystals ● bedding and contacts: beds evident due to crystal growth

		<ul style="list-style-type: none"> • diagenetic features: dissolution pits and little sylvite veins
217	646.8-645.5	<p>Displacive Halite</p> <ul style="list-style-type: none"> • color: chocolate brown mud, brown clear halite, and some areas of grey mud near the bottom of the section • bedding and contacts: no bedding seen • diagenetic features: dissolution pits and sylvite veins
218	645.5-643	<p>Missing Core</p>
219	643-642.3	<p>Displacive Halite</p> <ul style="list-style-type: none"> • color: chocolate brown mud and dark, clear, grey halite • sedimentary characteristics: large halite crystals that are subangular and 10% mud • bedding and contacts: no bedding seen • diagenetic features: dissolution pits and few sylvite veins
220	642.3- 641.7	<p>Mixed Bedded and Displacive Halite</p> <ul style="list-style-type: none"> • color: chocolate brown mud with various spots of reddish brown and brown halite • sedimentary characteristics: bottom growth halite crystals, cubic displacive halite crystals, and 5-10% mud • bedding and contacts: bedding formed from bottom growth crystals and mud • diagenetic features: dissolution pipes and pits filled with halite, sylvite veins
221	641.7-633.5	<p>Displacive Halite</p> <ul style="list-style-type: none"> • color: chocolate brown with grey mud and brown halite • sedimentary characteristics: angular mud clasts, large cubic, displacive halite crystals, mud abundance varies throughout • bedding and contacts: no bedding seen • diagenetic features: dissolution pits filled with clear halite and medium sized sylvite veins as you move up in section
222	633.5-633.16	<p>Displacive Halite that is Mud Rich</p> <ul style="list-style-type: none"> • color: chocolate brown mud and halite dissolved due to lack of plastic • sedimentary characteristics: 50-60% mud

		<ul style="list-style-type: none"> • bedding and contacts: no bedding seen • diagenetic features: large sylvite veins
223	633.16-629.8	<p>Displacive Halite</p> <ul style="list-style-type: none"> • color: chocolate brown with rare grey mud and halite is dark brown • sedimentary characteristics: small mud clasts, rare large mud areas, small halite crystals, mud abundance varies • bedding and contacts: no bedding seen • diagenetic features: sylvite veins and dissolution pits
224	629.8-629.7	<p>Bedded Halite</p> <ul style="list-style-type: none"> • color: clear to pink halite • sedimentary characteristics: very large halite crystals and no mud • bedding and contacts: sharp contact with 223 and 225 and bedding formed from crystal shape
225	629.7-627	<p>Displacive Halite</p> <ul style="list-style-type: none"> • color: same as unit 221 with some added red and brown • sedimentary characteristics: mud clasts, 15-20% mud, and cubic displacive crystals • bedding and contacts: sharp contact with 224 and no bedding seen • diagenetic features: potentially some dissolution pipes and pits
226	627-625.1	<p>Missing Core</p>
227	625.1-604.8	<p>Displacive Halite</p> <ul style="list-style-type: none"> • color: chocolate brown mud and brown halite • sedimentary characteristics: varying amounts of mud, mud clasts, cubic halite crystals, more salt rich at 615.4 m • bedding and contacts: no bedding seen • diagenetic features: dissolution pits filled with halite and mud
228	604.8-604	<p>Mudstone</p> <ul style="list-style-type: none"> • color: chocolate brown and grey mud and brown halite • sedimentary characteristics: rare displacive halite crystals and breaks apart like peds • bedding and contacts: no bedding seen

		<ul style="list-style-type: none"> • diagenetic features: thin to medium thickness sylvite veins and reduction spots?
229	604-581.1	<p>Displacive Halite</p> <ul style="list-style-type: none"> • color: chocolate brown mud and brown halite • sedimentary characteristics: 20-30% mud, cubic displacive halite crystals, subangular mud clasts, and mud varies throughout section • bedding and contacts: no bedding seen • diagenetic features: dissolution pipes are filled with clear halite crystals
230	581.1-569.6	<p>Mudstone</p> <ul style="list-style-type: none"> • color: 2.5 YR 3/2 brown with reddish tint • sedimentary characteristics: 90% mud, medium halite crystals, soil slickenslides • bedding and contacts: no bedding seen • diagenetic features: sylvite veins and color changes to grey in some sections, potential reduction?
231	569.6-502.2	<p>Mudstone</p> <ul style="list-style-type: none"> • color: 2.5 YR 3/2 brown with reddish tint • sedimentary characteristics: 100% mud, soil slickenslides, breaks apart like crumbling peds, root fossil? • bedding and contacts: no bedding seen • diagenetic features: gypsum efflorescence, definite reduction spots, and potential gypsum crystals and vein
232	502.2-501.82	<p>Siltstone</p> <ul style="list-style-type: none"> • color: host rock is 2.5 YR 4/3 and reduction spots are Gley 2 6/10B • sedimentary characteristics: silt sized grains and wavy discontinuous grey lamina • bedding and contacts: gradual contact change with unit 231, grey mud bed that's 6 cm thick • diagenetic features: circular reduction spots
233	501.82-501.28	<p>Siltstone</p> <ul style="list-style-type: none"> • color: grey Gley 1 7/10Y • sedimentary characteristics: silt sized grains and wavy discontinuous red lamina 2.5 YR 4/4 • bedding and contacts: sharp contact with 232 and 234 • diagenetic features: reduction zone?

234	501.28-492.7	Siltstone	<ul style="list-style-type: none"> • color: host rock is 2.5 YR 4/3 and reduction spots are Gley 2 6/10B • sedimentary characteristics: relatively massive, soil slickenslides, ripples? • bedding and contacts: sharp contact with 233 • diagenetic features: reduction spots
235	492.7-491.2	Sandstone	<ul style="list-style-type: none"> • color: Gley 2 8/5 PB • sedimentary characteristics: fine grain quartz grains, ~90% quartz grains, well cemented , massive • bedding and contacts: no bedding seen • diagenetic features: gypsum efflorescence
236	491.2-486.6	Siltstone	<ul style="list-style-type: none"> • color: 10 R 4/6 • sedimentary characteristics: large, rare halite crystals floating in the host rock and massive siltstone • bedding and contacts: no bedding • diagenetic features: reduction spots that are Gley 2 5/10 GB
237	486.6-486.4	Sandstone	<ul style="list-style-type: none"> • color: Gley 2 8/5 PB • sedimentary characteristics: fine grain quartz grains, ~90% quartz grains, well cemented, massive • bedding and contacts: no bedding seen • diagenetic features: gypsum efflorescence
238	486.4-484.8	Siltstone	<ul style="list-style-type: none"> • color: 10 R 4/6 • sedimentary characteristics: soil slickenslides • bedding and contacts: no bedding seen • diagenetic features: reduction spots
239	484.8-484.1	Mudstone	<ul style="list-style-type: none"> • color: Gley 2 5/10 G • sedimentary characteristics: soil slickenslides, breaks apart in sheets • bedding and contacts: no bedding seen

		<ul style="list-style-type: none"> • diagenetic features: reddish color 10 R 3/3 from weathering? And deposited in thin, vertical red sheets in cracks in the core
240	484.1-471	<p>Siltstone</p> <ul style="list-style-type: none"> • color: 10 R 4/6 • sedimentary characteristics: massive and well cemented • bedding and contacts: no bedding seen • diagenetic features: reduction spots with a bullseye pattern and veins filled with a white, non-salty mineral
241	471-469.8	<p>Mudstone</p> <ul style="list-style-type: none"> • color: host rock is Gley 1 3/5 G with a green weathering • sedimentary characteristics: maybe some chlorite? (Gley 1 7/5 GY), same mineral as unit 240, soil slickensides, rare reddish brown specks • bedding and contacts: no bedding seen
242	469.8-467.7	<p>Igneous Rock</p> <ul style="list-style-type: none"> • color: Gley 1 2.5/N and Gley 1 7/N • sedimentary characteristics: stringy black minerals, hornblende? (60%) and white chalk-like mineral (40%) • bedding and contacts: no bedding
243	467.7-467.5	<p>Igneous Rock</p> <ul style="list-style-type: none"> • color: Gley 1 3/N • sedimentary characteristics: greenish black host rock with black lineations, some quartz grains, streaks of brown • bedding and contacts: no bedding
244	467.5-467.4	<p>Mudstone</p> <ul style="list-style-type: none"> • color: 5 YR 4/3 • sedimentary characteristics: round clumps and breaks apart like blocky peds • bedding and contacts: no bedding seen • diagenetic features: reduction spots
245	467.4-464.8	<p>Igneous Rock</p> <ul style="list-style-type: none"> • color: Gley 1 3/N • sedimentary characteristics: greenish black host rock with black lineations, some quartz grains, streaks of brown

		<ul style="list-style-type: none"> • bedding and contacts: no bedding
246	464.8-462.8	<p>Mudstone</p> <ul style="list-style-type: none"> • color: 5 YR 4/3 • sedimentary characteristics: round clumps and breaks apart like blocky peds • bedding and contacts: no bedding seen
247	462.8-456	<p>Igneous Rock</p> <ul style="list-style-type: none"> • color: Gley 1 3/N • sedimentary characteristics: greenish black host rock with black lineations, some quartz grains, and streaks of brown • bedding and contacts: no bedding
248	456-455.7	<p>Mudstone with Igneous Debris Clasts</p> <ul style="list-style-type: none"> • color: 5 YR 4/3 and Gley 1 5/10Y • sedimentary characteristics: mud grades from grey to red, 80-90% mud, 10-20% igneous debris • bedding and contacts: sharp contact with units 247 and 249 • diagenetic features: reduction? in color gradient
249	455.7-454.7	<p>Igneous Rock</p> <ul style="list-style-type: none"> • color: Gley 1 3/N • sedimentary characteristics: greenish black host rock with black lineations, some quartz grains, streaks of brown • bedding and contacts: no bedding
250	454.7-453.8	<p>Mudstone</p> <ul style="list-style-type: none"> • color: 5 YR 4/3 • sedimentary characteristics: 90-95% mud, crumbles, ped-like structure • bedding and contacts: no bedding seen and sharp contact with 249 • diagenetic features: reduction? in mud
251	453.8-452.03	<p>Mudstone</p> <ul style="list-style-type: none"> • color: chocolate brown/red mud and somewhat purple in color • sedimentary characteristics: soil slickensides and very crumbly • bedding and contacts: sharp contact with unit 250 and no bedding seen • diagenetic features: reduction spots in mud

252	452.03-451.87	Mudstone	<ul style="list-style-type: none"> • color: glassy gypsum veins Gley 1 6/10Y, reduction spots Gley 1 7/5 GY, and red mud is 2.5 YR 4/3 • sedimentary characteristics: soil slickensides and well cemented • bedding and contacts: no bedding seen • diagenetic features: large gypsum veins and reduction spots
253	451.87-448.5	Mudstone	<ul style="list-style-type: none"> • color: chocolate brown/red mud and somewhat purple in color • sedimentary characteristics: soil slickensides and very crumbly • bedding and contacts: sharp contact with unit 250 and no bedding seen • diagenetic features: rare gypsum veins
254	448.5-447.8	Mudstone	<ul style="list-style-type: none"> • color: Gley 1 7/10 Y • sedimentary characteristics: soil slickensides, some areas of red coloring, 100% mud • bedding and contacts: sharp contacts with units 253 and 255 and no bedding seen • diagenetic features: reduction? zone and gypsum veins
255	447.8-428.9	Mudstone	<ul style="list-style-type: none"> • color: chocolate brown/red mud and somewhat purple in color • sedimentary characteristics: soil slickensides and very crumbly • bedding and contacts: sharp contact with unit 250 and no bedding seen • diagenetic features: chalky white veins become more common around 444.4 meters
256	428.9-428.2	Mudstone	<ul style="list-style-type: none"> • color: Gley 2 6/5 BG • sedimentary characteristics: well sorted, massive, soil slickensides, breaks apart like peds • bedding and contacts: sharp contact with units 255 and 257 • diagenetic features: gypsum veins
257	428.2-422.2	Mudstone	<ul style="list-style-type: none"> • color: chocolate brown/red mud and somewhat purple in color

		<ul style="list-style-type: none"> ● sedimentary characteristics: soil slickensides and very crumbly ● bedding and contacts: sharp contact with unit 250 and no bedding seen ● diagenetic features: chalky white veins become more common around 444.4 meters
258	422.2-421.63	Mudstone <ul style="list-style-type: none"> ● color: Gley 2 6/5 BG ● sedimentary characteristics: well sorted, massive, soil slickensides, breaks apart like peds ● bedding and contacts: sharp contact with units 255 and 257 ● diagenetic features: gypsum veins
259	421.63-407.5	Mudstone <ul style="list-style-type: none"> ● color: chocolate brown/red mud and somewhat purple in color ● sedimentary characteristics: soil slickensides and very crumbly ● bedding and contacts: sharp contact with unit 250 and no bedding seen ● diagenetic features: gypsum veins are very thick and long
260	407.5-404.6	Siltstone <ul style="list-style-type: none"> ● color: Gley 2 6/5 BG and 5 YR 5/4 ● sedimentary characteristics: well sorted and silt-sized grains ● bedding and contacts: no bedding ● diagenetic features: reduction?
261	404.6-387.24	Mudstone <ul style="list-style-type: none"> ● color: 2.5 YR 4/4 ● sedimentary characteristics: well sorted, very massive, a root feature? ● bedding and contacts: no bedding seen ● diagenetic features: reduction spots
262	387.24-378.4	Mudstone <ul style="list-style-type: none"> ● color: Gley 1 5/5G ● sedimentary characteristics: very massive ● bedding and contacts: no bedding seen and sharp contact with unit 261

Appendix 3: Thin Section Depths

Thin Section Depths	
Sample	Depth (m)
M1	919.1
M2	919.1
M3	871.4
M4	844.4
M5	844.4
M6	844.4
M7	844.4
M8	844.4
M9	486.6
M10	441.8
M11	965.9
M12	764
M13	943.9
M14	590.5
M15	966.2
M16	887
M17	802.4
M18	802.5
M19	448.5
M20	629.7
M21	413.45
M22	504.25
M23	901.6
M24	647.6
M25	919.1
M26	906.1
M27	906.2
M28	582.6
M29	843.2
M30	843.3
M31	844.5
M32	844.6
M33	844.7

Appendix 4: Billet photos

Appendix 5: Konica Minolta Chroma Meter Data

Konica Minolta Chroma Meter CR-400						
Depth (m)	Lithology	Color		Depth (m)	Lithology	Color
844.4	red mudstone	5.2YR 4.1/2.7		963.6	red mudstone	5.8YR 3.9/3.1
	displacive halite	5.4YR 3.4/1.7			gray mudstone	2.0Y 5.0/1.8
927.9	bedded gypsum	9.4YR 3.8/1.2		906.1	bedded gypsum	9.1YR 3.3/0.9
	gray mud	0.7Y 5.0/1.1			bedded halite	8.3YR 3.1/0.4
716.8	halite	5.1YR 2.7/0.5		841.2	bedded gypsum	7.1YR 3.5/1.3
					red mudstone	6.7YR 5.1/2.9
723.7	red mudstone	5.7YR 4.5/3.8			sylvite vein	4.7YR 5.1/4.1
965.17	red mudstone	5.9YR 3.9/3.1		489.3	siltstone	4.3YR 3.4/3.4
	sylvite vein	5.4YR 5.8/3.9				
				964.2	red mudstone	5.4YR 4.2/3.1
805.8	bedded gypsum	7.6YR 3.3/1.0				
				911.3	gray mudstone	3.5Y 5.6/0.9
846.1	halite	8.2YR 3.6/1.1			evaporite	3.8YR 3.3/1.4
965.2	siltstone	6.9YR 4.9/3.5		549.7	gray mudstone	4.3Y 4.9/1.2
814.4	red mudstone	5.6YR 3.6/2.1		928.5	blocky halite cement	9.2YR 4.5/0.6
	gray mudstone	2.7Y 4.1/1.0			bedded gypsum	5.8YR 3.0/0.9