2018

Salt Tectonism In The Carolina Trough

Ceren Postaagasi
University of South Carolina

SALT TECTONISM IN THE CAROLINA TROUGH

by

Ceren Postaagasi

Bachelor of Geophysical Engineering
Dokuz Eylul University, 2012

Submitted in Partial Fulfillment of the Requirements

For the Degree of Master of Science in

Geological Sciences

College of Arts and Sciences

University of South Carolina

2018

Accepted by:

James H. Knapp, Director of Thesis

Camelia C. Knapp, Reader

Andrew Leier, Reader

Cheryl L. Addy, Vice Provost and Dean of the Graduate School

ACKNOWLEDGEMENTS

First, I would like to thank you my advisor, Dr. James H. Knapp, whose admission to work with him gave me an opportunity to do Master's in the United States of America, and he always supported me in my journey. His expertise helped me through the interpreting and writing process of my thesis. A very special thanks to my committee members, Dr. Camelia C. Knapp and Andrew Leier who shared their experiences and supports, both through courses and thesis work. I took a different approach with their guidance that helped my thesis was formed. Their advices are always precious for me. Special acknowledgement is made to all professors in the School of the earth, Ocean and Environment in the USC. I gained experience about understanding the complex earth thanks to them. A special thanks to Turkish Petroleum to give me both moral and material support.

I would like to convey my warmest appreciation to my husband, Ahmet Postaagasi whose support is invaluable for me. I would like to thank my lab mates who always helped me whenever I need. Thanks my friends for giving me support throughout my time at the USC. When I move from the USA to go to Turkey, I know that I leave my family behind.

ABSTRACT

The Carolina Trough is a major linear sedimentary basin along the eastern continental margin of North America which formed as a result of tectonic and thermal subsidence during continental rifting in Mesozoic time (Hutchinson et al., 1982). The Carolina Trough is unique along the southeastern U.S. margin where the only known evaporite deposits are found, and this salt basin may reserve large amounts of oil and gas (Carpenter & Amato, 1992). Therefore, analysis of 2D multichannel seismic reflection surveys that were conducted in the Mid-South Atlantic Ocean in 1982 plays an important role in Petroleum industry. In addition, current interpretations of the distribution of salt structures in the Carolina Trough suggest that evaporites were deposited on oceanic rather than thinned continental lithosphere.

The aims of this study are to (1) map the salt structures in the Carolina Trough, (2) potentially place new constraints on the age and setting of evaporite deposition, and (3) re-evaluate timing and mechanism of salt structure development based on interpretation of previously proprietary 2D seismic reflection data released by the Bureau of Ocean Energy Management (formerly MMS and USGS). A total of 120 seismic reflection profiles from Marine Seismic Survey B-02-82-AT Depth and 7 seismic reflection profiles from Marine Seismic Survey B-04-82-AT were interpreted by using PETREL E&P Software Platform Version 2015. We suggest that the presence of the salt diapirs at the seaward side of the Carolina Trough, below the base of the continental slope, is evidence either that (1) salt migrated downdip during salt tectonism, (2) salt was deposited on oceanic crust on the

abyssal plain, or (3) continental crust extends beyond the base of the continental slope. Based on regional correlation of well data, the source interval for the salt appears to be of Upper Jurassic age.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Salt Domes have been known as “white gold” and mined for millennium in some areas such as arid coasts of the Red Sea and the Persian Gulf (Jackson, 1995). Therefore, this research is focused on the structures of salt domes, found on the seaward side of the Carolina Trough (Figure 1.1). At least 26 salt domes may occur in a narrow band in 450km long and 40km wide Carolina Trough (Dillon et al, 1983). Carolina Trough, located offshore of the Carolina Platform, is one of the deep sedimentary basins along the Atlantic continental margin (Trehu et al., 1989). The boundary of the trough to the east is by the position of the East Coast Magnetic anomaly (ECMA), and it overlies the outer shelf, slope and upper rise (Hutchinson et al., 1982). According to Hutchinson et al. (1982), the basement depths on the Carolina trough reach 11km, whereas the depth to the post rift unconformity are (basement) 12 km on the Carolina trough (Dillon et al., 1983). In this study, by using multichannel seismic reflection data, we have examined salt structures and tectonism in the continental margin basin off eastern North America, Carolina Trough.

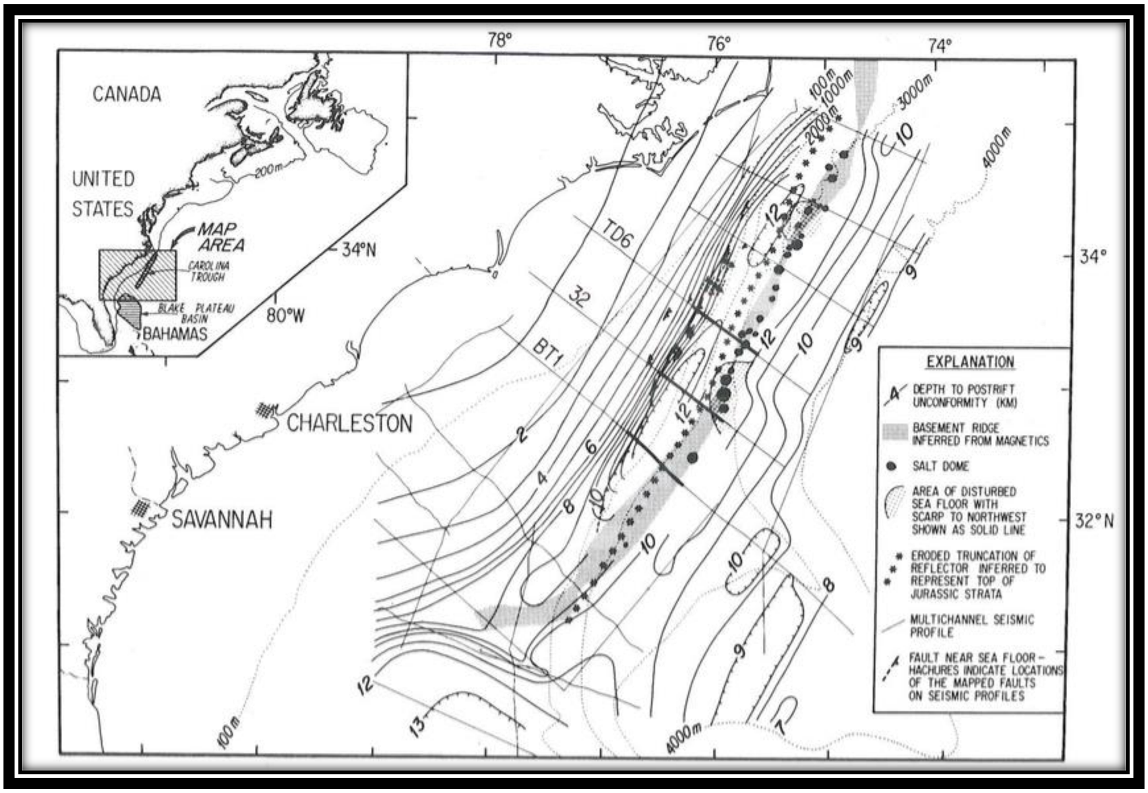

Figure 1.1 Location of Diapirs in the Carolina Trough (Taken from Dillon et al., 1983)

CHAPTER 2

GEOLOGIC SETTING

The Breakup of Pangea started with rifting between Laurasia and Gondwana during Triassic (Figure 2.1), and North America separated from Africa with the expanding Atlantic Ocean by the end of the Triassic (Wicander & Monroe, 2004, p.257).

An idealized cross section of the Carolina Trough is shown in Figure 2.2. The Carolina Trough was formed by Triassic-Early Jurassic rifting and stretching of continental crust, and subsidence of the Carolina Trough during Jurassic ended up with salt loading, and salt started to flow seaward and rise into diapirs (Figure 2.3) (Dillon et al., 1983). The overlying block of sedimentary rock subsided by continual removal of the salt from the main part of the basin, and this action formed a growth fault (Dillon et al., 1983). Figure 1.1 shows a major fault system along the northwestern side of the basin and a linear group of salt domes on tits southeastern side.

Basement deepens steeply at the hinge zone, and it is obscured beneath the post rift unconformity that flattens at a depth of about 12 km (Trehu et al., 1989). This unconformity is developed by beveling of the rifted blocks and the graben deposits, and then basaltic flows spread across part of the Carolina Platform (Dillon et al., 1983). A volcanic layer that covers post-rift unconformity (break-up unconformity) is apparently onlapped by the sedimentary section (Dillon et al., 1979). In addition, seaward of the volcanic layer, Triassic or Paleozoic rocks are cut on by older strata onlap across an angular unconformity (Dillon, 1983).

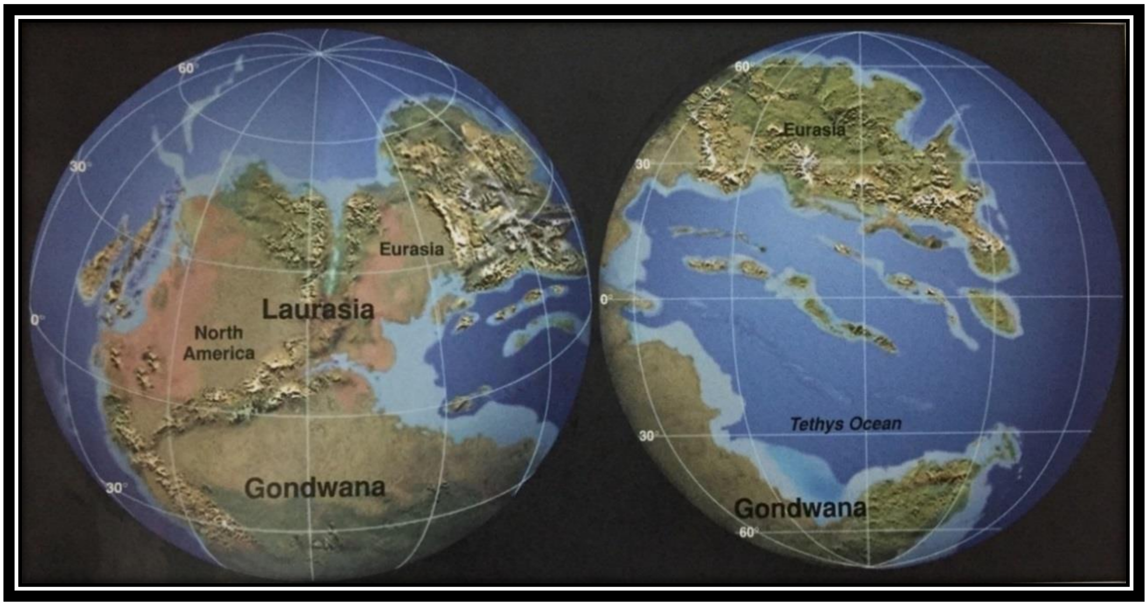

Figure 2.1 Paleogeography of the world (Mesozoic) (Wicander & Monroe, 2004, p.257).

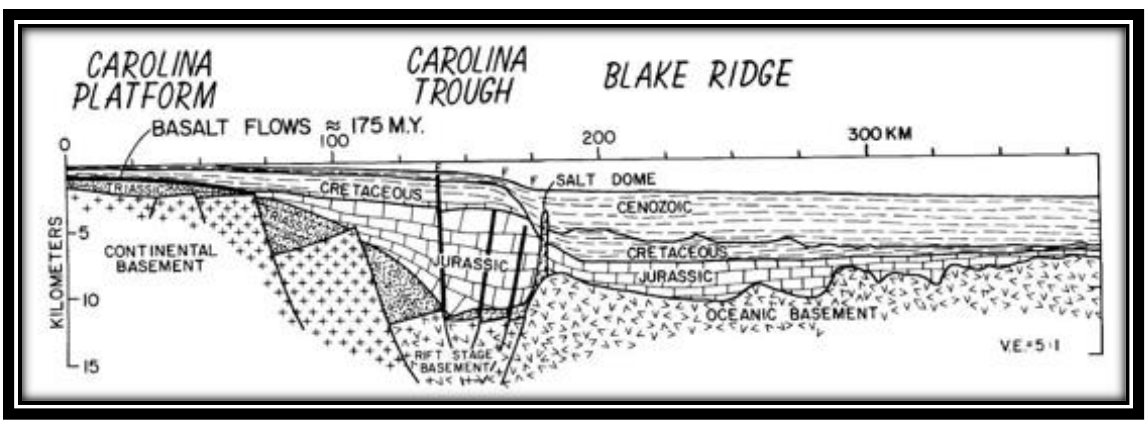

Figure 2.2 Cross section of the Carolina Trough (Taken from Dillon et al., 1983).

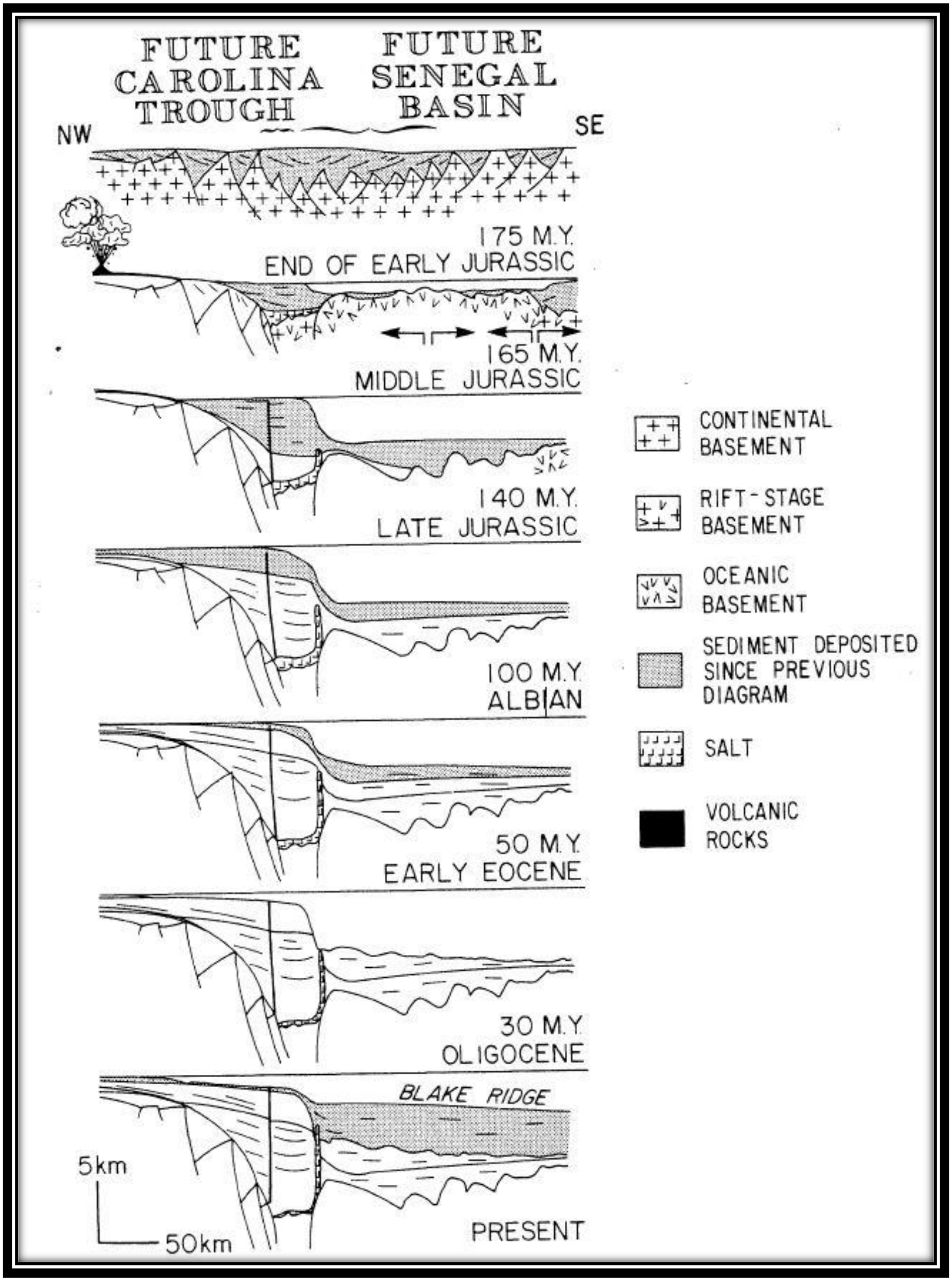

Figure 2.3 Geologic history of the Carolina Trough (Taken from Dillon et al., 1983).

CHAPTER 3

STUDY AREA AND DATASET

The Carolina Trough (Figure 3.1), which are the focus of this research, is bounded to the north by the Baltimore Canyon trough, to the south by the Blake Plateau basin, and to the west by the Carolina platform (Hutchinson et al., 1982).

The 2D Multichannel seismic reflection surveys that we used to determine features of salt domes in Carolina Trough were obtained commercially by the Bureau of Ocean Energy Management (formerly MMS and USGS) for geophysical and geological (G&G) exploration of oil and gas prospects on the U.S. Outer Continental Shelf. Public access can be available after 25 years later the issuance of the exploration permit.

2 Marine Seismic Surveys (B-02-82-AT Depth and B-04-82-AT Depth), had been conducted from Jan 1,1982 to Jan 31,1982 in the Atlantic Ocean, are analyzed in this study to understand structure of salt domes. The Survey that is called B-02-82-AT (Figure 3.2) is consist of 385 track lines, and its distance shot is 17,960 km. B-04-82-AT (Figure 3.3) has 43 track lines, and its distance shot 4,211km. The North American Datum 1983 (NAD83) was used as datum for the B-02-82-AT and, the World Geodetic System 1984 (WGS84) was used for B-04-82-AT as datum (The National Archive of Marine Seismic Surveys, USGS).

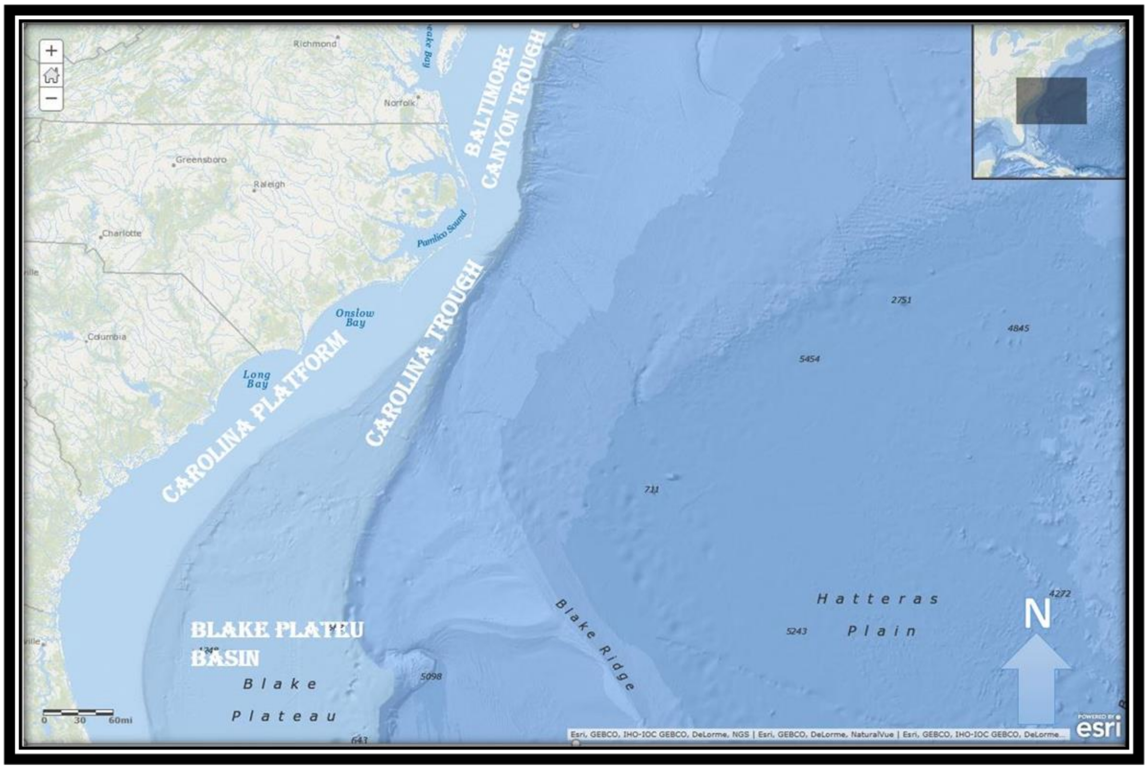

Figure 3.1 Location and Boundary of the Carolina Trough.

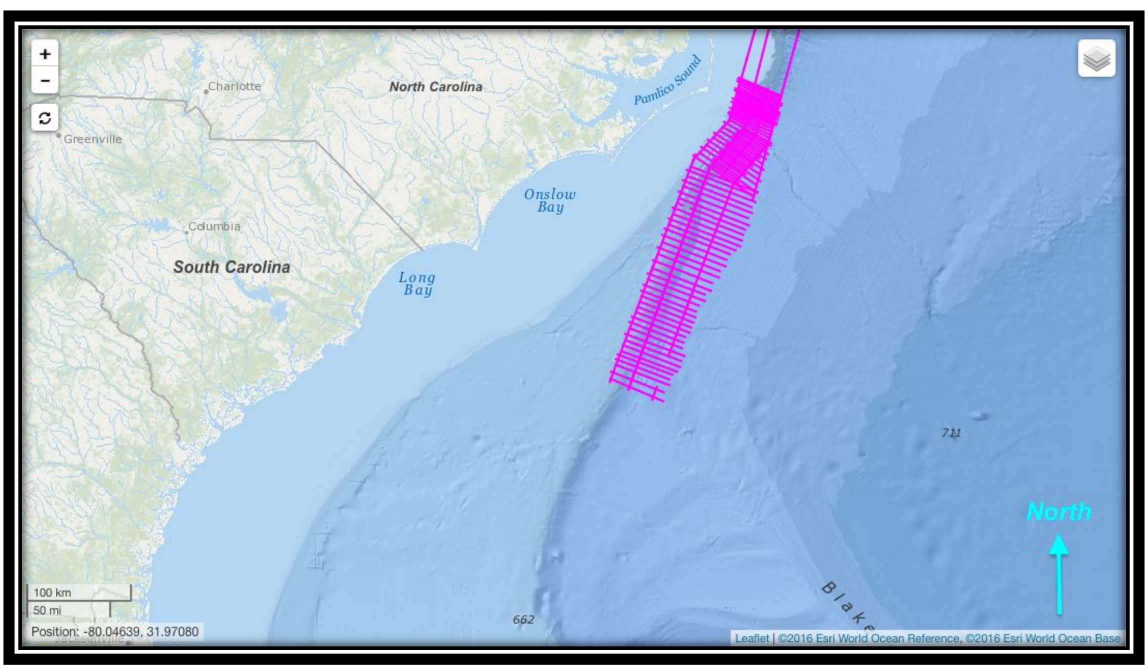

Figure 3.2 Seismic lines from B-02-82-AT survey are located in the Carolina Trough (Taken from USGS, The National Archive of Marine Seismic Surveys).

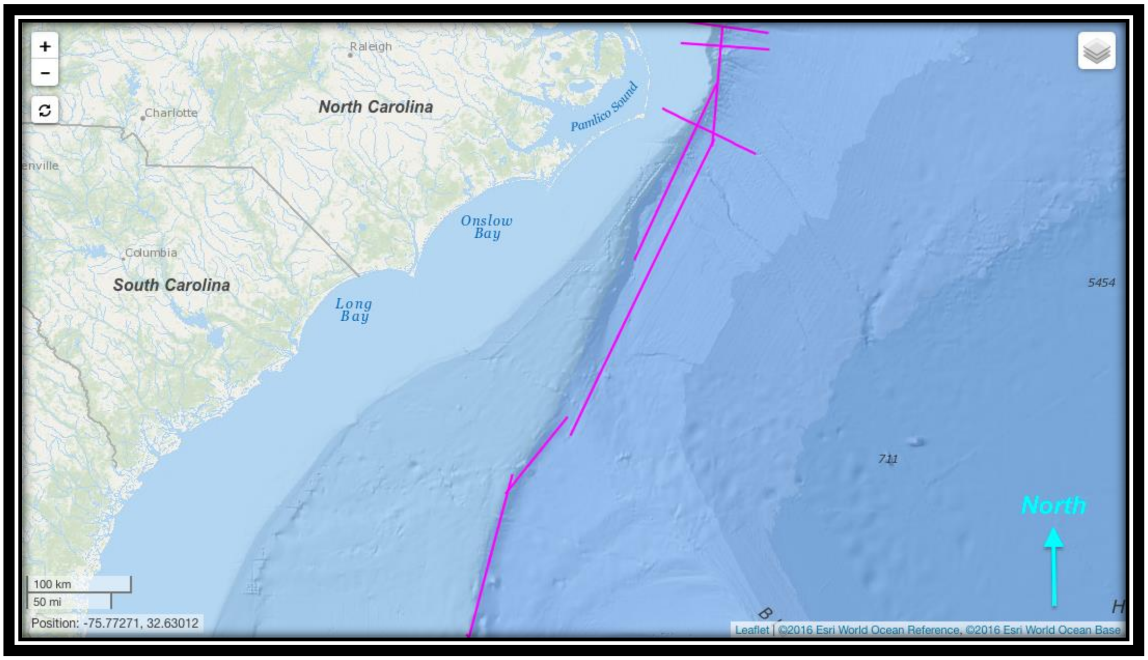

Figure 3.3 Seismic lines from B-04-82-AT survey are located in the Carolina Trough (Taken from USGS, The National Archive of Marine Seismic Surveys).

CHAPTER 4

HYPOTHESIS AND OBSERVATIONS

First, it is important point of this research is that salt deposits have been formed in tectonic basin, a rift basin (Figure 4.1), and this basin is likely to display rapid sea level changes due to repetitive tide and evaporation (Figure 4.2). Therefore, the shallow water evaporated rapidly, and its salt content precipitated in the rifting stage (Setterfield, 2015).

A shallow sea forms in the rift basin (Almutury &Al-Asadi, 2008). Thus, it is most likely to see rapid sea level change in the eastern margin of the North America in the rifting stage due to repetitive tide and rapid sea level evaporation. In addition, Dillon et al. (1983) state that the basins that have greater thinning of basement would have precipitated below sea level sooner. Thus, oceanic waters are received for a long time to terminate salt deposition. Furthermore, Carolina Trough and Scotian Basin, have extensive salt domes off eastern North America, have greater thinning of basement on account of greater thinning by stretching during the rifting stage, and being exposed a longer period of time is likely to cause accumulation of thicker salt layers on these early-subsiding basins (Dillon et al, 1983).

Although the age of evaporites has not been distinct, Poag (1991) proposed that salt was deposited during part of Middle Jurassic whereas the salt is inferred to be Early Jurassic age according to Dillon et al. (1983). I am positive that salt deposits have been formed in the rift basin, shallow water environment, probably during rifting (syn-rift).

However, the timing of breakup is still equivocal in the southeastern United States, and the ages of postrift rocks are unknown (Poag, 1991; Withjack et al., 1998).

The goal of this research to elucidate that continental rifting led to deposited salts at the base of continental slope on is evidence either that (1) salt migrated downdip during salt tectonism, (2) salt was deposited on oceanic crust on the abyssal plain, or (3) continental crust extends beyond the base of the continental slope.

Basing on Dillon et al. (1983) and Hutchinson et al. (1982), it is possible to suggest that evaporites appear to start to flow seaward and to rise as a dome shape after it was loaded by sediments due to differential loading and elevation differences due to tilting.

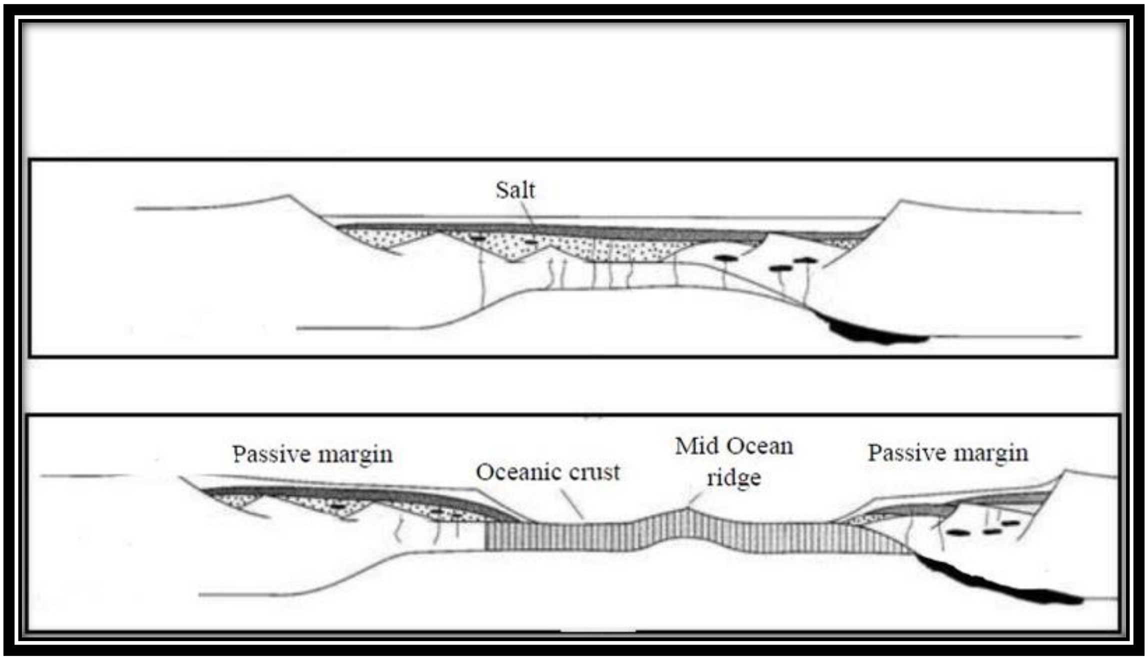

Figure 4.1 Opening tectonic phase (modified from Almutury &Al-Asadi, 2008).

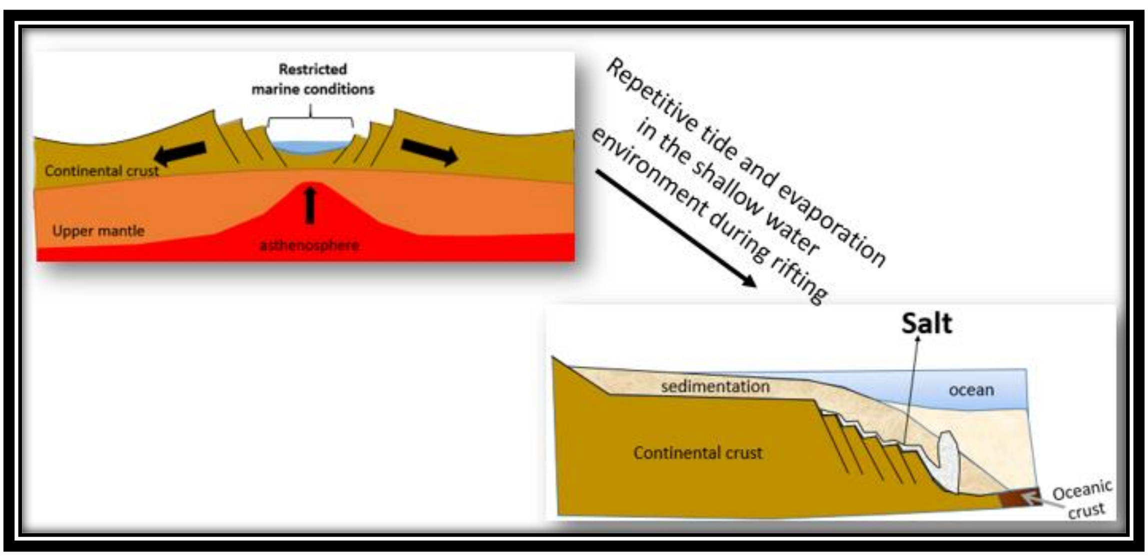

Figure 4.2 Illustration of the rifting stages and salt deposition in the Carolina Trough.

CHAPTER 5

DISCUSSION

The interpretation of this seismic reflection study indicates that there are more than 19 salt domes lay on an approximately 235 km long straight line in the Carolina Trough (Figure 5.1). These diapirs are seen on the narrow band along the East Coast anomaly (ECMA) (Figure 5.2). According to Grow et al. (1977), the diapirs are not the source of the anomaly; these diapirs do not have any noticeable gravity or magnetic signature. In addition, salt domes appear to be on the ECMA as a coincidence (Talwani et al., 1995, p.155).

Reflection pattern of the typical oceanic basement described by hyperbolic echoes whereas flat reflection horizons are seen towards the margin (Talwani et al., 1995, p.160). Seismic reflection profile on which we interpret diapirs show flat pattern. Therefore, salt diapirs in the Carolina Trough appear to be on the continental crust extends beyond the continental slope. Change in echo character is given in Figure 5.3 as “the landward limit of oceanic basement.

Mobile shale sometimes can be interpreted as a salt diapir due to their diapiric shape. However, there are some criteria to distinguish salt and mobile shale (Figure 5.4). Firstly, salt contacts and mobile shale contacts have different reflectivity; mobile shale has no reflective top whereas salt diapir has highly reflective top (Jackson & Hudec, 2017, p.394). Secondly, the reflections beneath the shale is displayed well while no clear reflections are seen below salt (Jackson & Hudec, 2017, p.391). Thirdly, subvertical

fracture feeds mud volcanoes (Jackson & Hudec, 2017, p. 391). Finally, mud volcanoes erupt episodically, their shape thus can look like “Christmas tree”, but salt does not show episodic behavior; salt stop moving if the source is exhausted or salt is below a strong roof (Jackson & Hudec, 2017, p.391).

There are some control mechanisms on salt flow, and these mechanisms can be explained with differential loading. In the continental margin, it is seen as a combination of dipping salt and varying thicknesses of overburden layers (Fossen, 2010, p. 381). Therefore, it is likely that this differential subsidence can initiate the diapir activity, and salt can start to flow seaward and rise as a diapir (Example of this diapir is given in Figure 5.5 and location map of the interpreted line is given in Figure 5.6). Before salt flow, the salt is approximately stratiform (Jackson & Talbot, 1986). This flow is likely to create feeder layer in the Carolina Trough. Even though our wells controls are far away from the study area, it is likely to say that the source interval for the salt appears to be of Upper Jurassic age., basing on the high amplitude their feeder layer and regional correlation of well data. Transco 1005-1, COST GE-1 and Exxon 564 were used for well correlation. Likely, Grow & Markl (1977) proposed that the diapirs appears in the IPOD/USGS line can initiate in the deep Jurassic or Lower Cretaceous sedimentary rocks. Moreover, in the Bahama basin, a few Late Jurassic domed feature have been interpreted as salt structure (Ball et al., 1968; Sheridan, 1981; Poag, 1991).

The seismic horizon 2 is picking to understand intrusion of the diapirs. We can comment roughly about the age of horizon 2 even though our wells controls are far away from our study area. It is likely to say that horizon 2 probably separate Cenozoic age sediments from Cretaceous at the continental slope. When the position of the seismic

horizon 2 is checked regarding to seafloor, it outcrops in some parts of the Carolina Trough (especially near the Cape Lookout). Diapirs generally show up at the base of the continental slope, and rise until horizon 2. Therefore, their intrusions seem clearly on the horizon 2 (Figure 5.7). Moreover, two diapirs deforms the sea surface topography (Figure 5.8). These two diapirs, on the Seismic line PR82-X233D-D and PR82-X233A-D (Figure 5.9) are named as a Salt 1 and Salt 2 respectly whose intrusion cause deformation of the sea floor (Figure 5.10).

The USGS Line 32 is a popular line that is interpreted by Hutchinson et al. (1982); Dillon et al. (1983) and Trehu et al. (1989). According to Hutchinson et al. (1982), the Jurassic Lower Cretaceous shelf edge was covered by a thicker Tertiary wedge covers in line 32 (Figure 5.11 shows location of line 32). Furthermore, Hutchinson et al. (1982) propose that salt diapirs arise in the deep Jurassic sediments. Figure 5.12 shows line 32 and its interpretation by Dillon et al. (1983).

USGS line 32 in our data and the line PR82-X268-D that cut the USGS Line 32, were interpreted and compared with alternative interpretation of line 32. Figure 5.13 shows these seismic lines; white line represents PR82-X268-D and yellow line represents USGS LINE 32.

Salt intrusion seems clearly (Figure 5.14). Furthermore, it is possible to identify Jurassic-Lower Cretaceous Shelf edge in this line. Some growth faults can be identified landward side of the Trough. Moreover, Dillon et al. (1983) suggested a strong relationship between the main growth fault and the salt diapirs.

It is possible to see same salt intrusion on the PR82-X268-D (Figure 5.15). This salt could be either a part of salt diapirs that is depicted on the line 32 (Figure 5.14) or it

could be an incipient salt diapir adjacent salt dome on the line 32. Also, some stretch faults can be identified on the top of the salt dome as given in Figure 5.15. When we are looking at closely this salt diapir, some fundamental characteristic of salt diapirs can be identified. They are onlap of deep strata against the diapirs and an overturned collar around the shoulders of the diapirs (Figure 5.15). Furthermore, Jackson (1995) proposed that a diapir stops rising if its roof becomes too thick. Therefore, when their morphologies are checked on this seismic line, it is likely to say that they are not in the “brittle era”, they are probably in the “fluid era”. Likewise, Dillon et al. (1983) suggest that the flow of salt has still continued for a long time, and the seafloor in an area of active sedimentation is deformed by present activation of salt diapirs.

Some faults are identified landward side and top of the salt dome on seismic line PR82-X268-D. Likely, Dillon et al. (1983) marked a presence of a growth fault on their research and they maintain a strong relationship between the morphology of the Carolina Through and the location of the main growth fault and the salt diapirs, and they propose that seaward migration of salt can form a growth fault. Furthermore, the argument presented by Dillon et al. (1983) points out these faults that is landward side of the Carolina Trough on our seismic can be growth faults.

North part of the Carolina Trough, some incipient salt diapirs are seen on the 2 different seismic lines. Figure 5.16 represents location of these seismic lines PR82-221-D (80 km long) and PR82-X241-D (90 km long) from survey B-02-82-AT. Figure 5.17 and Figure 5.18 give information about appearance of salt diapirs and growth faults in the Carolina Trough.

Salt diapirs are represented with red colors in this interpretation in Figure 5.17. When their morphologies were checked on this seismic lines, it is likely to say that these diapirs are not mature. They are probably in fluid era. When we examine these diapirs in terms of stage of diapirism, the salt dome, on the left-hand side, in the mound stage (pillow stage) and the diapir, on the right-hand side, in the dome stage (diapir stage).

Diapirs are so minimal as given in the Figure 5.18, and they are probably in the mound stage. Furthermore, presence of growth faults can be easily identified, and an antithetic fault and rollover anticline can be identified as accompanied structures adjacent growth faults on PR82-221-D. Also, some stretch faults develop at the top of the salt on PR82-221-D as given in Figure 5.18.

We have some constraints while Salt is being interpreted in 2D data since we couldn't see diapirs in different aspect unlikely their appearance in 3D dataset. Some diapirs are cut by 2 or more seismic line whereas only one seismic line passes through some salts. A diapir, named salt 1, the biggest salt in the Carolina Trough, cut by 2 seismic lines (Figure 5.19), and its appearances in different aspects are given in Figure 5.20 and Figure 5.21. Salt 1 has risen diapirically from depth of 6250 ms to 2750 ms. Its bulb width is about 9 km in NW-SE direction while approximately 7 km in SW-NE direction. Its stem appears in only one seismic lines and it is about 2 km in width.

When we analyze diapirs in our dataset in terms of types of salt structures, they generally appear as salt anticlines and salt stocks (Figure 5.22). Salt anticlines are immature salt structures, and salt stocks are result of diapiric intrusion (Jackson & Talbot, 1986). When we look at the salt in 3D window, it is likely to say that it is a salt stock shape. Salt stocks can appear in conical or barrel shapes, and its top may swell sideway to form "bulb"

on a stem (Jackson & Talbot, 1986). Their bulb and root sometimes can be seen, but their stems cannot be seen in some seismic lines. This may lead to misinterpretation due to constraints in 2D data, and its shape looks like a detached salt stock because it is hard to distinguish detached salt from salt stock that has wide bulbs and narrow stem. However, it cannot be a detached salt stock, when we look at closely stem part, we can see deformed in the seismic horizon, we can understand that it is a salt stock. Also, stocks may have stems much more narrow than is commonly envisaged due to viscosity contrast between salt and its cover (Jackson & Talbot, 1986). Therefore, we cannot see it in the seismic image. Salt 5, the second biggest salt in the Carolina Trough, can be a good example. Salt 5 cut by 4 different seismic lines (Figure 5.23). We couldn’t see stem; we can see only its bulb in the seismic line PR82-X233A-D (Figure 5.24) and 28034-D (Figure 5.25). However, we can see stem in the PR82-X256-D and PR82-X255-D. The bulb of the salt 5 is about 6 km in width in NE-SW direction, and its width is approximately 3 km in NW-SE direction. Its stem is about 1.8 km in width in NW-SE direction, but we couldn’t see stem in the NE-SW direction.

In addition to Carolina Trough, salt may have accumulated in also Scotian Basin, Georges Bank Basin, Blake Plateau and Baltimore Canyon trough (Poag, 1978). Salt diapirs in the Baltimore Canyon Trough can be good example to compare with salts in the Carolina Trough because the southern Baltimore Canyon Trough is similar to the Carolina Trough in terms of the separation from Africa (Grow & Sheridan, 1981). 8 salt diapirs were observed in the Baltimore Canyon trough off New Jersey and under the continental slope off North Carolina (Grow & Markl, 1977; Grow et al., 1977; Poag, 1978). Salt diapirs in the Baltimore Canyon Trough are located near the ECMA, likely salt diapirs in the Carolina

Trough. Linear chains of Salt diapirs have been found both in the Carolina Trough and Baltimore Canyon Trough (Grow & Sheridan, 1981). However, the number of salt diapirs in the Carolina Trough are more compared to the number of diapiric structure along the Carolina Trough (Grow & Markl, 1977; Dillon et al., 1983). According to Grow & Sheridan (1981), 3 diapirs along the ECMA is located in the Baltimore Canyon Trough. A salt diapir interpreted as a shallow salt diapir by Grow et al. (1988) in the Baltimore Canyon Trough comes from same depth (approximately 6.5 s) with the biggest salt diapir (salt 1) in the Carolina Trough (Figure 5.26). Also, sedimentation thickness on the top of this salt is almost same with salt 1. However, the age of salt is interpreted as older than upper Jurassic although both diapirs come from same depth. When we checked salt diapirs that are shown in models created by Miller et al. (2014) and Grow & Sheridan (1988) in the Baltimore Canyon Trough, their structures look like cylindrical diapirs like salts in Figure 5.17 and, they do not have bulbs like mushroom diapirs, unlikely salt 1 and salt 5. Also, their roofs are not thick, unlikely salt canopy. However, salt diapirs in the Baltimore Canyon Trough form in the Landward side and seaward side of the trough (Figure 5.27). According to updated model given in Figure 5.27, thick salt is seen under the continental slope. However, it is likely to say that it is not expected to see such a thick salt layer in this region.

When the spatial order of the salt diapirs in the Carolina Trough is checked, it is likely to say that the mature salt diapirs are generally seen in the South of the Carolina Trough.

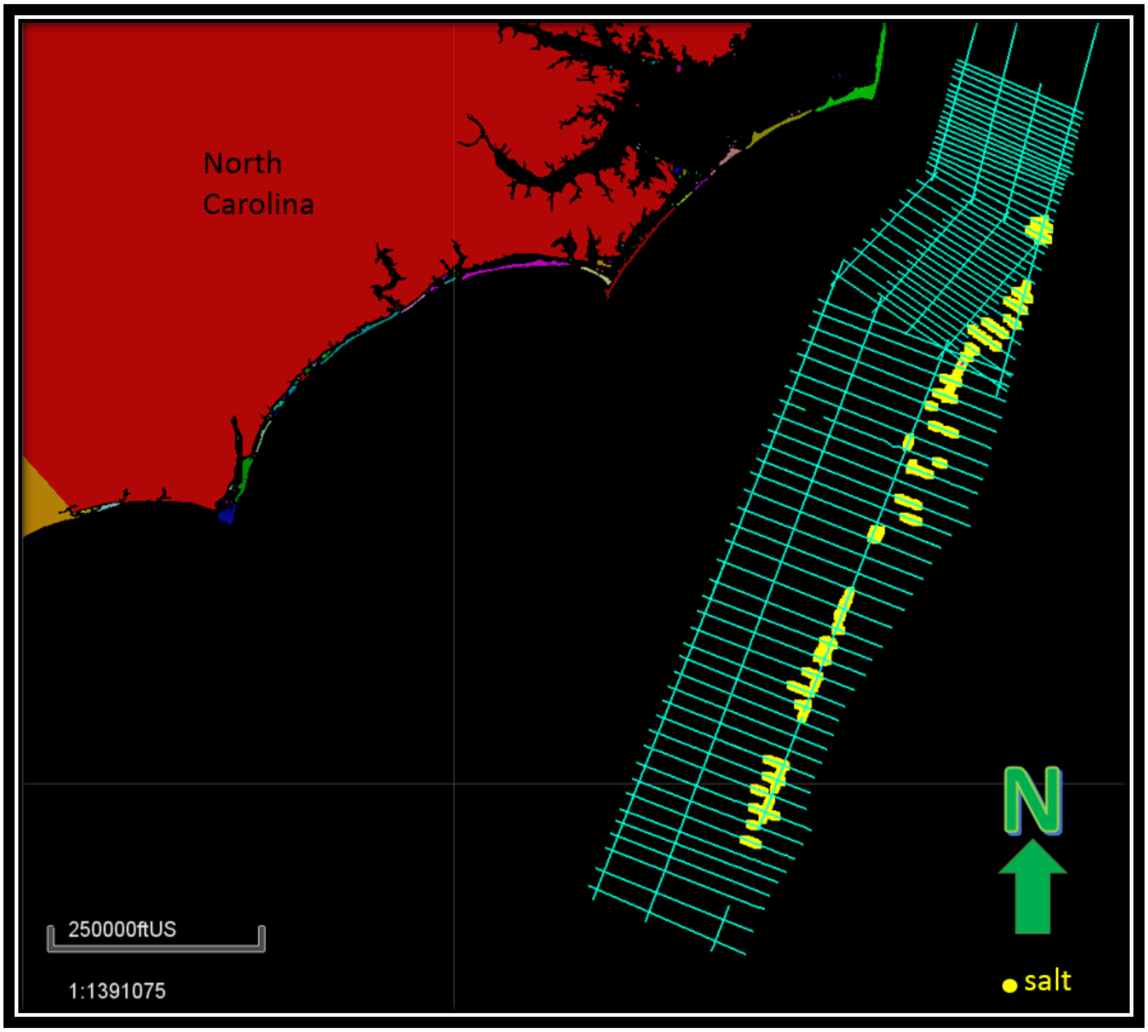

Figure 5.1 Salt domes in the Carolina Trough.

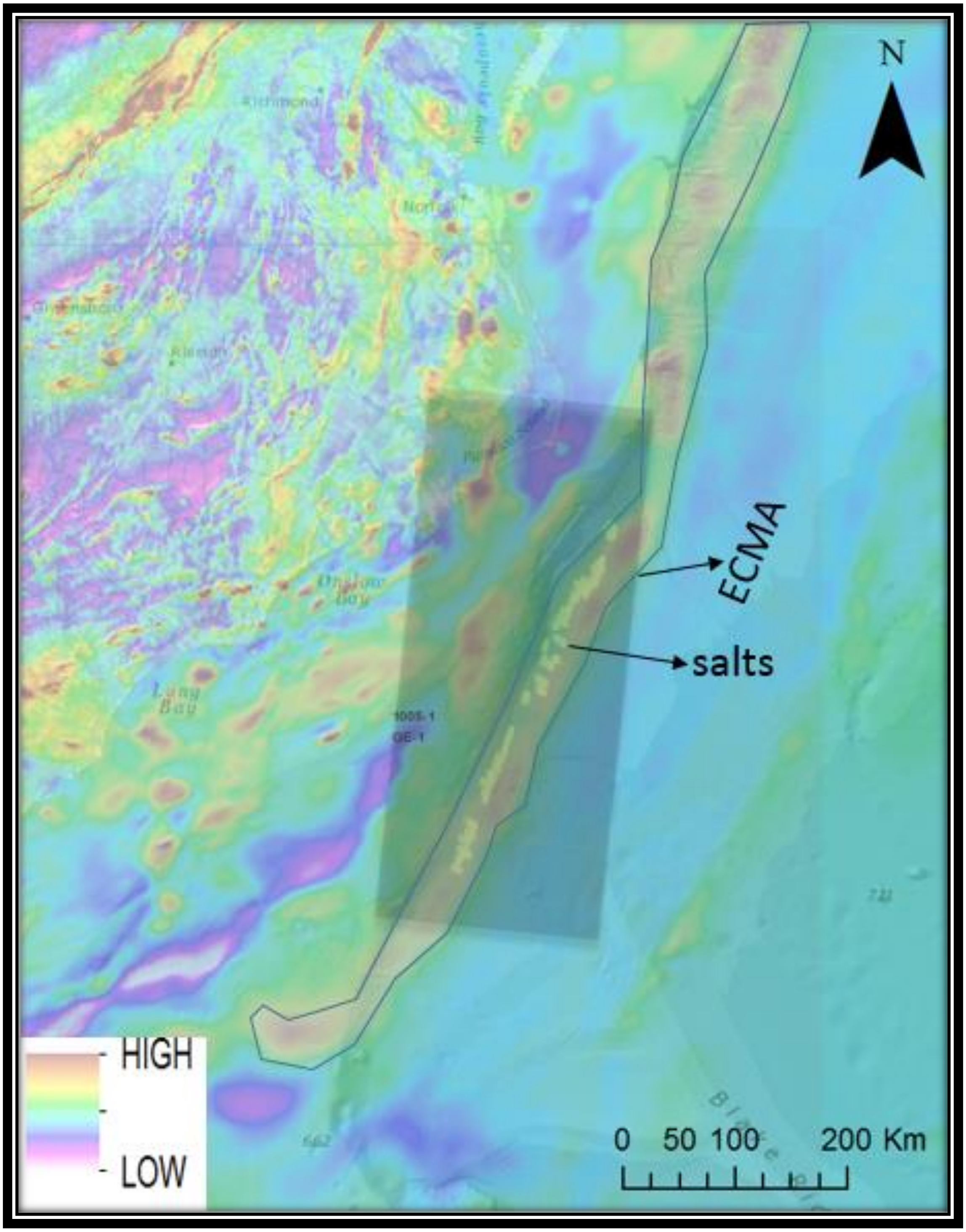

Figure 5.2 Appearance of salt domes on the magnetic map.

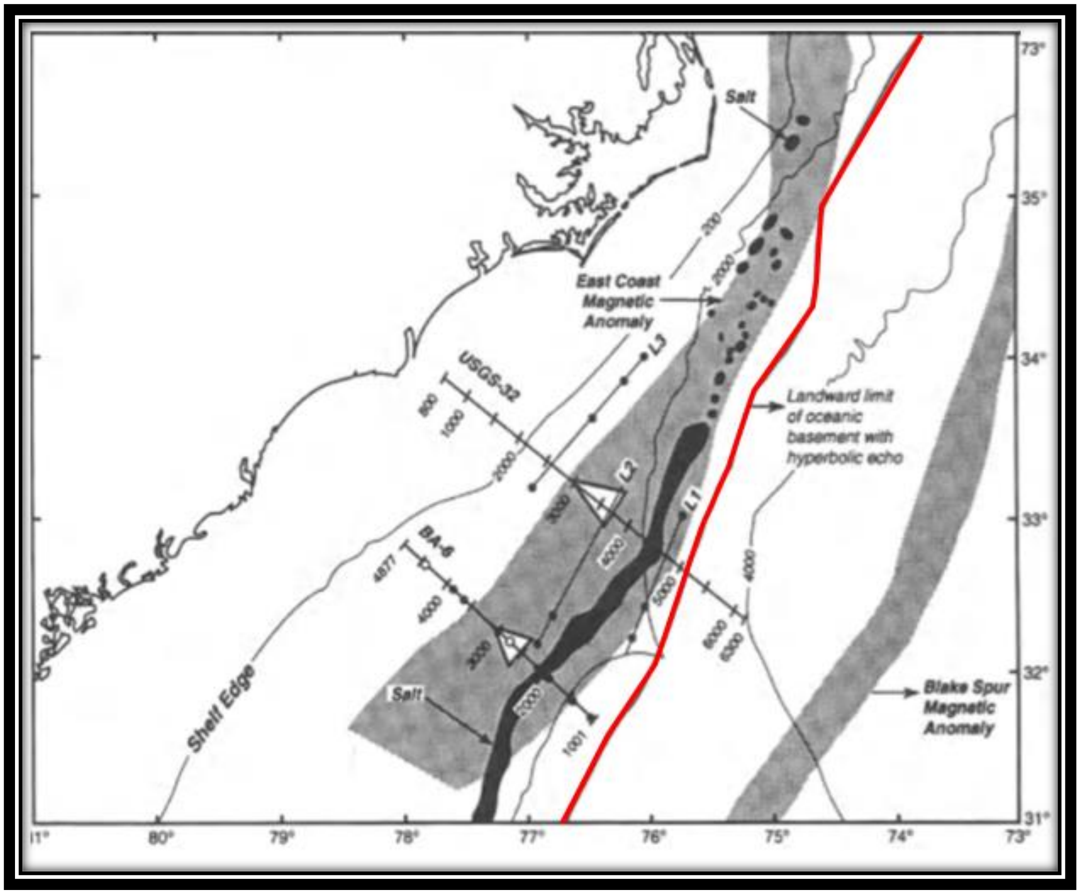

Figure 5.3 Location of the Landward limit of oceanic basement with hyperbolic echo (Modified from Talwani et al., 1995, p.158).

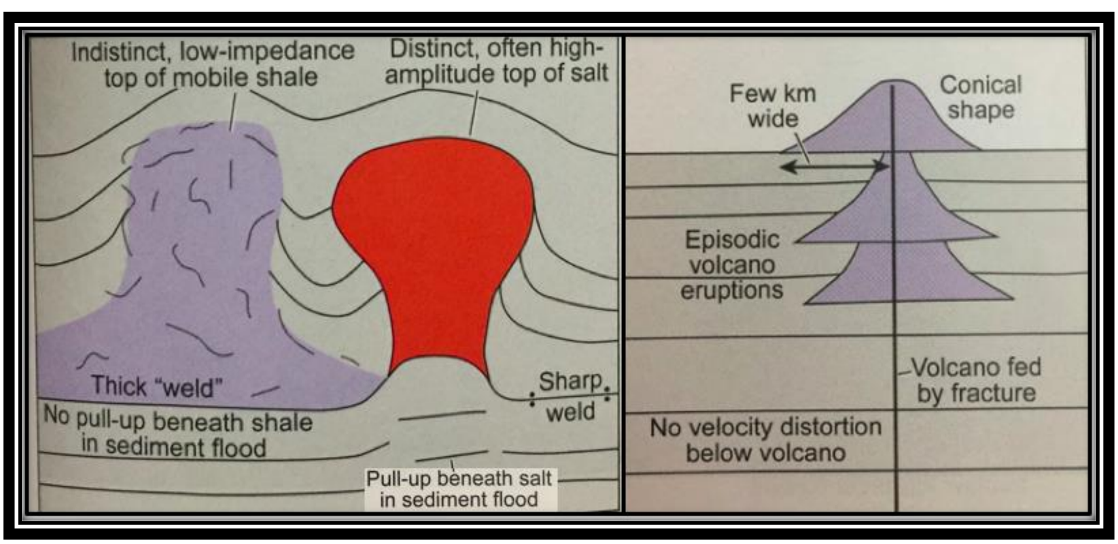

Figure 5.4 Geologic and Geophysical Criteria to distinguish Salt and Shale (Jackson & Hudec, 2017, p.393).

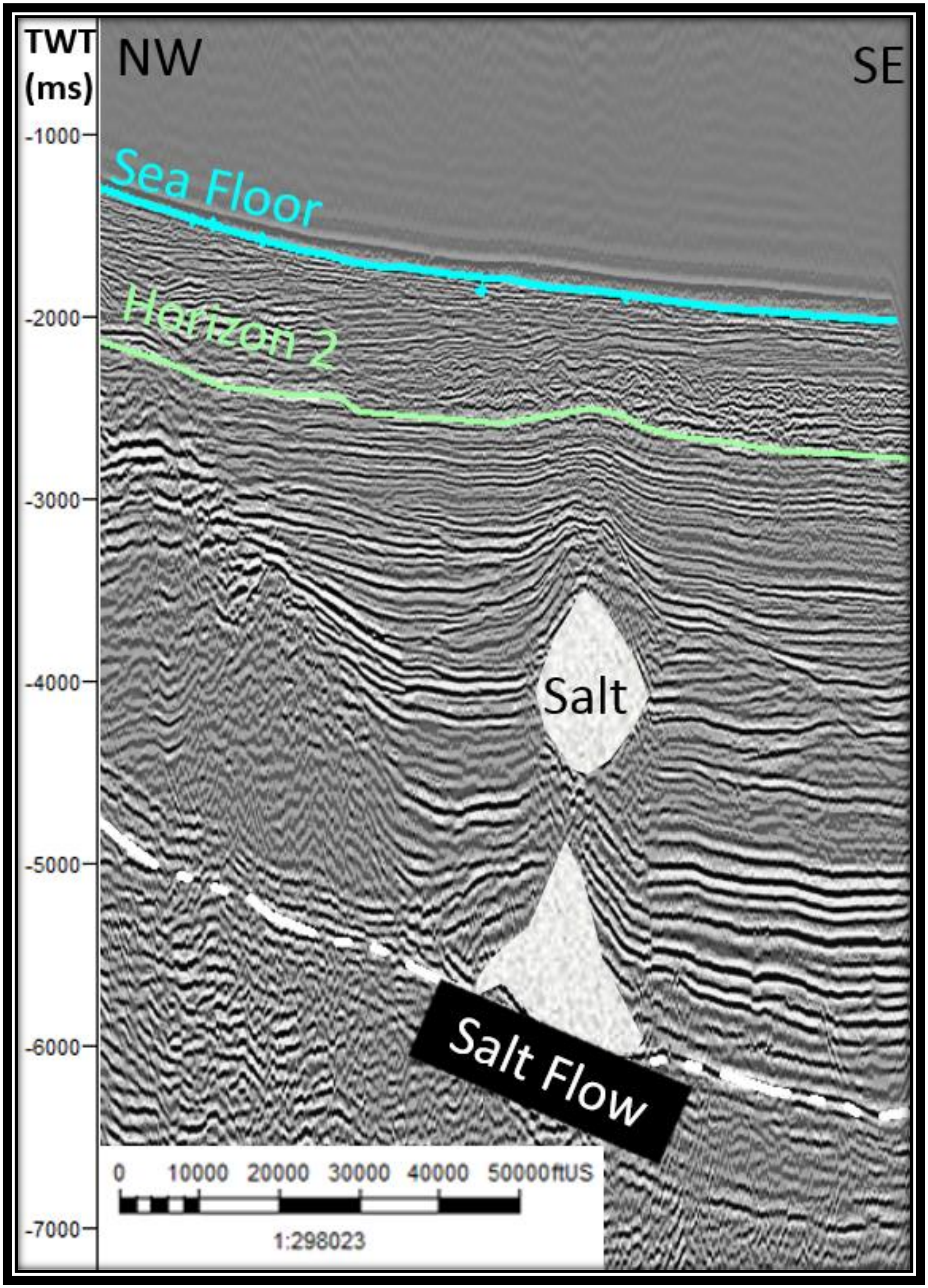

Figure 5.5 Salt Flow and A Diapir in the seismic line PR-82-X263.

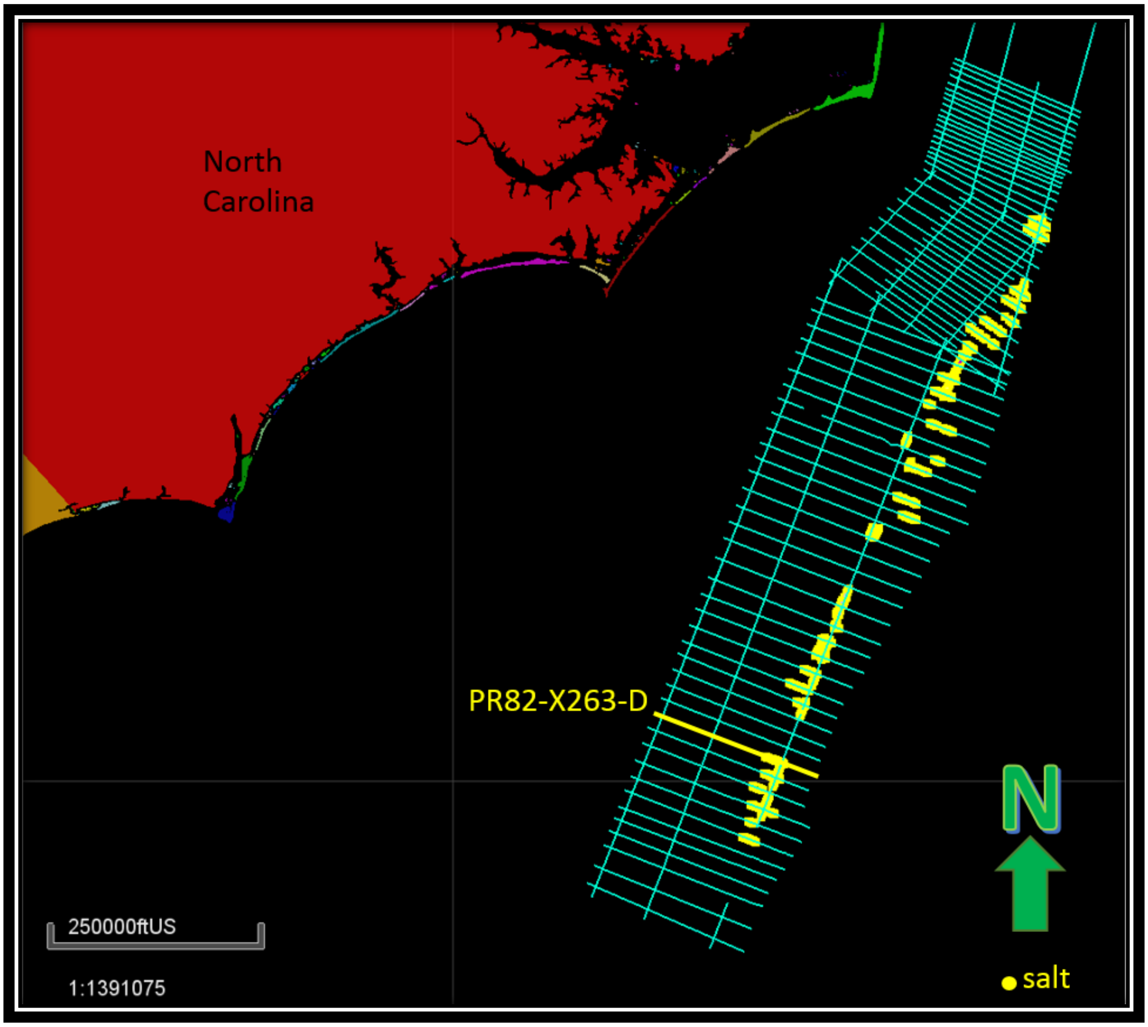

Figure 5.6 Location of the seismic line PR82-X263-D.

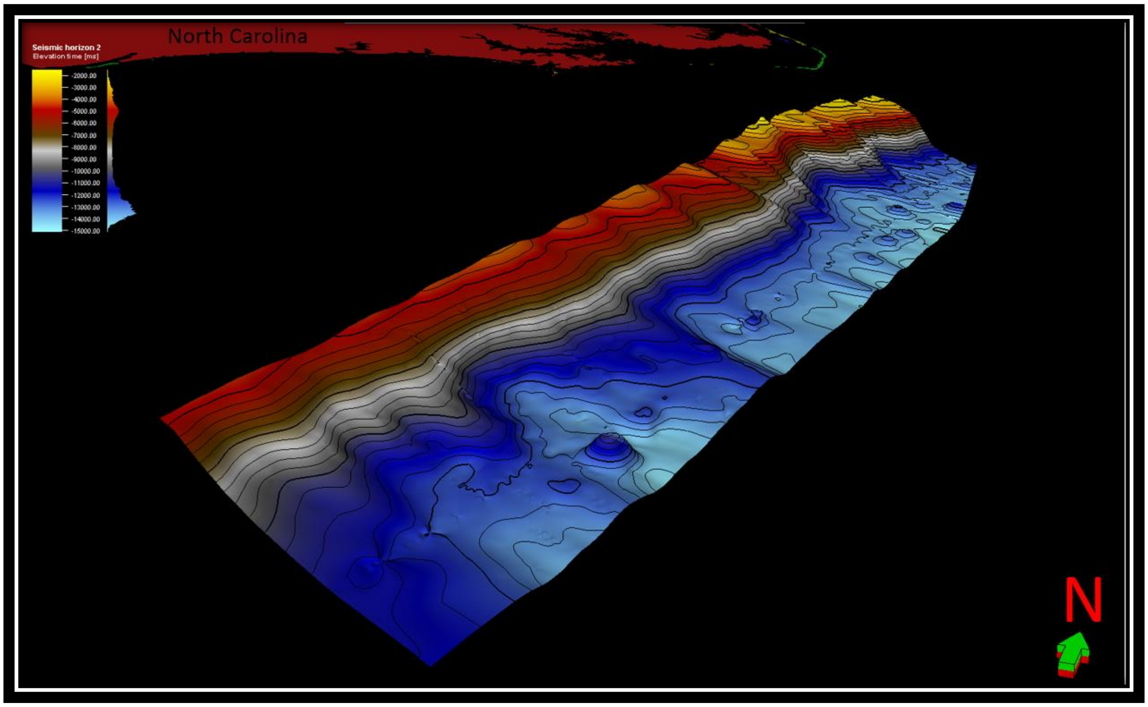

Figure 5.7 Surface for Horizon 2.

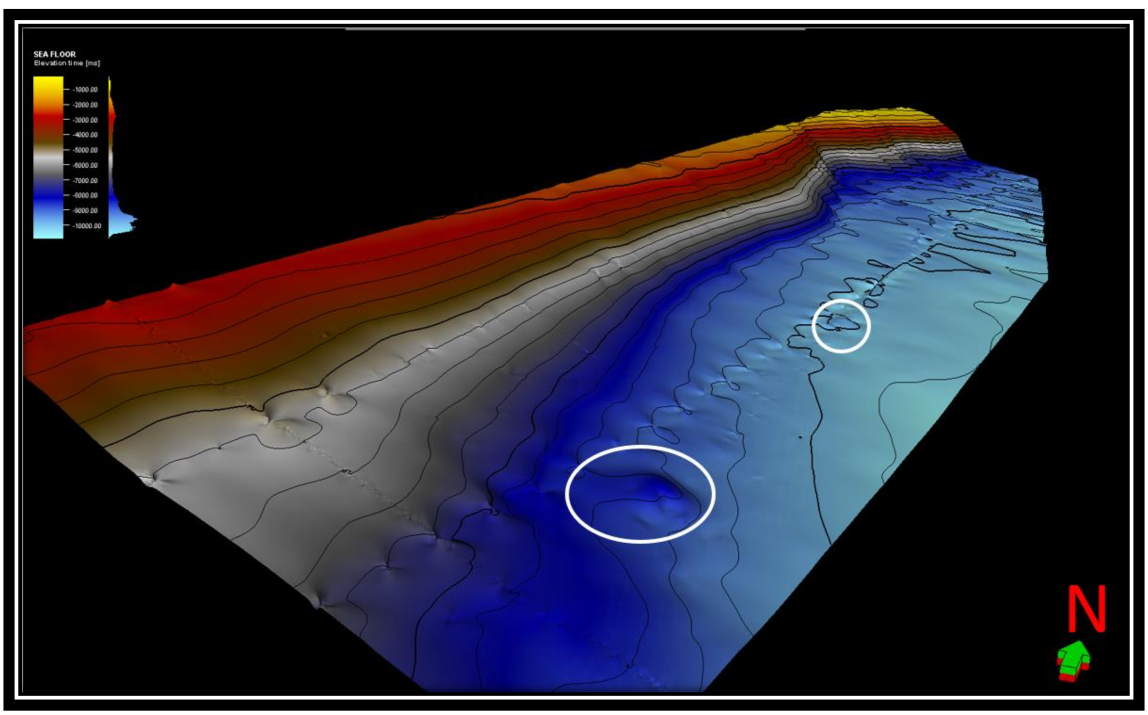

Figure 5.8 Sea Floor surface and appearance of the deformations due to diapirs.

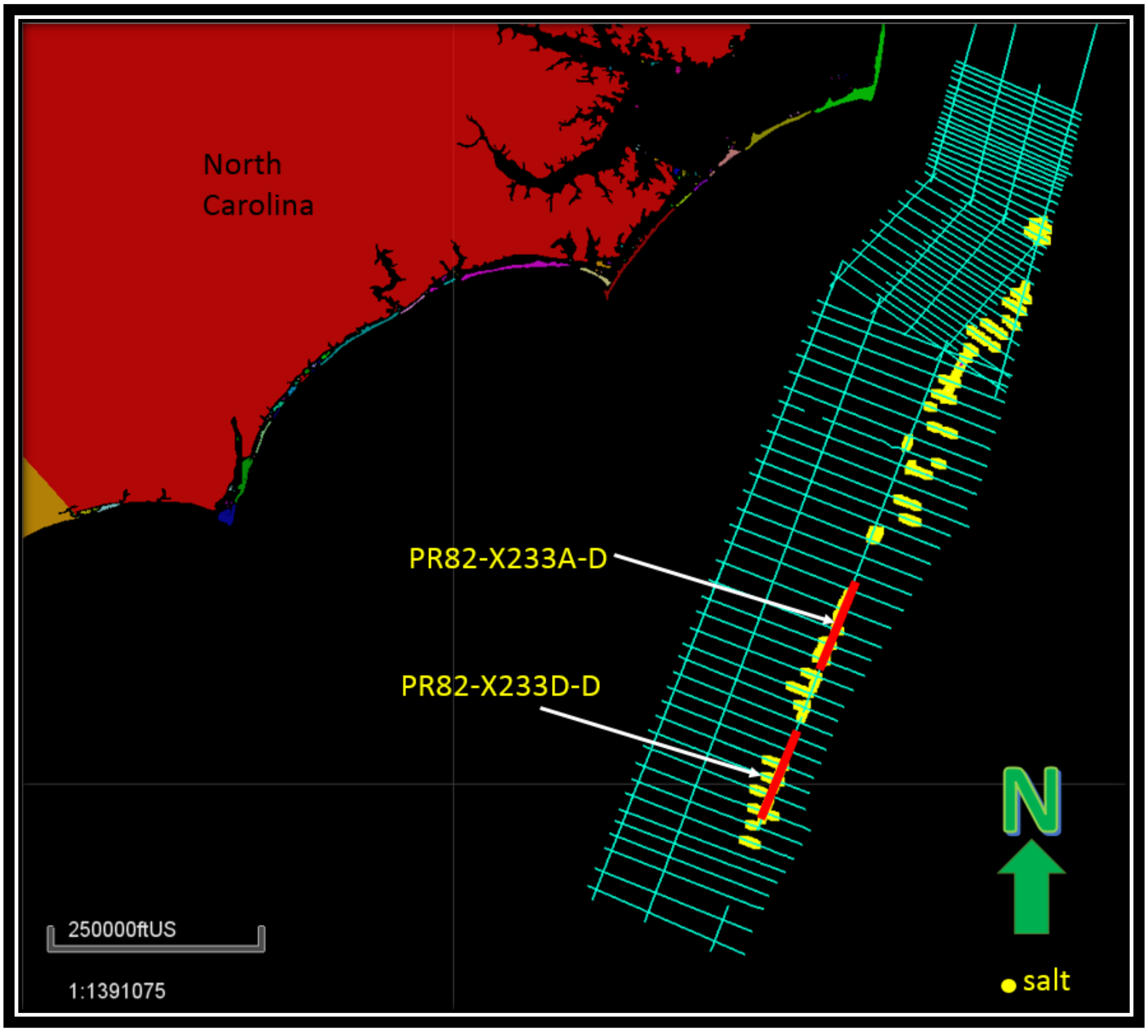

Figure 5.9 Location map of the PR82-X233D-D and PR82-X233A-D.

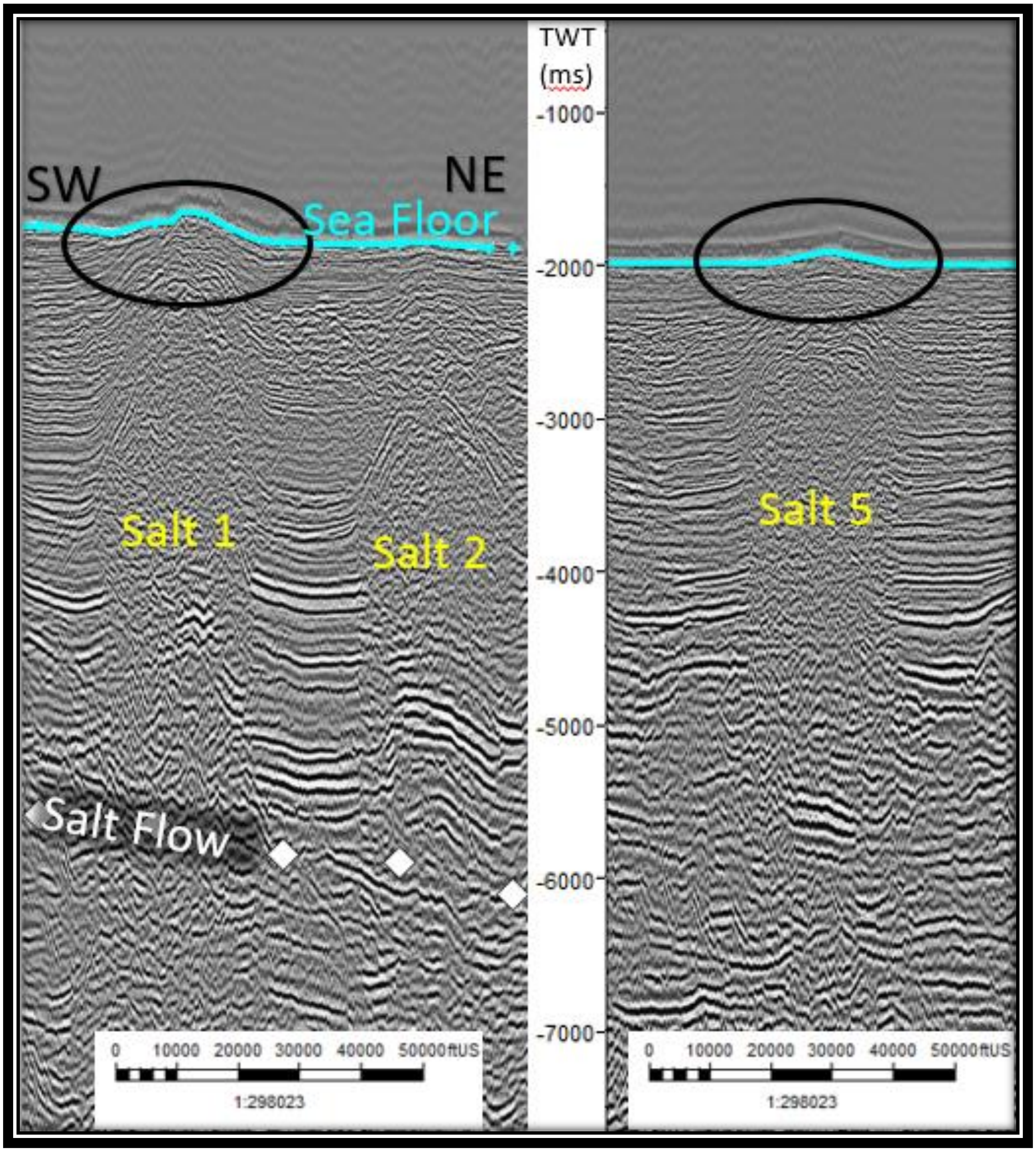

Figure 5.10 Deformation on the sea floor due to diapir 1 and diapir 5.

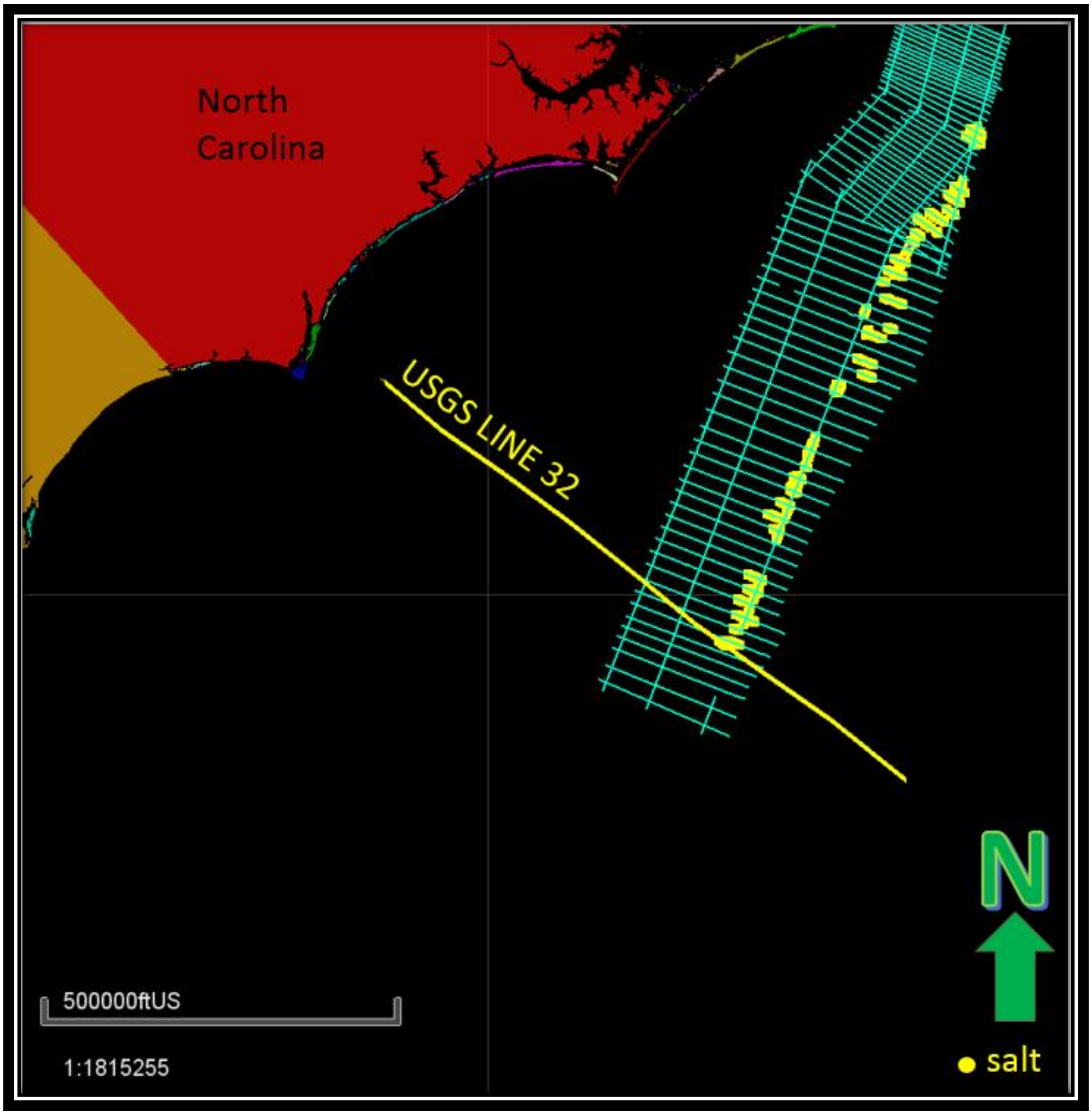

Figure 5.11 Location map of the USGS line 32

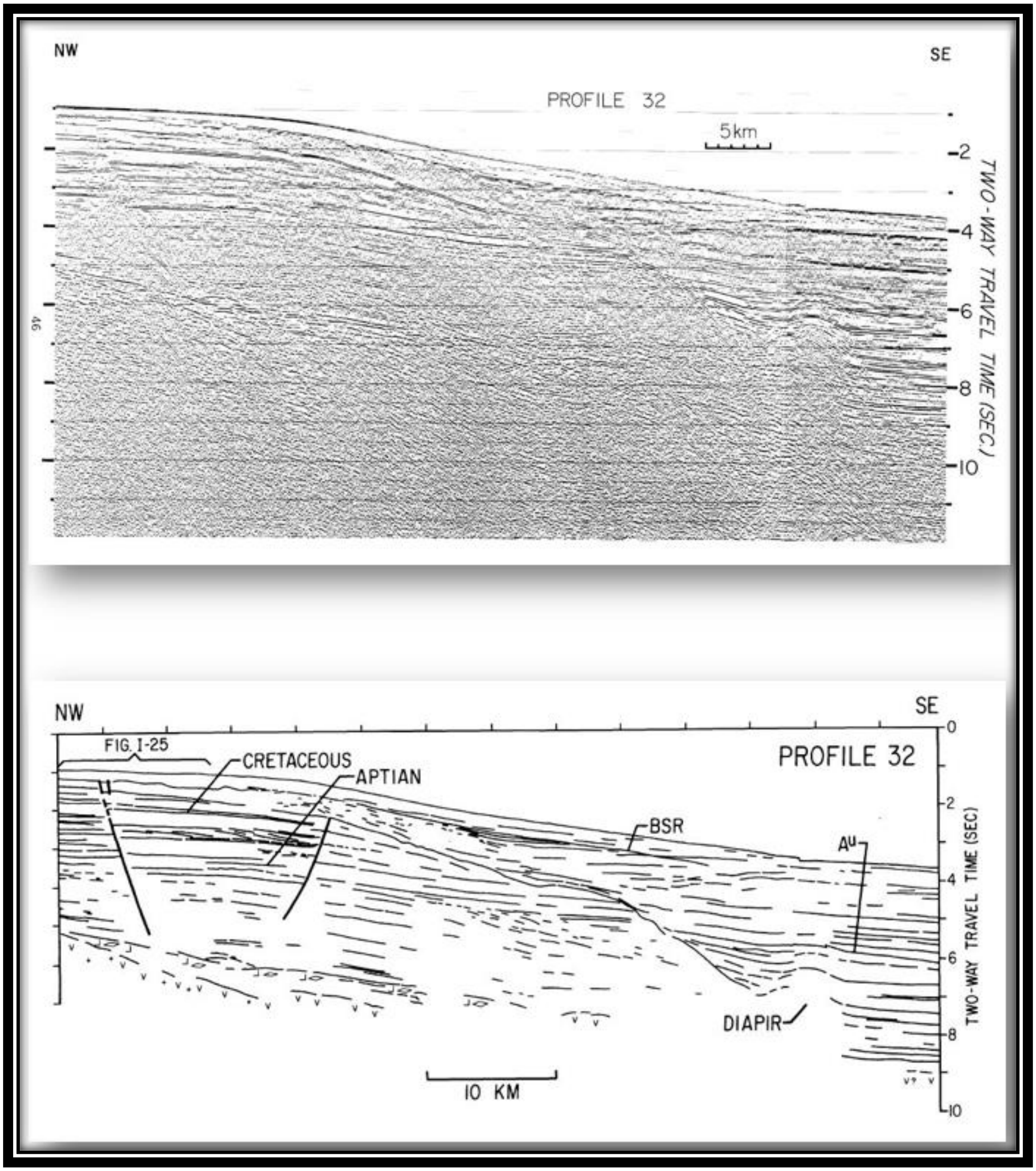

Figure 5.12 USGS Line 32 and its interpretation (Au: an unconformity that covers most of the western North Atlantic basin, BSR: The reflection generated at the phase boundary; bottom simulating reflector) (Dillon et al., 1983).

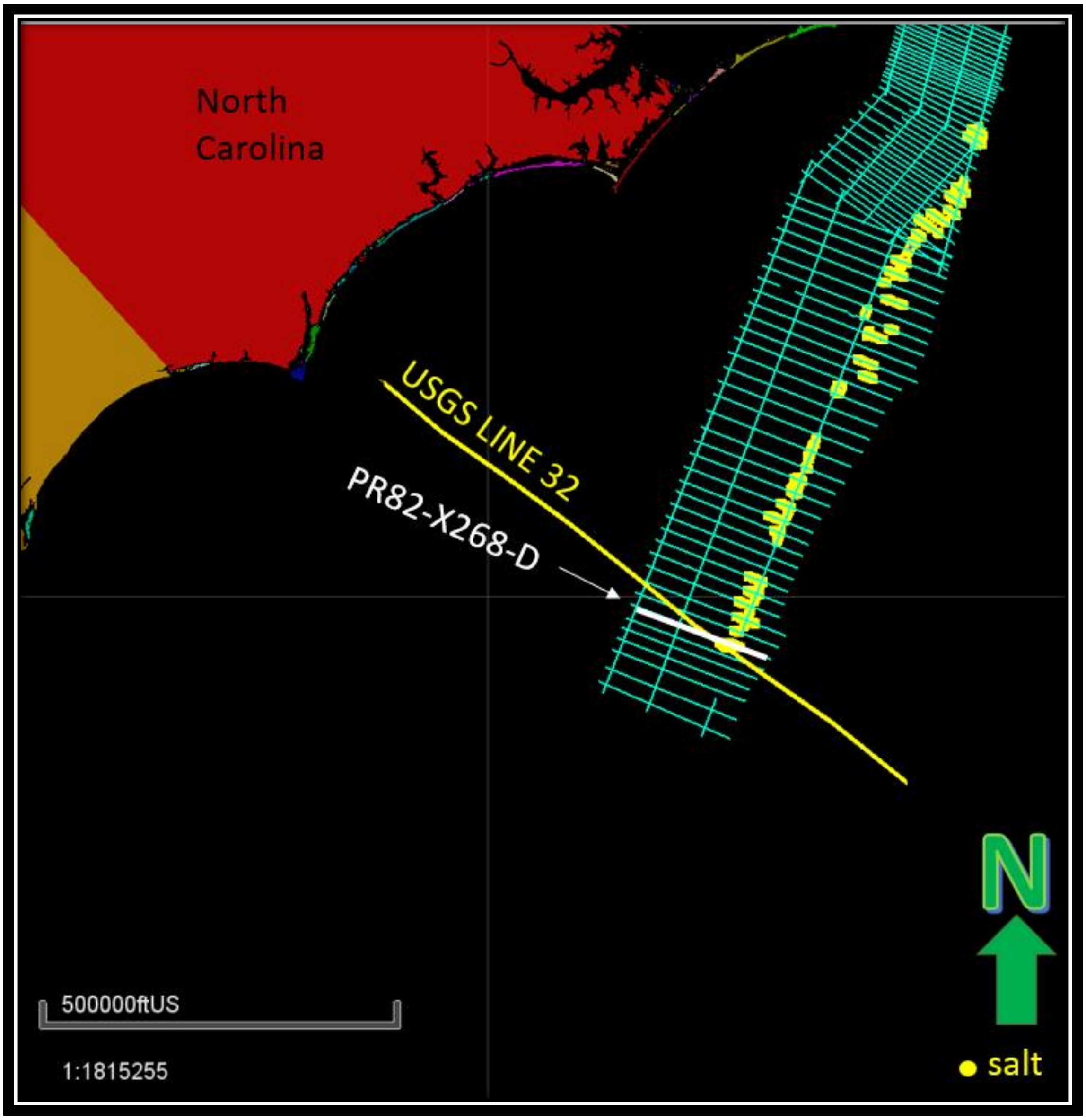

Figure 5.13 Location of the seismic lines PR82-X268 that cut on the USGS Line 32.

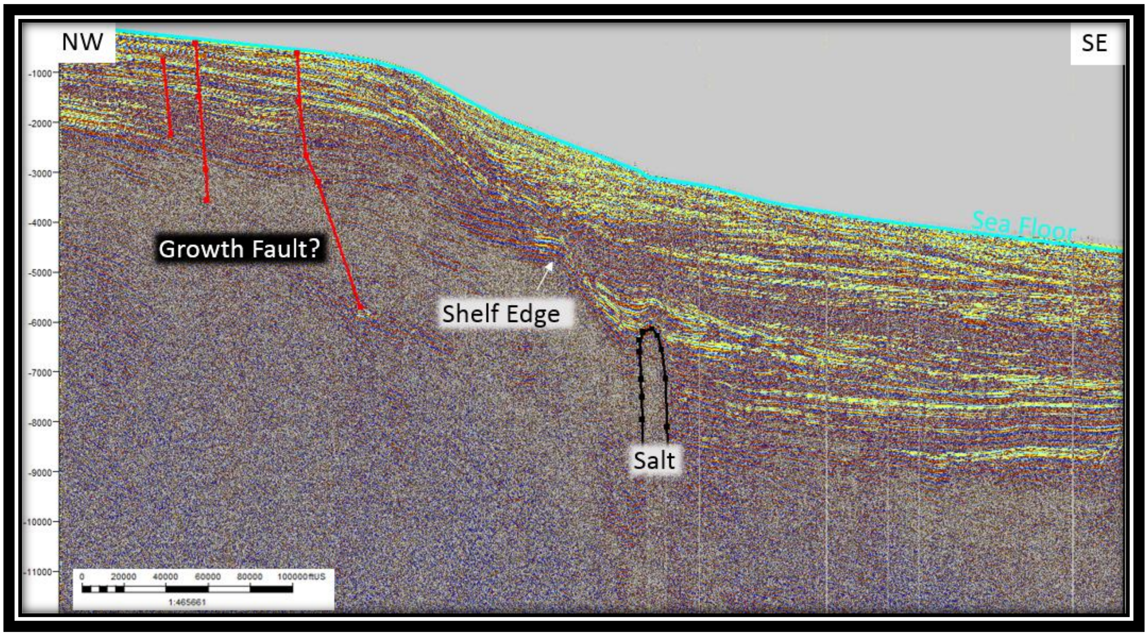

Figure 5.14 Appearance of the salt intrusion in the USGS line 32.

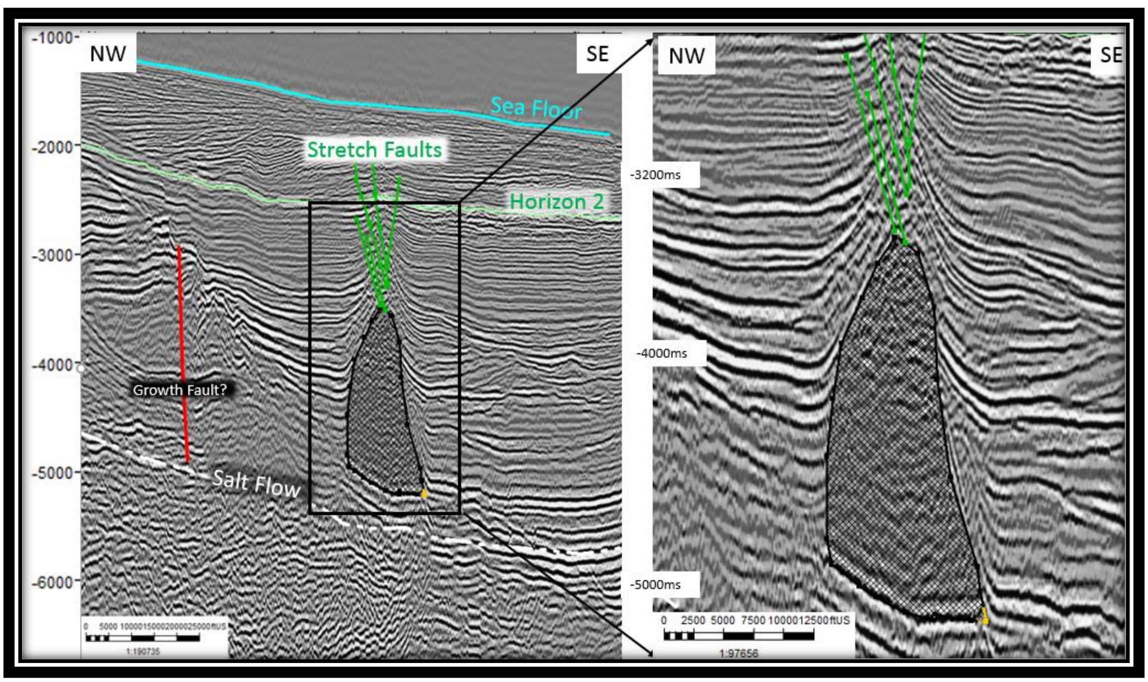

Figure 5.15 Interpretation of the line PR82-X268-D, cut USGS line 32.

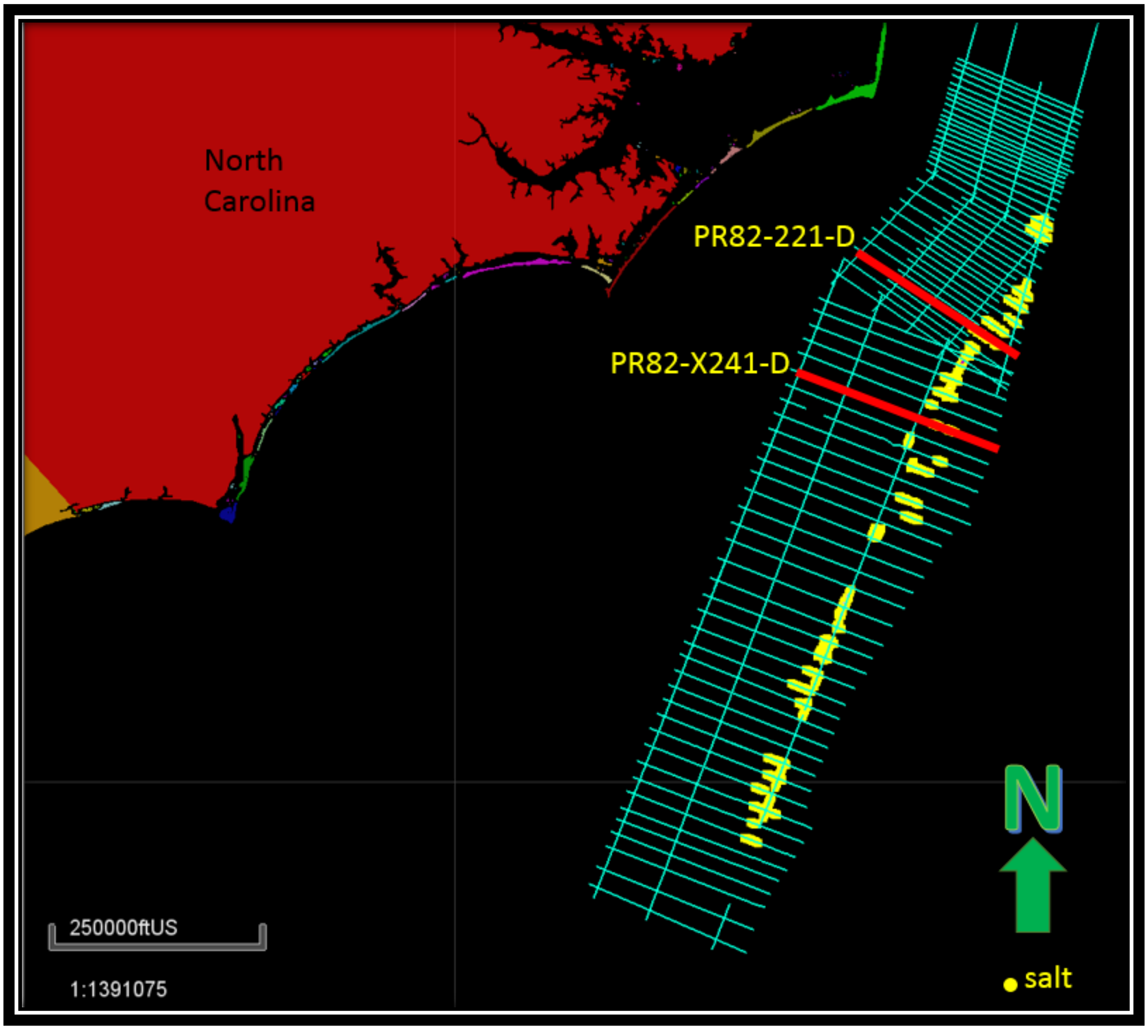

Figure 5.16 Location map of PR82-X241-D (90km) and PR82-221-D (80km).

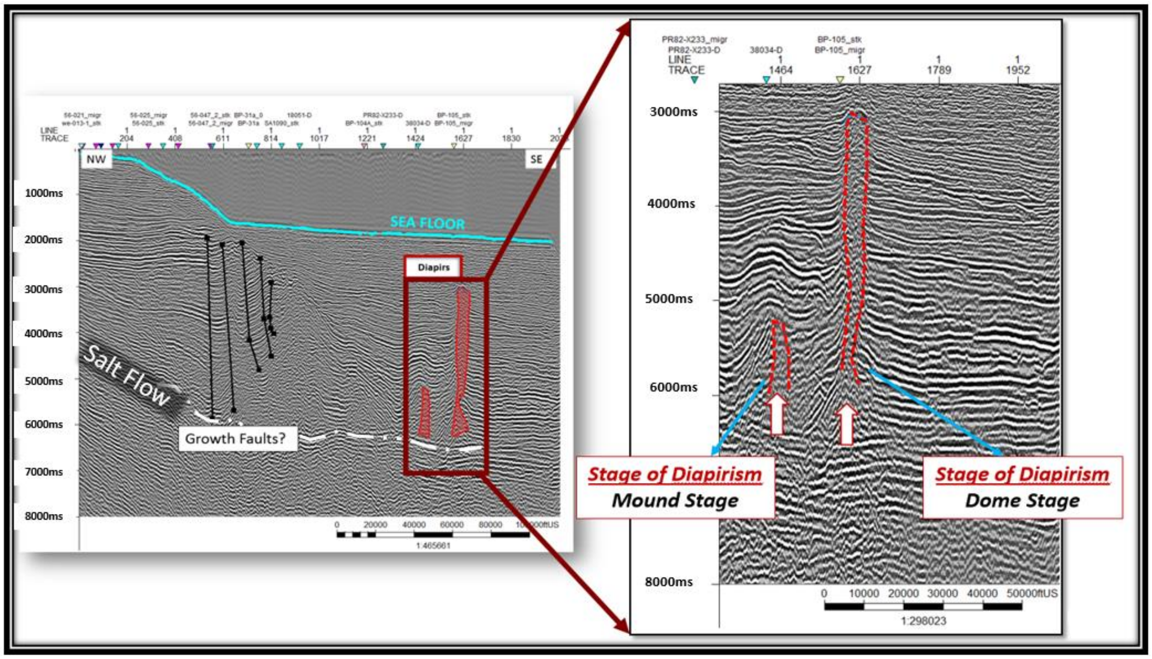

Figure 5.17 Appearance of the salt dome and the growth faults on the PR82-X241-D.

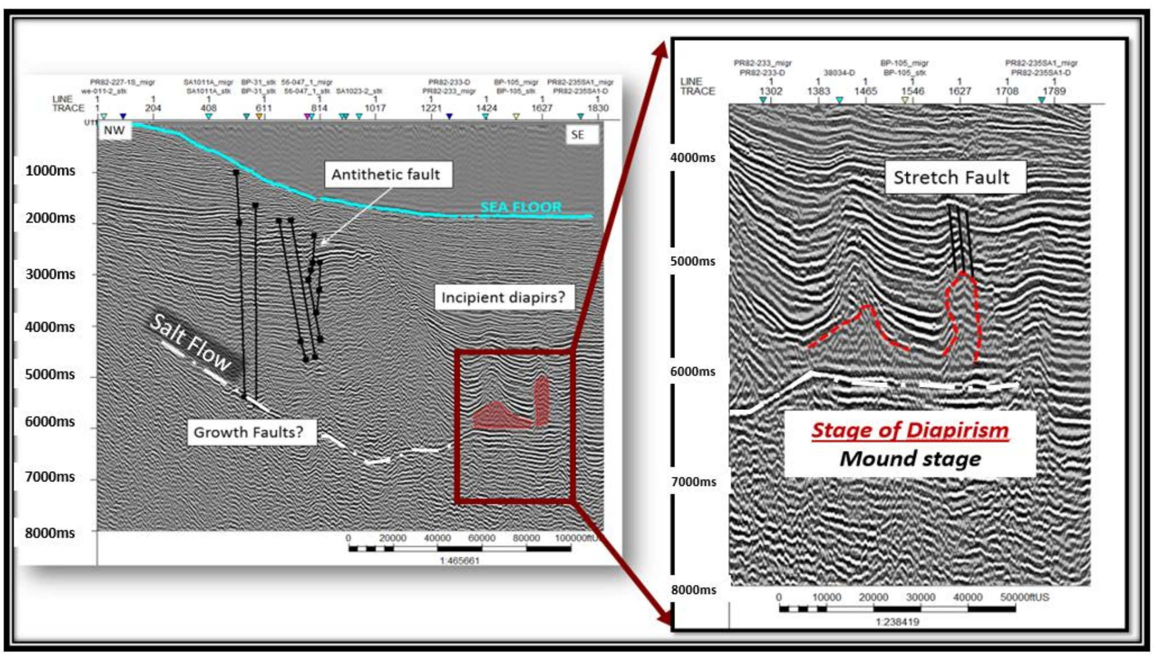

Figure 5.18 Appearance of incipient salts and the growth faults on the PR82-X221-D.

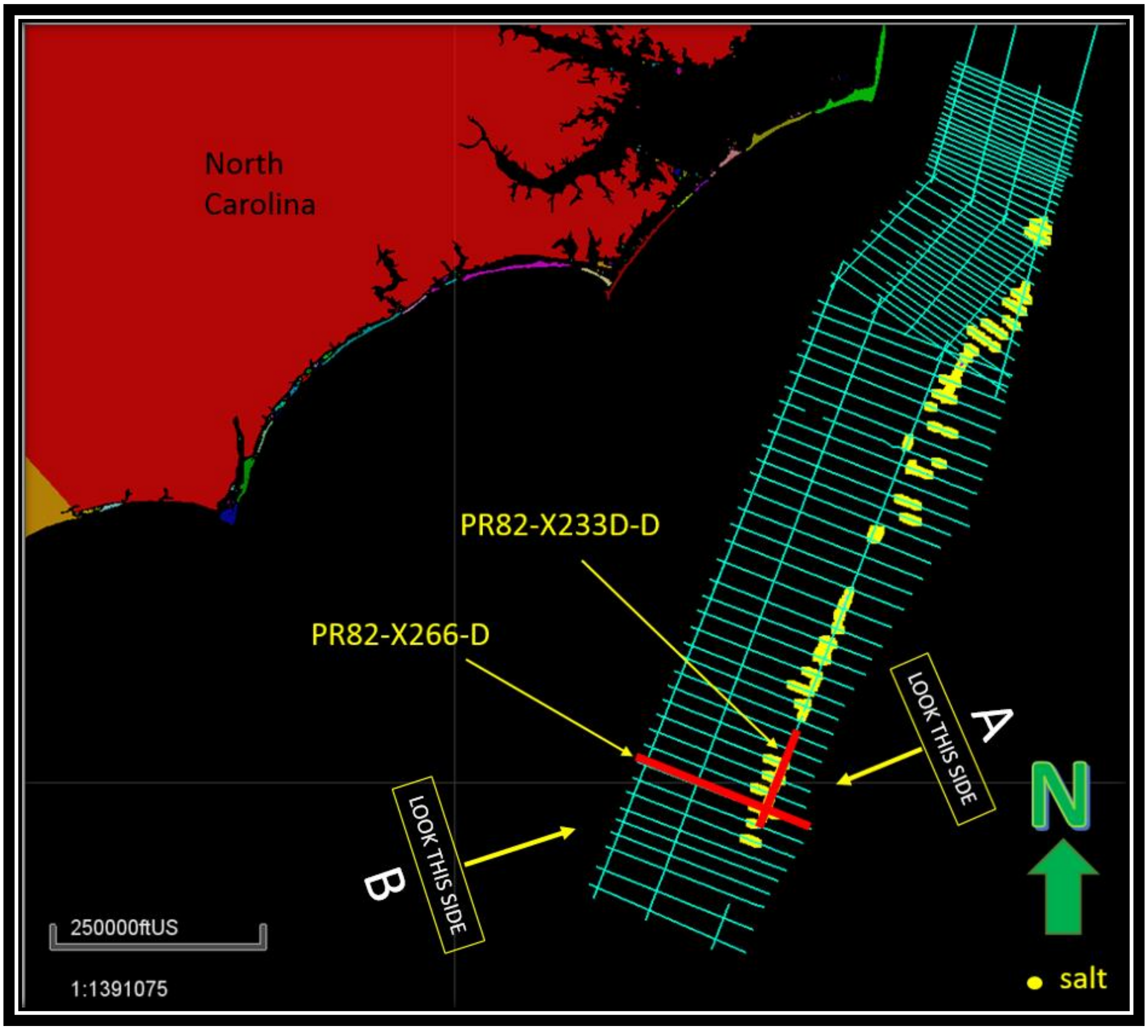

Figure 5.19 Location map, A and B are given in Figure 5.20 and Figure 5.21.

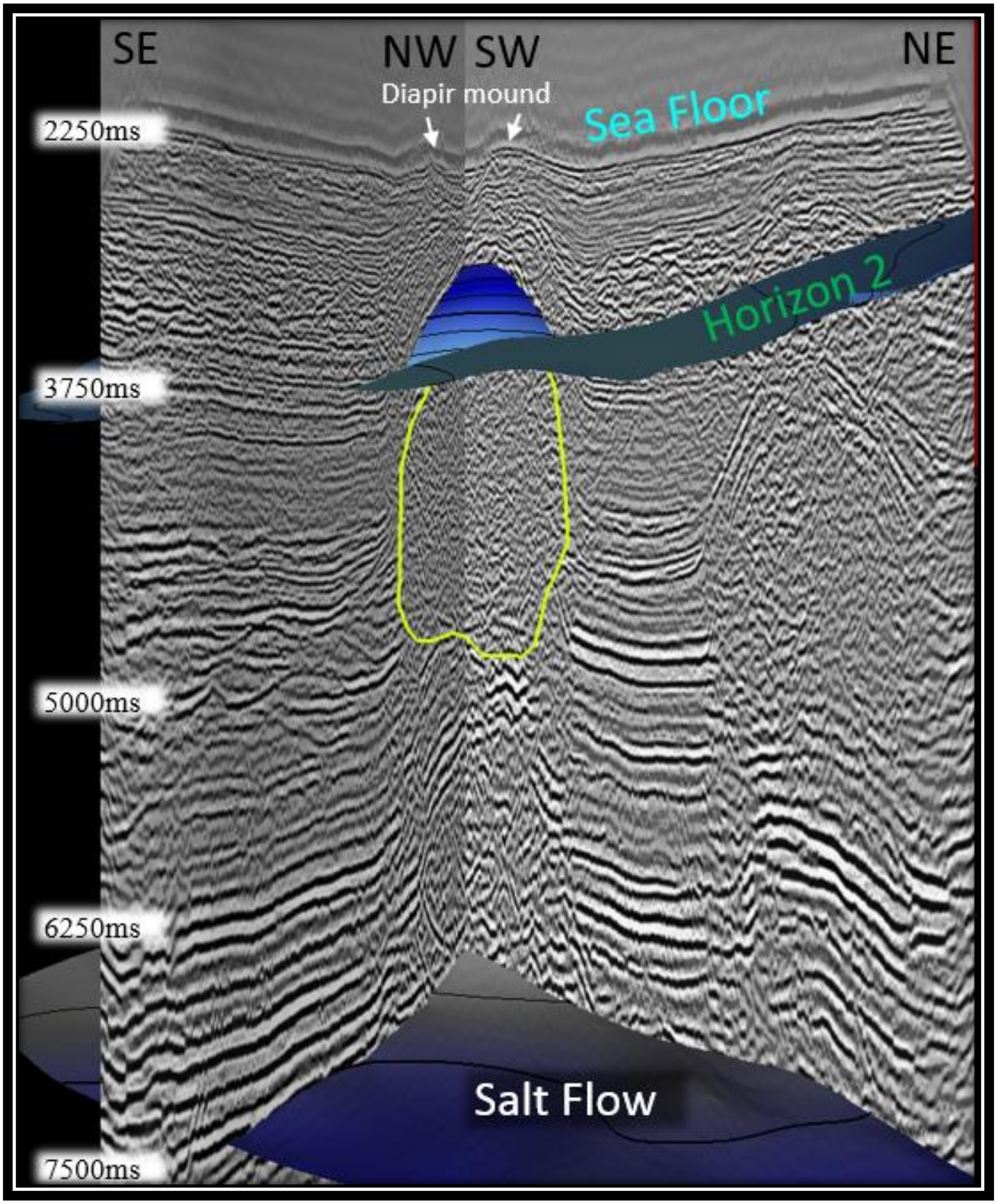

Figure 5.20 Appearance of the Salt 1 (A).

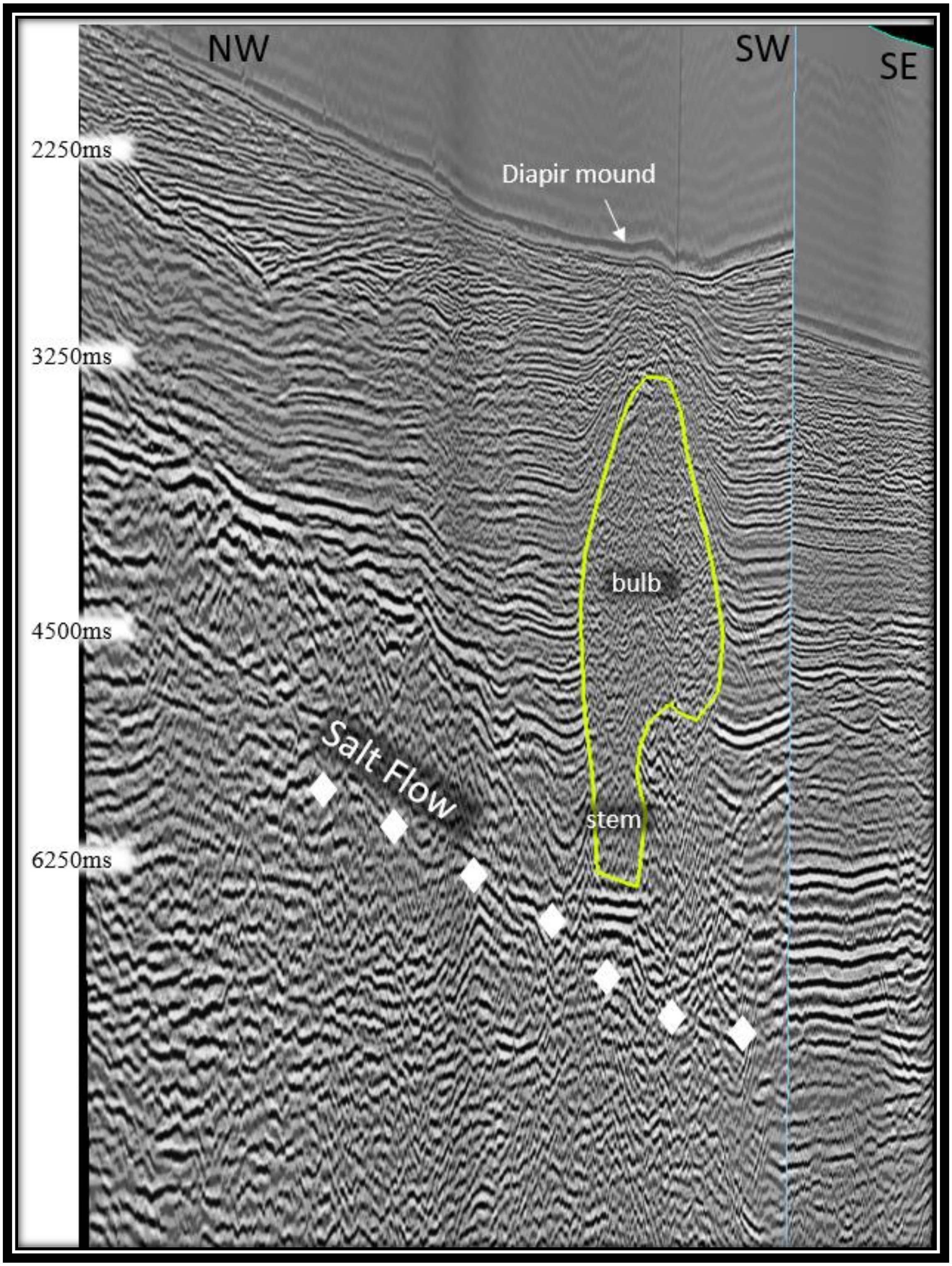

Figure 5.21 Appearance of the Salt 1 (B).

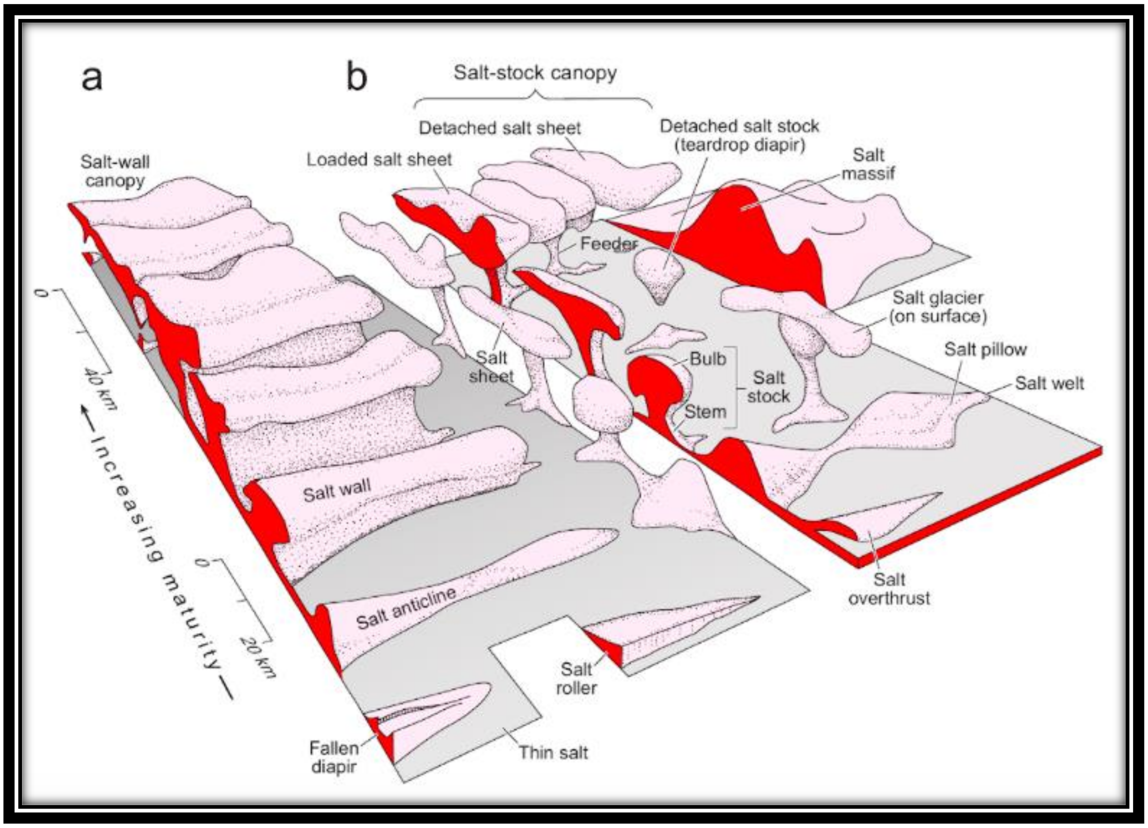

Figure 5.22 The main types of salt structures (Jackson & Hudec,2017, p.9).

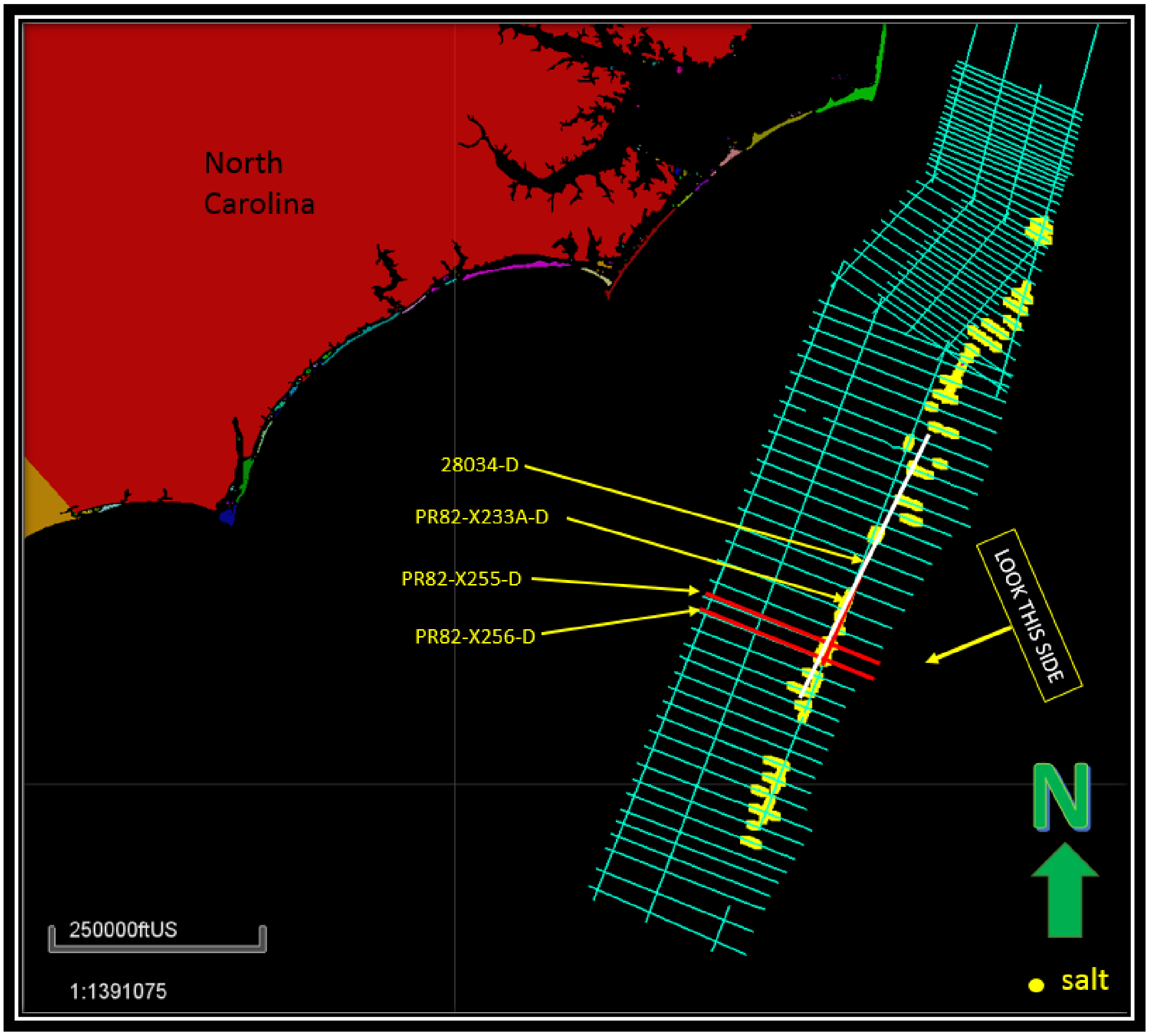

Figure 5.23 Location map of the seismic lines.

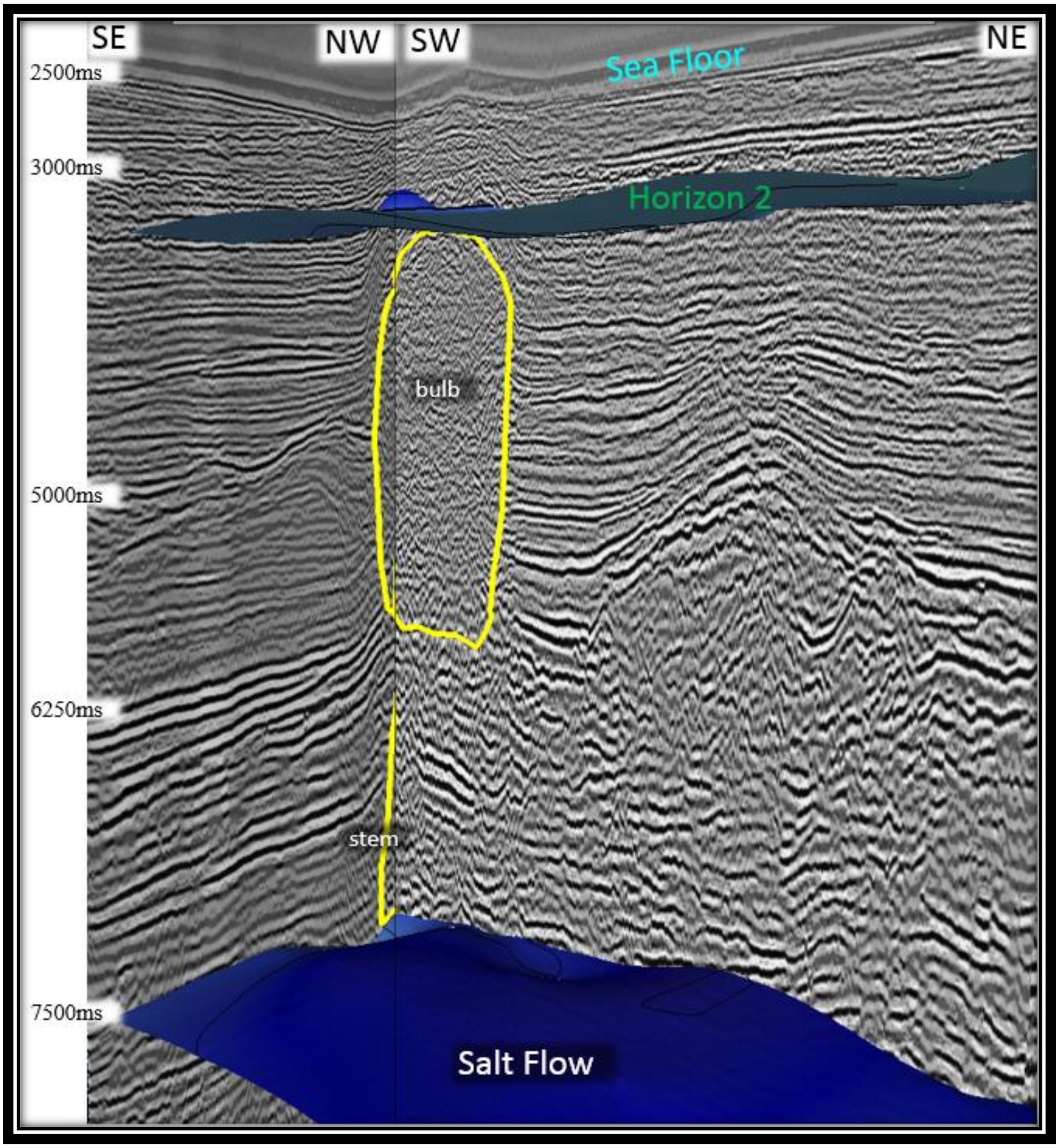

Figure 5.24 Appearance of the salt 5 between PR82 X256-D and PR82-X233A-D.

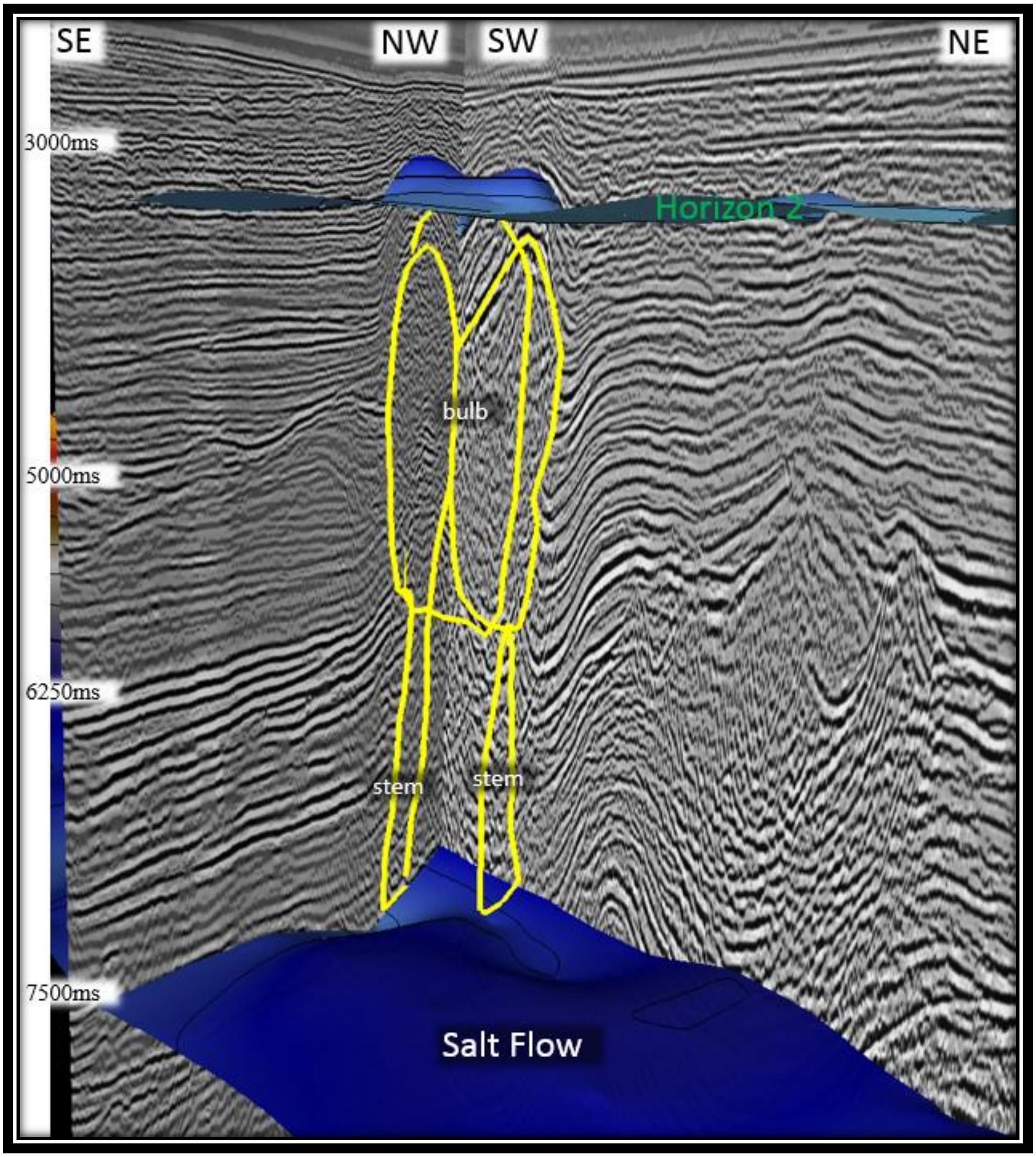

Figure 5.25 Appearance of the salt 5 between PR82 X256-D and 28034-D.

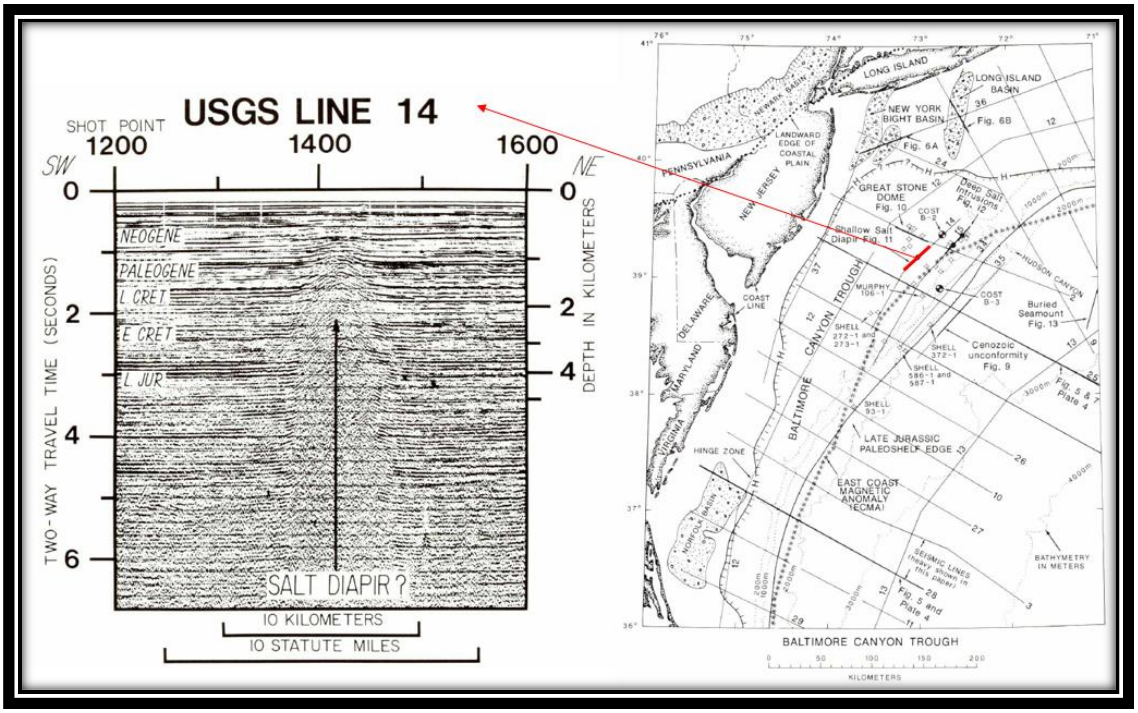

Figure 5.26 A Salt diapir in the Baltimore Canyon and its location (Grow et al., 1988).

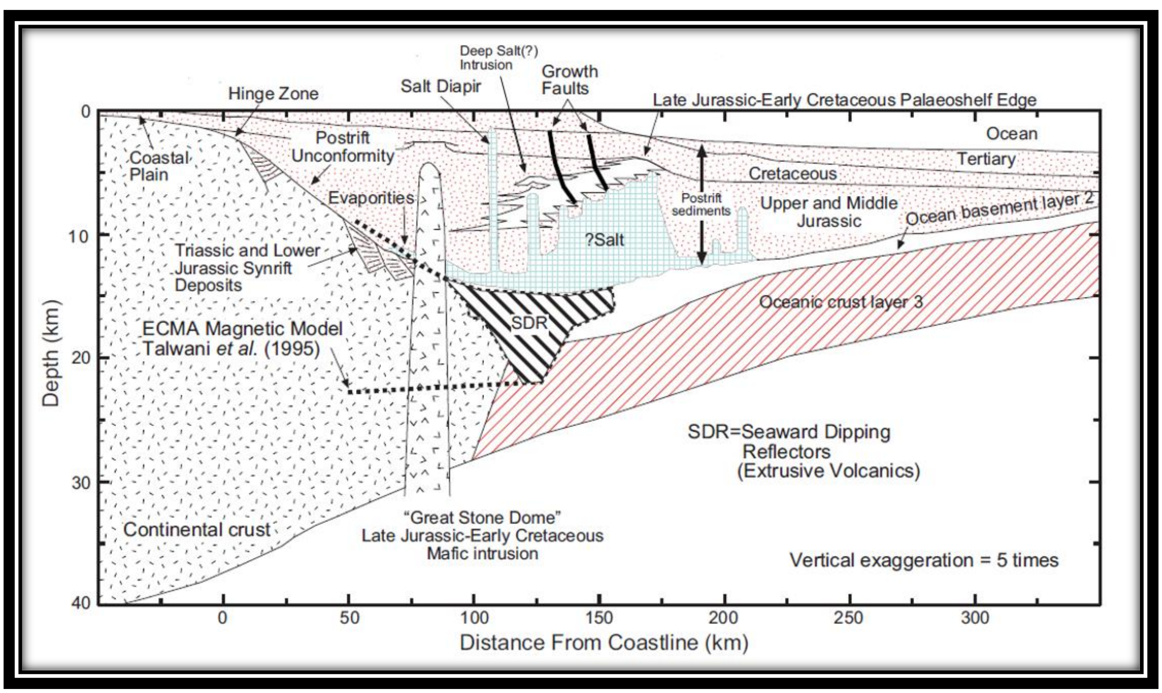

Figure 5.27 Salt diapirs in the Baltimore Canyon Trough (Miller et al., 2014).

CHAPTER 6

CONCLUSIONS

An isolated shallow ocean basin has limited water circulation which leads to deposition of salt, but the possibility of salt production decrease when the axis of sea floor spreading becomes submarine because the size of ocean rapidly doubles (Talwani et al., 1995, p.177). During the rifting stage, very shallow sea water covered the area dries up and its water level change repeatedly, and rapid water evaporation and precipitation of its salts on the floor of the rift basin. Salt deposits in the Carolina Trough were created by this action.

As result of interpretations more than 19 salt domes were identified in the Carolina Trough. Salt 1 and Salt 5, two biggest salts in the trough, cause deformation of the sea floor. There are different interpretations in literature about age of the salt diapirs in the Carolina Trough because there is no well control in the Carolina Trough. Basing on regional correlation of well data, salt appears to be on the Upper Jurassic (Figure 6.1). Salt appears to flow on the Upper Jurassic age horizon seaward side and rise into diapirs due to differential loading and elevation differences. Also, we can suggest that salt diapirs appear to be on the continental crust extends beyond the continental slope. Even though, we have some constraints due to 2D data, the structures of the salts on the Carolina Trough are anticlines and salt stocks. The number of incipient salt diapirs are more than the number of mature salt diapirs.

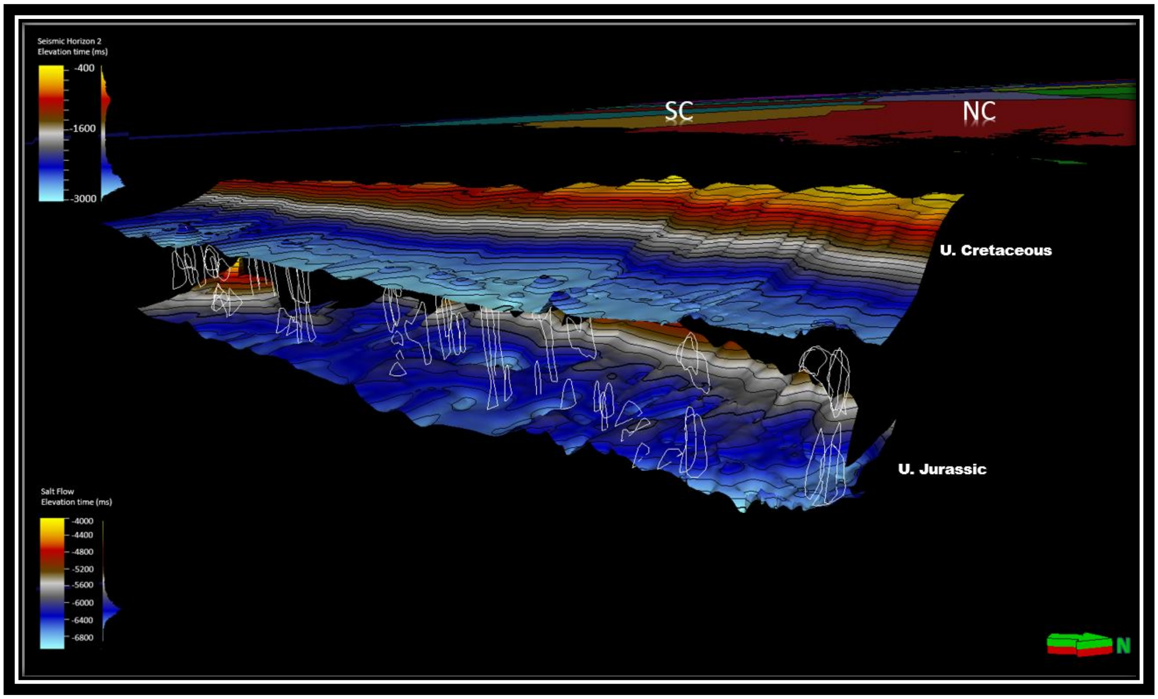

Figure 6.1 Salt diapirs appear to be between U Jurassic and U. Cretaceous layers.

REFERENCES

Almutury, W. G., & Al-Asadi, M. M. (2008). Tectonostratigraphic History of Mesopotamian Passive Margin during Mesozoic and Cenozoic, South Iraq. Journal of Kirkuk University–Scientific Studies, 3(1)., 31–55.

Ball, M. M., Gaudet, R. M., & Leist, G. (1968). Sparker Reflection Seismic Measurements in Exuma Sound Bahamas. in Transactions-American Geophysical Union, 49(1), 196-197.

Carpenter, G., & Amato, R. (1992). Carolina Trough Potential Summarized, Oil and Gas Journal, 90(7), 84-87

Dillon, W. P., Paull, C. K., Buffler, R. T., & Fail, J. P. (1979). Structure and Development of the Southeast Georgia Embayment and Northern Blake Plateau: Preliminary Analysis: Rifted Margins, in Watkins, J. S., Montadert, Lucien, and Dickerson, P. W., eds., Geological and geophysical investigations of continental margins. AAPG, Memoir, 29, 27-41.

Dillon, W. P., Popenoe, P., Grow, J., Klitgord, K., Swift, B. A., Paull, C. K., & Cashman, K. V. (1983). Growth Faulting and Salt Diapirism: Their Relationship and Control in the Carolina Trough, Eastern North America, in Studies in Continental Margin Geology, edited by Watkins, J. S., & Drake, C. L. AAPG Memoir, 34, 21-46.

Dillon, W. P. (1983). Geology Report for Proposed Oil and Gas Lease Sale No. 90, Continental Margin Off the Southeastern United States, U.S. Department of The Interior, U.S. Geological Survey, Open File Report 83-186, Chapter I, 11-15

Fossen, H. (2010). Structural Geology, Cambridge University Press, Cambridge, U.K.

Grow, J. A., & Markl, R. G. (1977). IPOD-USGS Multichannel Seismic Reflection Profile from Cape Hatteras to the Mid-Atlantic Ridge. Geology, 5(10), 625-630.

Grow, J. A., Dillon, W. P., & Sheridan, R. E. (1977). Diapirs Along the Continental Slope Off Cape Hatteras. Presented at Ann. Int. Meet. Soc. Explor. Geophys., 47th, Calgary.

Grow, J. A., & Sheridan, R. E. (1981). Deep Structure and Evolution of the Continental Margin Off the Eastern United States. Oceanologica Acta, Special issue.

Grow, J. A., Klitgord, K. D., Schlee, J. S., & Sheridan, R. E. (1988). Structure and Evolution of Baltimore Canyon Trough. The Geology of North America, 2, 269-290.

Hutchinson, D. R., Grow, J. A., Klitgord, K. D., & Swift, B. A. (1982). Deep Structure and Evolution of the Carolina Trough, in Studies in Continental Margin Geology, edited by Watkins, J. S. & Drake, C. L. AAPG Memoir, 34, 129-152.

Jackson, M. P. A., & Talbot, C. J. (1986). External Shapes, Strain Rates, and Dynamics of Salt Structures. Geological Society of America Bulletin, 97(3), 305-323.

Jackson, M. P. A. (1995). Retrospective Salt Tectonics, in Jackson, M.P.A., Roberts, D.G & Snelson, S. eds., Salt Tectonics: A Global Perspective: AAPG Memoir, 65, 1-28.

Jackson, M. P. A., & Hudec, M. R. (2017). Salt Tectonics: Principle and Practice. Cambridge University Press.

Miller, K. G., Browning, J. V., Mountain, G. S., Sheridan, R. E., Sugarman, P. J., Glenn, S., & Christensen, B. A. (2014). History of Continental Shelf and Slope Sedimentation On The US Middle Atlantic Margin. Geological Society, London, Memoirs, 41(1), 21-34.

Poag, C. W. (1978). Stratigraphy of The Atlantic Continental Shelf and Slope of the United States. Annual Reviews Earth Planet Sci., 6(1), 251-280

Poag, C. W. (1991). Rise and Demise of the Bahama-Grand Banks Gigaplatform, Northern Margin of the Jurassic Proto-Atlantic Seaway. Marine Geology, 102(1-4), 63-130.

Setterfield, B., (2015). Salt Deposits and the Flood. Retrieved from http://setterfield.org/salt_deposits/salt_deposits_text.html

Sheridan, R. E. (1981). Comment and Reply On Erosional Origin of the Blake Escarpment: An Alternate Hypothesis. Geology, 9(8), 338-330.

Talwani, M., Ewing, J., Sheridan, R. E., Holbrook, W. S., & Glover, L. (1995). The Edge Experiment and The U.S. East Coast Magnetic Anomaly. In Rifted Ocean-Continent Boundaries, 155-181, eds Banda, E., et al., Amsterdam: Kluwer

Trehu, A. M., Ballard, A., Dorman, L. M., Gettrust, J. F., Klitgord, K. D., & Schreiner, A. (1989). Structure of the Lower Crust Beneath the Carolina Trough, U.S. Atlantic Continental Margin. Journal of Geophysical Research, 94(B8), 10585-10600.

Wicander, R., & Monroe, J. S. (2004). Historical Geology: Evolution of Earth and Life Trough Time, Fourth Edition, Toronto, Canada, Brooks Cole.

Withjack, M. O., Schlische, R. W., & Olsen, P. E. (1998). Diachronous Rifting, Drifting, and Inversion on the Passive Margin of Central North America: An Analog for Othre Passive Margins. AAPG Bulletin, 82(5), 817-835