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Tectonic Studies of the Atlantic Margin in the Southeastern United States

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TECTONIC STUDIES OF THE ATLANTIC MARGIN IN THE SOUTHEASTERN UNITED STATES

by

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ABSTRACT

Reanalysis of published seismic and well data from the South Georgia Embayment provides important new constraints on the geologic structure and evolution of the Eastern North American margin. A lower Paleozoic stratigraphic section (Silurian to Devonian) sampled in offshore wells drilled in the late 1970's, can be correlated continuously along the entire ~250 km N-S length of the BA-3 profile acquired in 1989. Other than gentle warping and minor fault offsets, this Paleozoic section is essentially undeformed, precluding both Paleozoic contractional deformation associated with Appalachian orogeny, or subsequent Mesozoic extensional deformation and magmatism associated with continental rifting and formation of the Central Atlantic. Accordingly, crustal properties generating the Brunswick Magnetic Anomaly (BMA) in the central portion of the profile were most likely imparted during Proterozoic tectonic and magmatic processes, and the BMA is an inherited feature of the Gondwanan continental crust pre-dating the basal Paleozoic unconformity. Similar "layered basement" was previously identified on numerous other seismic reflection profiles on the continental margin, implying (1) the Suwanee and Brunswick/Charleston terranes were part of Gondwana, and acted as a coherent and stable block of continental crust throughout the Phanerozoic evolution of southeastern North America, and (2) the Alleghanian suture must sit north of these occurrences, and most likely coincides with the boundary on the magnetic map defined by Higgins and Zietz (1983). Paleozoic collisional tectonics were subsequently followed by extensional processes during the Mesozoic. The southern central

Atlantic Ocean along the east coast of North America is commonly associated with a large volcanic province, referred to as the Central Atlantic Magmatic Province (CAMP) emplaced during this time of extension. A prominent seismic reflection, known as the J-Horizon, underlies this entire region and has been historically correlated to a sedimentary basalt contact. However, the J-Horizon has been reevaluated onshore as a contact between Coastal Plain sediments and the base of the coastal plain, regardless of the presence of basalt. This study reevaluates the character and origin of the J-Horizon beneath the Carolina Trough and Blake Plateau Basin in order to reevaluate the extent of a continental flood basalt associated with CAMP. Offshore wells have been identified near the distribution of "J" that penetrate basement rock, none of which encounter Jurassic basalt; however, no wells have been directly drilled in this proposed region. From correlating well and seismic data throughout the region, analysis suggests that, as with the onshore, the J Horizon represents a boundary between overlying Coastal Plain sedimentary rocks, and underlying Mesozoic rift basin and Paleozoic basement rocks. These data indicate that CAMP is not as aerially widespread as previously estimated in the Southeastern United States. This new interpretation removes the strongest line of evidence connecting the central Southern Atlantic Ocean to open 200 Ma and consequently removes evidence suggesting the opening of the central Atlantic Ocean of North America was diachronus.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

INTRODUCTION

The Atlantic Margin of the United States is one of the most widely studied passive margins containing numerous studies and associated data. A suite of geophysical data such as seismic, gravity and magnetics along with geologic well data has been acquired off the east coast of the United States. Our study primarily focuses on magnetic, seismic and well data from onshore South Carolina, Georgia and Florida, as well as offshore in the Carolina Trough and Blake Plateau Basin. We investigate tectonic history of the southeastern Atlantic Margin through the Phanerozoic. This history spans a Wilson cycle, beginning with the closing of the Rheic Ocean and ending with the opening of the Atlantic Ocean. The first chapter of this study aims to constrain the location of the Paleozoic suture associated with the collision of Gondwana and Laurentia. We examine past studies and available data in order to mark the suture north of Florida, into Georgia, South Carolina and into part of North Carolina. This implies that a large portion of the southeastern United States constitutes Gondwanan crust. We also provide new insight regarding the origin of a prominent regional magnetic anomaly, the Brunswick Magnetic Anomaly (BMA). We provide data that suggest a Proterozoic origin for the BMA, a feature previously only associated with Phanerozoic processes. The second chapter of the study investigates rifting processes associated with the Central Atlantic Magmatic Province (CAMP), one of the most aerially extensive volcanic provinces, and the timing of the opening of the Atlantic Ocean. We provide data constraining the extent of massive

flood basalt previously thought to span across a large region in the southeastern United States and insight toward constrains of the opening of the Atlantic Ocean. Our study provides new insights toward the tectonic setting and processes that shape the Atlantic Margin of the southeastern United States.

CHAPTER 1

SOUTH CAROLINA IS AFRICAN: GONDWANA REVISITED

1.1 INTRODUCTION

The Atlantic Margin of the United States experienced collisional tectonics during the Paleozoic, marking a period of orogenic events when Laurentia accreted exotic terranes terminating with the collision of Gondwana. Many studies contributed to defining the boundaries between exotic terranes remaining attached to North America after continental rifting during the Mesozoic (Wilson et al., 1966; Higgins and Zeitz 1983; Klitgord et al., 1984; Horton 1989; Hibbard et al., 2002; Steltonpohl et al., 2008; Hatcher et al., 2010; Thomas et al., 2010; Pollock et al.. 2012; Mueller et al., 2013). In the southeastern United States, the Carolina terrane is generally defined as the last outboard volcanic arc terrane that accreted onto Laurentia before peri-Gondwanan or Gondwanan collisions (Steltonpohl et al., 2008; Pollock et al., 2012). The peri-Gondwanan terranes have been defined in various manners and include the Uchee, Savannah River, Brunswick, Charleston and Suwannee terranes. A major geophysical feature, the Brunswick Magnetic Anomaly, has often been correlated as partly coincident with the suture of the Suwannee Terrane (Mcbride et al., 2005). We present a reinterpretation of published seismic and well data that document an undeformed, continuous sequence of Paleozoic stratigraphy overly the BMA. The presence of these undeformed sediments implies that the crustal properties which produce the BMA predate the Paleozoic collision, making this anomaly an inherent feature of the Suwannee Terrane. Our

interpretation implies the suture between Gondwana and Laurentia occurs north of the BMA and the extent of seismic line BA-3. Our interpretation coincides with recent studies that identify the similarity between these terranes based on magnetics and geochemistry (Muller et al., 2013 Parker 2014). The boundaries presented suggest a different tectonic and paleogeographic history of the region.

1.2 BACKGROUND

The Brunswick Magnetic Anomaly (BMA) is a magnetic low located parallel to the Atlantic margin south of Cape Hatteras, swings onshore of Georgia and continues west into eastern Alabama (Figure 1). The magnetic low can be mapped continuously for ~1,000 km, has an average wavelength of ~50 km and instensity greater than -600 nT. After identifying the anomaly using aeromagnetic data (Taylor et al., 1968), a rigorous debate followed regarding the origin of this anomaly. Historically, the origin of the anomaly fell between two arguments: a Paleozoic suture (Nishenko and Sykes 1979, Daniels 1983,Williams and Hatcher 1983, Nelson et al. 1985) or resulting from Mesozoic extension (Pickering 1977, Popenoe and Zietz 1977, Klitgord Behrendt 1979 Hutchinson et al 1983).

Arguments attribute Mesozoic processes forming the BMA due to crustal extension resulting in the formation of rift basins and the emplacement of magmatic material. Mesozoic basins were initially interpreted on seismic profiles offshore (Klitgord Behrendt 79 Hutchinson et al. 1983), however, the basins identified on USGS line 32 were determined as diffractions and no rift related basins were identified on more recently acquired profiles that would coincide with the BMA (Austin et al., 1990; Oh et al., 1991). Mcbride et al. 1989 generated a magnetic model of volcanic material

emplaced during Mesozoic rifting, concluding volcanic material could be responsible for the BMA. Parker 2014 present a new magnetic model that suggests the BMA is likely due to a deep crustal structure outboard of the Laurentian margin rather than Mesozoic volcanics.

Onshore, the BMA was found coincident with the Suwannee suture based on well data separating Paleozoic stratigraphy south of the BMA and Piedmont rocks north of the BMA (Chowns and William 1983) and deep dipping reflectors identified on seismic data (Nelson et al. 1985), however, the relationship proved overall discordant. Wells containing felsic rocks were identified north of BMA and the dipping reflectors identified as the suture are poorly constrained (Chowns and Williams 1983, Tauvers and Muelberger 1987). Hatcher et al. 2010 suggest the occurrence of Suwannee rocks north of the BMA is due to thin skin overthrusting of the Suwanee Terrane over Laurentia. This suggests the BMA is still a result of the Suwanne suture zone, but resulting from deeper crustal structure.

The BMA has also been suggested as the magnetic difference between the Charleston/Brunswick and Suwannee terranes **(**Nishenko and Sykes, 79; Williams and Hatcher, 82; and Daniels et al., 83), however, Higgins and Zietz 1983 state these terranes are identical but have a different depth to magnetic basement. It has been suggested that the Uchee, Charleston and Savannah River terranes maybe be infrastructure to the Carolinia terrane (Hibbard et al. 2002), but lithospheric similarities based on geochemical analysis suggests these terranes mark the basement of the Suwanee terrane (Mueller et al. 2013).

1.3 DATA

We present seismic reflection profile BA-3 with well constraints from the COST GE-1 and Transco 1005-1 wells. These two wells are the only two wells offshore in the Blake Plateau Basin or Carolina Trough that penetrate below the post rift unconformity. The COST GE-1 and Transco 1005-1 wells penetrate Lower Ordivician to Upper Devonian basement rocks that are approximately equivalent (Simonies, 1979; Poppe et al., 1995). Using sonic and density logs, we created a synthetic seismogram to match our well data to seismic data. The COST GE-1 well is ~1 km from line BA-3 and Transco 1005-1 is ~2 km from line BA-3.

Seismic line BA-3 was collected by UTIG as part of acquisition of ~1200 km of MCS data using the Geophysical Company of Norway (GECO) *My* commercial vessel. Fifteen OBS/OBH devices were deployed along the line in order to collect seismic refraction data and provide insights toward crustal velocities. The velocity model generated for these data is present in Lizarralde et al., 1994. The BA seismic data was processed using CGG's software at The University of Texas System Center for High Performance Computing (Oh et al. 1993). We received the processed BA-3 seismic stack, containing every 4th CDP and $t^{0.8}$ scaling applied.

1.4 INTERPRETATION

We are confident from correlation between logs and seismic that we can identify the post rift unconformity and stratigraphy below the unconformity. We interpret the Paleozoic stratigraphy beneath the post rift unconformity as continuous across the entire profile (Figure 2B). There are minor discontinuities and faults apparent on the section, however,

we interpret the reflectors to be the same across the profile on the basis of continuity and reflection character. From 70-100 km and 125-150 km we determine zones of minor faulting, however, it is possible to map reflectors through this section. From 160-170 km, steep dipping reflectors are apparent on the profile. We determined these reflections are out of plane diffractions on the basis of more gentle dipping reflections identified cutting across the steeply dipping reflections.

Seismic line BA-3 is also displayed on a crustal scale down to 15.5 seconds two way travel time (Figure 2,C). On this profile, we identify the Moho as a deep zone of reflectivity. The depth of the Moho remains consistent through the profile to 240 km. Seaward of this point we identify the Moho as a shallower depth representing a slightly thinner continental crust.

1.5 DISCUSSION

As seen on seismic line BA-3, a continuous, essentially undeformed lower Paleozoic (Ordovician-Devonian) stratigraphic section can be mapped along the entire 280 km of profile BA-3 on the shelf of South Carolina and Georgia. The base of the Paleozoic stratigraphy marks the boundary between Paleozoic sedimentary rocks and Neo-Proterozoic to early Paleozoic basement. The crust underlying this Paleozoic unconformity has acted as a coherent, single, structural block since early Paleozoic time, and has not experienced significant contractional, extensional, or transform deformation since then. Similarly, Phanerozoic magmatism, if present, would appear to be of limited extent within this block of crust.

The Brunswick Magnetic Anomaly (BMA) between km 110 and 170 on BA-3 appears generated from crust underlying this Paleozoic unconformity, and accordingly, is

most reasonably interpreted as an inherited feature which predates Paleozoic orogeny and Mesozoic rifting.

Correlation of the early Paleozoic stratigraphic sequence on BA-3 with known subsurface stratigraphy of the Suwanee terrane of Florida and southern Georgia (Poppe et al 1995) implies that the entire onshore and offshore region of Florida, southern Georgia, and eastern South Carolina is underlain by crust of African affinity, which acted as a stable, coherent block of crust within the Paleozoic continental collision and subsequent Mesozoic continental rifting to form the Atlantic.

Barring a polygenetic origin for the BAMA, the lateral extent of this magnetic anomaly should define the minimum extent of crust of African origin prior to Paleozoic orogeny, suggesting that the northern boundary of the Suwanee/Brunswick/Charleston composite terrane coincides with the disappearance of the BMA at the latitude of Cape Lookout on the North Carolina shelf.

This boundary coincides westward and southward with the northern boundary defined on the magnetic anomaly map of the Charleston/Brunswick terrane, suggesting that all of this crust should now be considered to be of the same affinity prior to collision. Additional support comes from seismic profiles BA-4, BA-5, BA-6 and USGS 32. Stratified basement has been identified on all of these profiles beneath the post-rift unconformity updip from the BMA (Hutchinson et al., 1983, Austin et al., 1990, Oh et al. 1991, Holbrook et al., 1994). The northern most line, USGS 32, has layered stratigraphy present below the unconformity, implying Paleozoic stratigraphy extends to offshore Cape Fear. The Alleghenian suture lies north of the Paleozoic strata, most reasonably as the Carolina-Mississippi fault. This interpretation is also supported by geochemical

analysis that demonstrates the Uchee, Savannah River, Charleston and Suwannee terranes are all of Gondwanan or Peri-Gondwanan affinity and may have acted as an intact crustal block (Mueller et al., 2013).

1.6 IMPLICATIONS

Implications of this interpretation include that (1) the Suwanee-Wiggins suture of Thomas et al 1989 is a Proterozoic terrane boundary internal to the African crust, and is a passive marker during subsequent Phanerozoic deformation, (2) the Alleghanian suture between the Gondwanan and Laurentian continents is located along the northern and western boundary of the former Charleston/Brunswick terrane, (3) extension within the South Georgia rift basin took place primarily, if not exclusively, within crust of African affinity, (4) a major change in crustal structure of Eastern North America takes place at the latitude of Cape Lookout, NC, where the crust is dominated by African affinity to the south, and of Peri-Gondwanan affinity to the north.

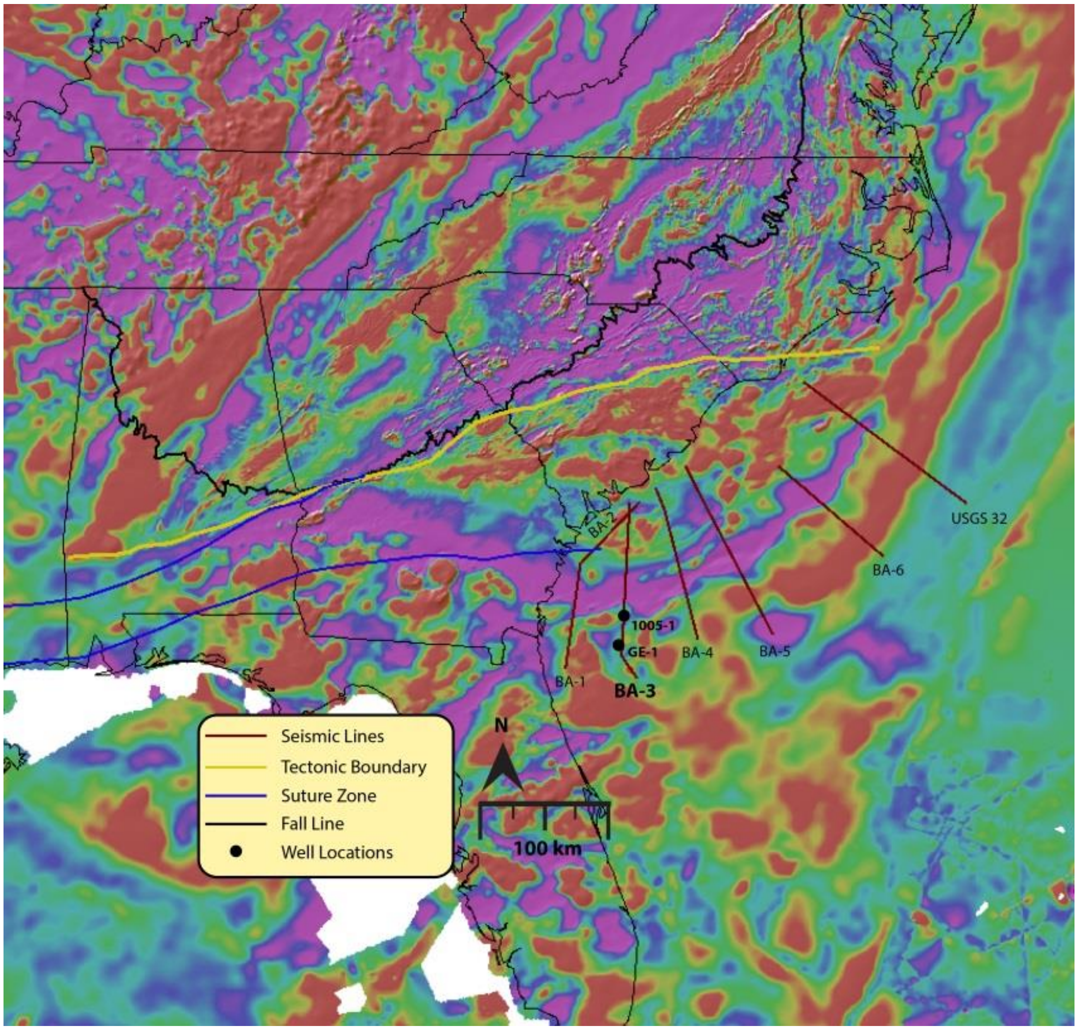

Figure 1.1. Map of southeastern North America showing aeromagnetic anomaly patterns, locations of seismic and well data, and the divisions of major tectonic boundaries from Higgins and Zeitz 1983 and Thomas 1989. The Brunswick Magnetic Anomaly (BMA) is evident from the magnetic anomaly map marking a magnetic low that spans south of Cape Hatteras, swinging onshore Georgia, to eastern Alabama. Seismic profiles include lines 1-6 from the BA seismic survey as well as USGS lines 32. All of these seismic lines have been interpreted to contain stratified basement present below the post rift unconformity. The two wells, COST GE-1 and Transco 1005-1, are the only wells in the region to penetrate rocks below the post rift unconformity. The wells provide well constraints for seismic profile BA-3. Also, the map contains the tectonic boundary of two terranes interpreted by Higgins and Zeitz 1983 on the basis of varying magnetic signature. The broad (~100km wide) suture zone interpreted by Thomas 1989 is included.

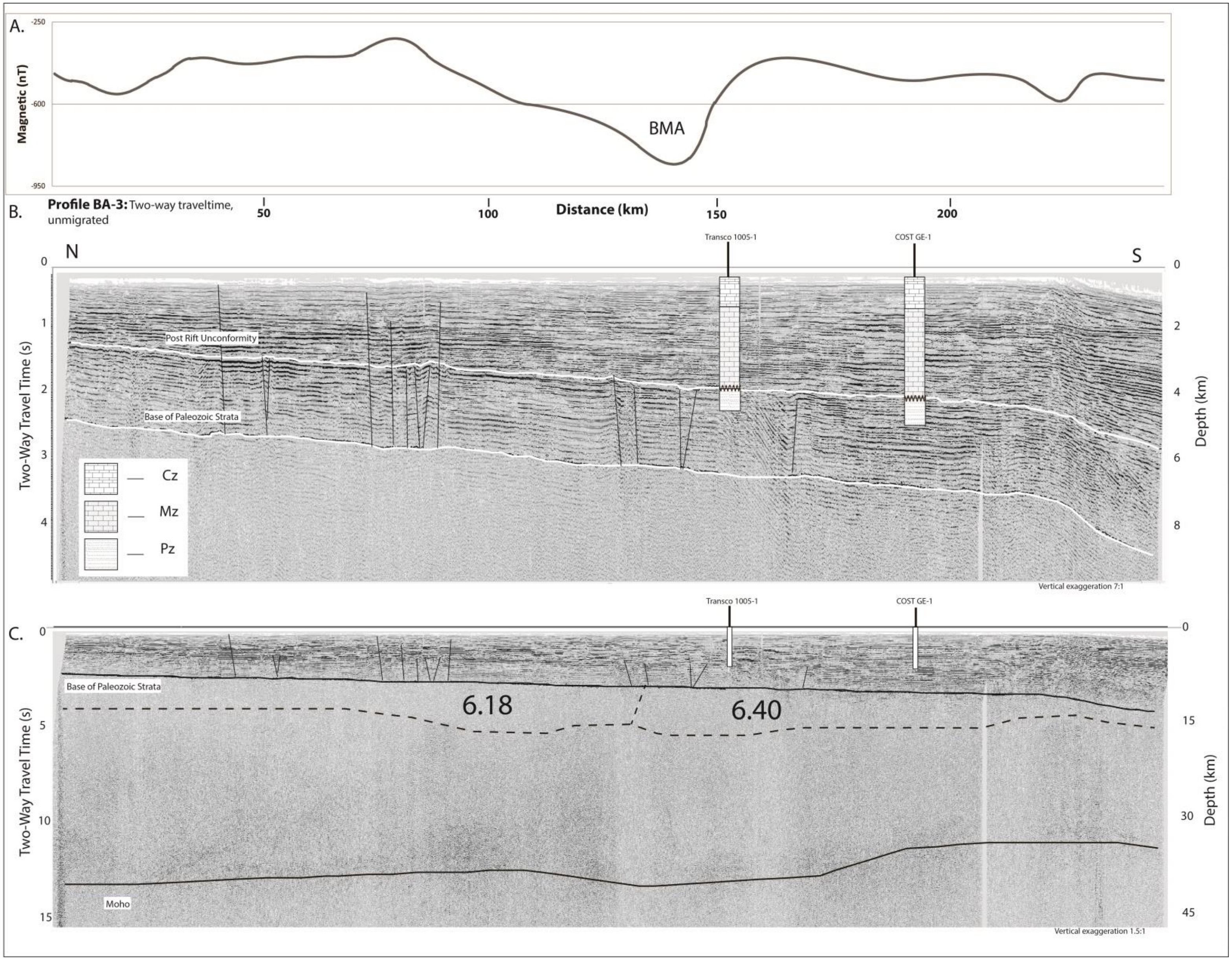
A.
Magnetic (nT)
-250
-600
-950
BMA
B.
Profile BA-3: Two-way traveltime, unmigrated
50
100
Distance (km)
150
200
Transco 1005-1
COST GE-1
N
S
Two-Way Travel Time (s)
Depth (km)
Post Rift Unconformity
Base of Paleozoic Strata
Cz
Mz
Pz
Vertical exaggeration 7:1
C.
Transco 1005-1
COST GE-1
Base of Paleozoic Strata
6.18
6.40
Two-Way Travel Time (s)
Depth (km)
Moho
Vertical exaggeration 1.5:1

Figure 1.2. A: Magnetic Profile along profile BA-3. B: Interpreted BA-3 section with well ties to Transco and COST wells. Interpretations include the post rift unconformity, the base of Paleozoic stratigraphy, and faults identifiable below the post rift unconformity. C: Crustal scale image of seismic line BA-3. Interpretations include the base of Paleozoic stratigraphy and the Moho. The location of the Moho suggests normal continental crustal thickness until ~230, where crustal thinning in apparent. Superimposed in the seismic section are velocities (km/s) from the velocity model generated by Lizarralde et al. 1994. The velocity model demonstrates different internal velocities for the crustal section below the Paleozoic stratigraphy.

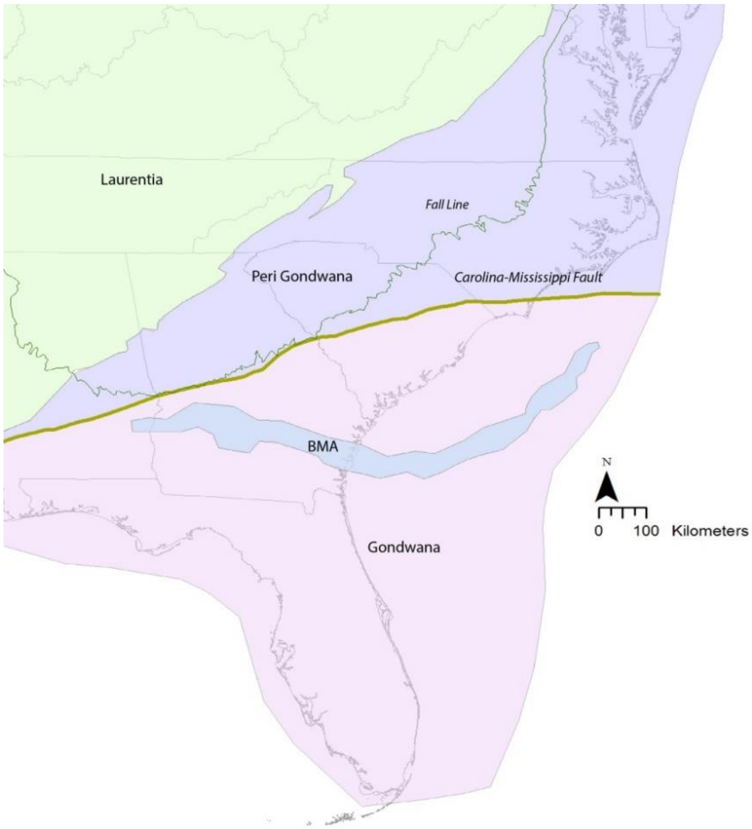

Figure 1.3. Revised tectonic map showing Charleston/Brunswick/Suwanee as an intact piece of Africa, with a northwestern boundary defined by the Carolina-Mississippi fault (Higgins and Zietz, 1983) and continuing out to the truncation of the BMA. This model presents the BMA located exclusively within the African crustal block

CHAPTER 2

REANALYSIS OF THE SOUTHEAST ATLANTIC MARGIN POST-RIFT UNCONFORMITY AND EXTENT OF THE CENTRAL ATLANTIC MAGMATIC PROVINCE

2.1 INTRODUCTION

Amidst the breakup of the super continent Pangaea, rifting was accompanied by extensive volcanism resulting in a large volume of magmatic material emplaced over a short period of time. Evidence of magmatism is preserved in dikes, sills and extrusive lava flows on North and South America, Africa and Europe known as the Central Atlantic Magmatic Province (CAMP) (Marzoli et al., 1999). CAMP spans 7 million square kilometers, making it one of the most aerially extensive magmatic provinces (Marzoli et al., 1999; McHone 2000). Geochronology analysis radiometrically dates all CAMP volcanics to roughly 200 Ma, indicating the material deposited during a short period of time and was synchronous with rifting events that took place near the Triassic Jurassic boundary (Olsen et al. 1997; Marzoli et al. 1999; Mchone 2000; Hames 2000; Olsen et al. 2003). CAMP provides insight toward rift basin and passive margin evolution, as well as the timing and nature of the opening of the Atlantic Ocean.

The South Georgia Rift-Basin (SGR) of North America formed during continental rifting that began in the Triassic and continued through the Jurassic. The SGR was interpreted to contain a massive CAMP continental flood basalt overlying all of the

synrift basin sediment (Chowns and Williams, 1983; Mcbride et al. 1989). The revised structure of the SGR constrains the extrusive basalt flows to few isolated locations

(Figure 1) (Heffner et al. 2012). Previous geophysical interpretations suggest this continental flood basaltextends to the offshore region, geographically underlying the Carolina Trough and Blake Plateau Basin (Dillon et al. 1979). The extent of the CAMP continental flood basalt identified in the SGR was mapped from correlation with a high amplitude seismic reflection known as the J-Horizon**;** however, the J-Horizon has been reevaluated as a contact between sediments and the base of the Coastal Plain regardless of the presence of basalt onshore (Heffner et al. 2012). We examine the implications of these findings in the offshore, where the J-Horizon extends, and subsequently, where the CAMP continental flood basalt was projected. By reexamining seismic profiles and well data, we determine the J-Horizon correlates to a regional contact between post rift sedimentary rocks and pre-rift basement rather than a continuous flood basalt. We determine the J-Horizon does not exclusively correlate to CAMP and does not represent a 200 Ma isochron. Our interpretation implies the timing of southern central Atlantic Ocean is not constrained to 200 Ma and the opening of the central Atlantic Ocean along the east coast of the United States was not necessarily diachronus.

2.2 BACKGROUND

2.2.1 PASSIVE MARGIN FORMATION

Passive margins form as a result of lithospheric extension accompanied by a thermal anomaly leading to continental breakup (Mckenzie 1979). The process of continental breakup is classified into two stages: rift and drift. The rift stage denotes the period of crustal thinning and extension while the drift stage indicates the generation of new

oceanic crust (Balley 1982). The change from rift to drift phase indicates a change from mechanical to thermal subsidence, leading to different depositional patterns. After continental extension and during the beginning of the drift phase, an erosional period preserved in the rock record as the post rift unconformity (PRU) forms (Klitgord et al., 1988). Based on the amount of extension and magmatic input that occurs during the rifting process, passive margins classify as either volcanic or non-volcanic (Mutter et al. 1988). Common features observed on volcanic passive margins include landward basaltic flows and a volcanic wedge observed in seismic as seaward dipping reflectors (SDRs) (Hinz 1981; Planke 2000). SDRs have been identified in seismic reflection data along many continental margins and have been attributed to volcanic sequences associated with the final pulse of continental rifting and the onset of seafloor spreading (Hinz et al. 1981 Eldholm et al 1987 White et al. 2007).

2.2.2 TECTONIC SETTING

Our study focuses on the crustal structure beneath the Carolina Trough and the Blake Plateau Basin, located in the Atlantic Margin of the eastern United States. These two structures are post rift sedimentary basins that have been the major depocenter of the Appalachian Mountains since the Jurassic. During Mesozoic time, continental thinning and extension caused rifting and separation of the North America and African plates leading to widespread volcanism, defining this passive margin as a volcanic margin (Hinz et al. 1981, White and McKenzie 1989, McBride et al. 1989, Austin et al. 1990, Oh et al. 1995). Seismic reflection and refraction studies provide constraints on crustal structures

leading to the interpretation that this volcanic margin contains a large continental flood basalt, a wedge of inner SDRs and outer SDRs (Austin et al., 1990; Lizaralde et al., 1994; Holbrook et al., 1995; Oh et al., 1995).

2.2.3 J-HORIZON

2.2.3.1 ONSHORE

The J-horizon is a strong smooth seismic reflection identified near Charleston, South Carolina (Shilt et al. 1983). The reflection appears continuous and widespread in proximity to the SGR and originally correlated to a sedimentary basalt contact (Shilt et al. 1983; Hamilton et al. 1983). A thick sequence of basalt identified in the Clubhouse Crossroads well drilled in Summerville, SC (Gottfried et al. 1983) served as the control point to interpret the J-Horizon as an extensive Jurassic age basalt flow. The basalt identified in the Clubhouse Crossroads well has been dated to 200 Ma and identified as part of CAMP (Hames 2000). The SGR basin contains Triassic age syn-rift deposits and was interpreted to have this CAMP continental flood basalt overly all of the rift basin sediment (Mcbride 1989). The structure of the SGR has been redefined and basalt has been constrained to few isolated regions (Heffner et al., 2012). Therefore, the J-Horizon does not correlate to a sedimentary basalt contact, but actually represents the base of the coastal plain (Heffner et al. 2012).

2.2.3.2 OFFSHORE

The J-Horizon was first observed offshore on multichannel seismic profiles collected by the United States Geological Survey and correlated as a sediment basalt contact (Dillon et al. 1979). This interpretation was formulated based on the similar reflection observed

onshore. The Clubhouse crossroads well is the closest well control that was used to correlate the J-Horizon, located ~80 km away. The strongest line of evidence supporting a large flood basalt province offshore South Carolina was correlation with the J-Horizon onshore. Since the J-Horizon located onshore has been determined as the base of the coastal plain, we reevaluate the existing data offshore to reinterpret the nature of this seismic reflection.

2.2.4 OPENING OF THE ATLANTIC OCEAN

Sedimentation poorly constrains the opening of the central Atlantic Ocean of North America. The best stratigraphic constraints are provided by the youngest sedimentation below the PRU and the oldest sediment above the PRU. The youngest sediment observed below the PRU are Triassic age syn-rift sediments found onshore of the southern central Atlantic Ocean. The oldest post rift sediment identified offshore through well logs is late Jurassic in age. Seismic data shows that additional post rift strata lies beneath the oldest sediment identified on the southern central Atlantic, however, there is no definitive age for this sediment. Therefore, stratigraphy constrains the opening of the southern central Atlantic between Late Triassic and Late Jurassic time. Rift basins onshore of the northern central Atlantic contain Early Jurassic sedimentation and wells have identified late Jurassic sediments offshore in the northern central Atlantic. The opening of the northern central Atlantic is constrained between the Early Jurassic and Late Jurassic and thought to have opened ~185 Ma (Manpeizer and Cousminer, 1988). Klitgord et al. 1988 postulated the central north Atlantic opened within a relatively short period of time and represents one event.

The sequence of SDRs located offshore in the Carolina Trough and Blake Plateau

Basin formed during the final pulse of continental breakup and the initiation of sea floor spreading (Austin et al., 1990; Oh et al., 1995). In the Carolina Trough, the J-Horizon overlies the sequence of SDRs. Therefore, the opening of the southern central Atlantic has been reevaluated to opening 200 Ma (Withjack et al., 1998). This reasoning led to the hypothesis that the opening of the central Atlantic of North America was diachronus (Withjack et al., 1998; Schlische et al. 2003).

2.3 WELL DATA AND SEISMIC SURVEYS

In the Carolina Trough and Blake Plateau Basin, a number of exploratory wells have been drilled for scientific purposes and oil and gas exploration. Despite numerous wells in this region, few penetrate basement rocks. The two wells that directly penetrate basement in the Blake Plateau Basin are the COST GE-1 well (Rhodehamel 1979, updated in Poag et al. 1991), and the Transco 1005-1 well (summarized in Dillon and Popenoe 1988). These wells penetrate post rift deposits as early as late Jurassic overlying Paleozoic basement (Figure 2) (Poppe et al. 1995). Below the post rift unconformity, the COST GE-1 well penetrated weakly metamorphosed sedimentary rocks and meta-igneous rocks (Scholle, 1979). These igneous rocks are more prevalent toward the bottom of the well and have been dated to 355 Ma (Scholle, 1979). This provides a minimum age of Devonian for the sediments in this Paleozoic section below the unconformity. The Transco 1005-1 well penetrated Silurian shale and Ordovician quartzite underneath the post- rift unconformity (Poag and Valentine 1988). It is important to note that neither of these wells encounter Jurassic basalt, therefore, no Jurassic age basalt has been drilled in the Blake Plateau Basin. No deep offshore wells penetrate below the post rift unconformity in the Carolina Trough.

A number of multichannel seismic lines have been acquired and analyzed in the Carolina Trough and the Blake Plateau Basin. Seismic data clearly shows an increase in reflectivity on the post rift unconformity in the area marked the "J" Horizon. This region represents a large acoustic impedance on the unconformity. On seismic lines near our closest well control, Transco 1005-1, the amplitude of the reflection decreases. The seismic data near the Transco 1005-1 well illustrate a series of dipping reflections identified as graben structures containing unmetamorphosed Paleozoic sediments (Poppe et al 1995).

Line BA-6 is located in the Carolina Trough has been interpreted to contain the continuous J-reflection as Jurassic age basalt overlying the unconformity (Austin et al 1990). This profile also contains a series of SDRs located below the post rift unconformity (Austin et al. 1990).

We interpret line BP-6 to contain the post rift unconformity identified as a disconformity landward of shotpoint 1100 and predominately an angular unconformity seaward of shotpoint 1100 (Figure 3). The unconformity appears to truncate reflections seaward of shotpoint 1100 and the post rift reflections above the unconformity onlap onto this surface. A series of SDRs are identified that coincide with the SDRs identified on line BA-6. The post rift unconformity overlies the sequence of SDRs identified on this seismic profile.

2.4 REINTERPRETATION

After reevaluating seismic and well data across the region, we reinterpret the J-Horizon to be characteristic of a contact between post rift sediments and pre-rift basement. The

increased reflectivity of the J-Horizon represents changes in the Paleozoic basement rocks as seen onshore. Well control from the COST GE-1 and Transco 1005-1 indicate that the unconformity overlies Devonian and older meta-sedimentary rocks. We identify similar Paleozoic stratigraphy to underlie the post rift unconformity in the Carolina Trough.

The well data from the Clubhouse Crossroads penetrate a basalt syn-rift sedimentary contact. No contact between CAMP basalt and Paleozoic basement has been observed onshore. On this basis, we determine the Clubhouse Crossroads well does not serve as a sufficient analog to interpret the nature of the unconformity offshore, where no syn-rift stratigraphy is present. Therefore, we reinterpret the J-Horizon as a portion of the post rift unconformity and a non-volcanic surface representing the rift drift transition beneath the Carolina Trough and Blake Plateau Basin.

2.5 DISCUSSION

We determine the J-Horizon is not indicative of Jurassic age basalt offshore of South Carolina. The basalt identified in the Clubhouse Crossroads well does not represent a widespread continental flood basalt, but is part of isolated extrusive igneous flows associated with CAMP. This limits the aerial extent of volcanic material emplaced ~200 Ma during the CAMP event. The surface named the J-Horizon does not represent an isochron representing ~200 Ma because the reflection is not exclusively associated with CAMP. This seismic reflection represents the post rift unconformity, which is a time transgressive surface. Therefore, this surface cannot be used as a time constraint regarding the opening of the southern central Atlantic Ocean of North America. Our best time constraints on the opening of the southern central Atlantic Ocean are stratigraphic

constraints that place the opening of the Atlantic Ocean between Late Triassic and Late Jurassic. Also, we suggest that SDRs located offshore were not emplaced during CAMP, but are part of a later volcanic pulse associated with the opening of the central Atlantic Ocean. Our interpretation supports the hypothesis that the central Atlantic Ocean opening within a short period of time around ~185 (Klitgord et al., 1988) because no evidence would suggest that the opening of the central Atlantic Ocean was diachronus.

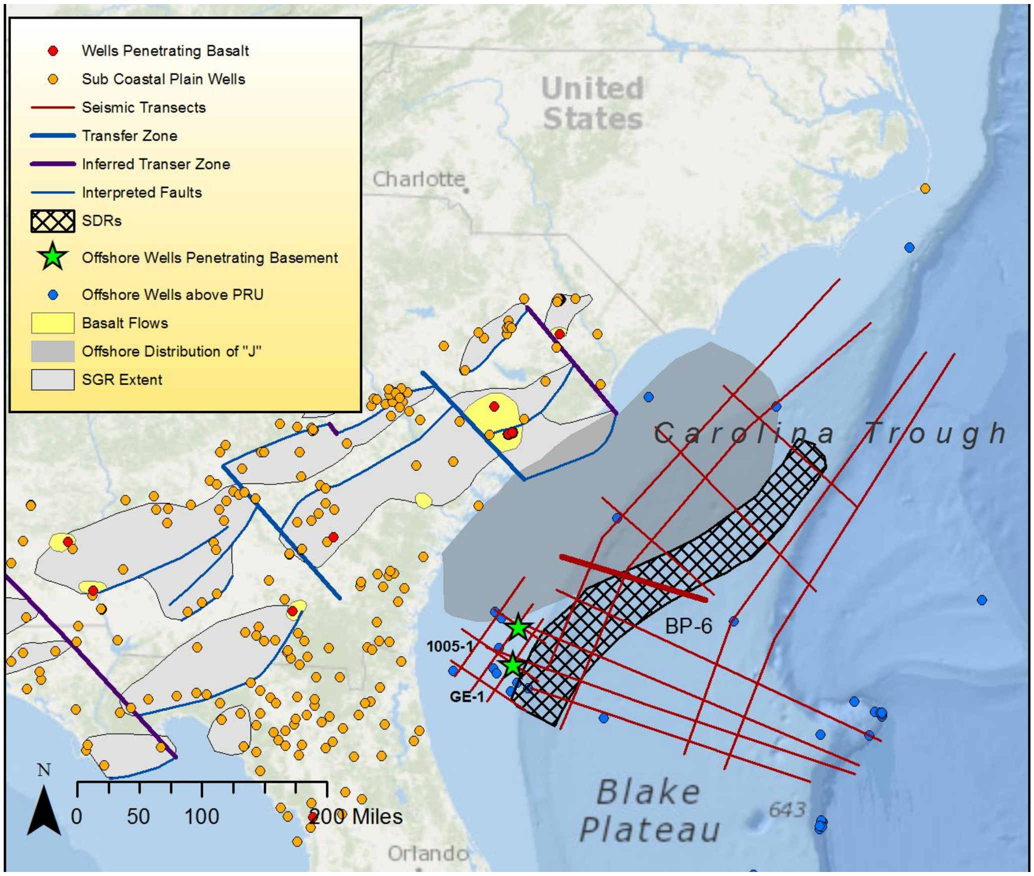

Figure 2.1. Map of Carolina Trough and Blake Plateau Basin including the extent of the South Georgia Rift Basin and revised extent of basalt onshore (from Heffner and Knapp). The onshore wells depict well penetrations below the post rift unconformity that do encounter Jurassic age basalt and wells that penetrate below the post rift unconformity that do not encounter basalt. The two wells offshore that penetrate below the post rift unconformity are highlighted and the location of seismic lines BA-6 and BP-6 are highlighted. The offshore distribution of “J” is the shaded grey region (from Dillon et al. 1983) and the location of SDRs identified (from Oh et al., 1995) is represented by the checkered pattern.

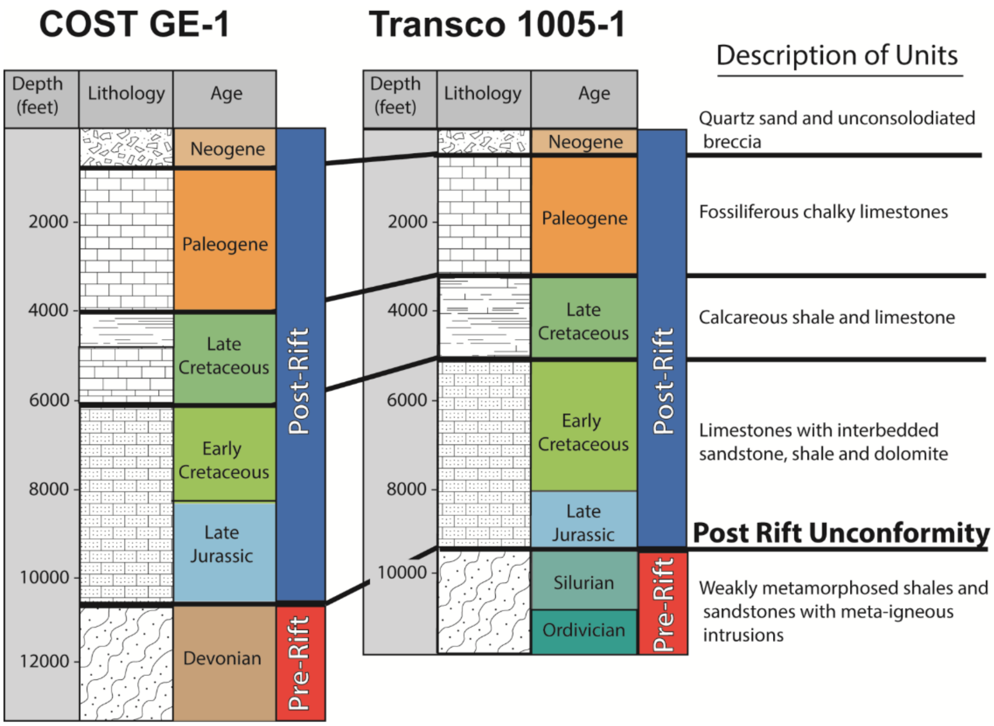

Figure 2.2. Summary of COST GE-1 well and Transco 1005-1 wells. These two stratigraphic columns reveal the two offshore wells that penetrate Paleozoic basement. Both of these wells indicate a contact between late Jurassic post rift sediment and pre rift Paleozoic basement at the post rift unconformity. Neither of these wells penetrate Jurassic age basalt.

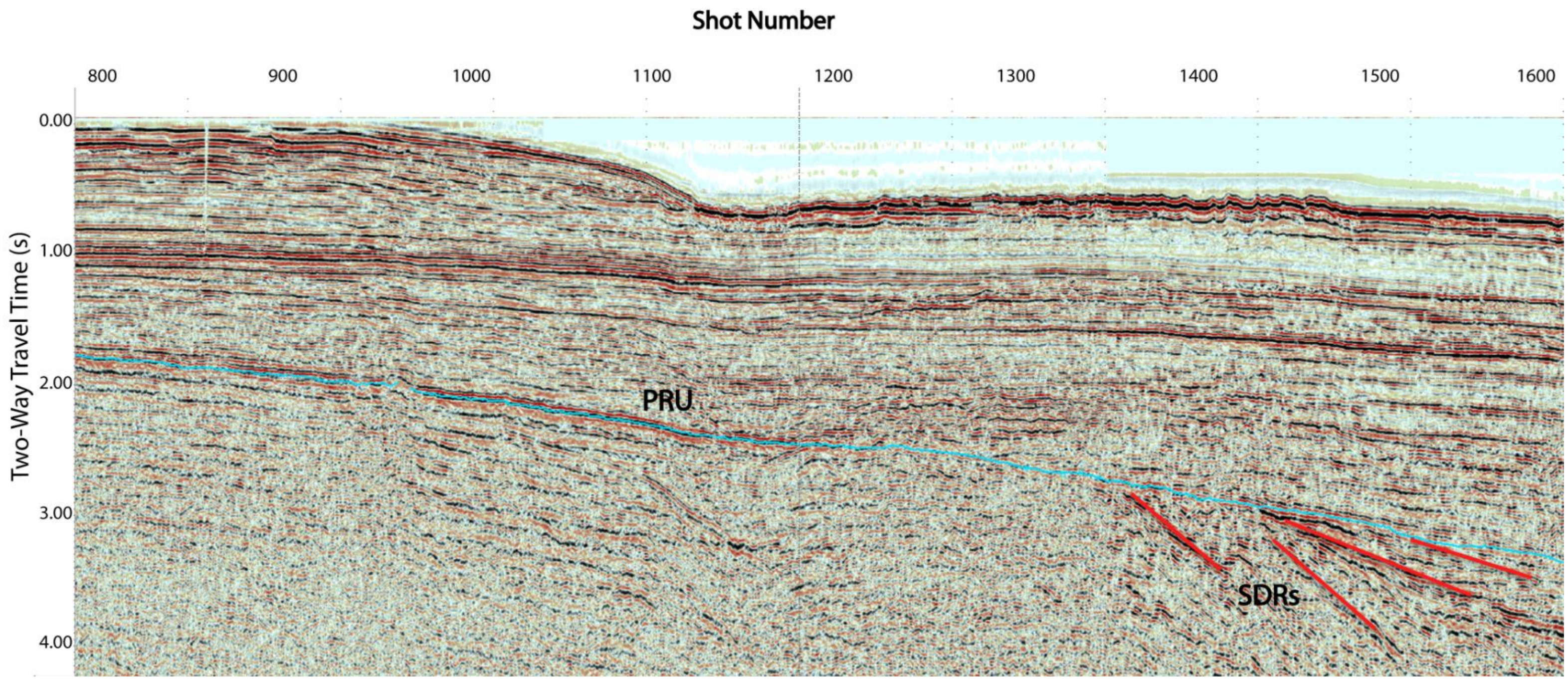

Figure 2.3. Seismic line BP-6 illustrating the post-rift unconformity as well as packages of SDRs interpreted as a volcanic sequence. The post-rift unconformity is identifiable as a regional angular unconformity. The sequence of SDRs underlies the post rift unconformity in the Carolina Trough.

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