ABSTRACT

Magnetic Investigation of the Continental-Oceanic Crustal Boundary; Northern Gulf of Mexico

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Current mapping of magnetic intensity data shows that the Gulf Coast magnetic anomaly is not one anomaly but two distinct anomalies, with one portion trending parallel to the margin before curving northward through central Texas, and then northeastward into the Balcones Fault Zone along the eastern trace of the Ouachita Deformation Front, and the other following the coastline into Louisiana. Multiple profiles perpendicular to the geologic strike of the anomalies lead to the interpretation of these anomalies as the superposition of a normal rifting feature and a pre-existing crustal feature remnant of a complex tectonic history in the region. The location of the pre-existing feature and the rift anomaly suggest pre-rifting lithosphere conditions influenced the rifting process as seen in other passive rifting models.

Magnetic Investigation of the Continental-Oceanic Crustal Boundary; Northern Gulf of Mexico

by

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A Thesis

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CHAPTER ONE

Introduction

Continental rifts are elongate, normal fault-bounded troughs formed by extension of the continental crust. If lithospheric extension and thinning proceeds to the point of complete rupture of the lithosphere, continental breakup occurs and a new ocean basin forms between the two diverging rifted, passive margins (Sengor and Natal'in, 2001; Merle, 2011). Passive margins mark the transition from continental to oceanic crust within a single tectonic plate and are commonly classified as volcanic or non-volcanic depending on the extent and timing of volcanism in the rifting process, though these classifications can be misleading (Merle, 2011).

Two mechanisms have been proposed for lithospheric extension and thinning leading to continental breakup (Merle, 2011). The first method of rifting is attrributed to the action of mantle currents, which apply heat and stress to the base of the lithosphere directly beneath the rift. This form is called active rifting. The mantle currents that cause active rifting could exist in the form of mantle plumes (White and McKenzie, 1989) or overturning of the asthenosphere (Mutter et al., 1988). In either case, the result is thought to be initial uplift, followed by extensive magmatic activity that begins before rifting. Magmatic intrusion occurs in the forms of plutons, dikes, sills, and crustal underplating. Volcanism occurs as extensive lava flows that fill the rift basin, resulting in so called seaward dipping reflectors, recognizable on the resulting passive margins.

In the second mechanism of continental breakup, lithospheric extension is attributed to far -field stresses due to plate motion. This form of lithospheric extension is called passive rifting. In passive rifting, faulting and mechanical thinning of the upper crust and stretching of the lower lithosphere are thought to precede uplift and volcanism. Thinning continues as the rift matures until the lithosphere is severed and new oceanic crust is formed. The location of lithospheric failure in passive rifting is commonly thought to be controlled by pre-existing lithospheric weaknesses that are exploited during the application of the far field stresses. In many cases the rifting stops before the lithosphere is completely ruptured, though if the rifting process does proceed to the point of complete continental breakup the newly formed oceanic crust is bounded by passive margins and seafloor spreading begins. Evolution of these margins is dominated by subsidence with little late stage volcanism. Most passive-rifted margins are therefore characterized by large amounts of sediment loading.

Many passive margins in the world have been studied extensively including the Cuvier and Exmouth margins that formed during the separation of Australia and India (Hopper et al., 1992), the Walvis and Pelotas Basins that mark the rift between South America and Africa (Menzies et al., 2002), and the United States East Coast margin that characterizes the opening of the Atlantic Ocean (Grow and Sheridan, 1988). These margins all show similar features (rift pillows, seaward dipping reflectors, and crustal thinning and extension within transitional crust), but the extent of each feature differs in each margin. The rift pillow is the main rift feature seen in all passive margins and is interpreted as a mafic igneous complex attributed to underplating or serpentinization of the mantle as rifting occurs (Mickus et al., 2009; Alsop and Talwani, 1984; Skogseid, 2001; Menzies et al., 2002). The placement of the rift pillow ranges from a width and depth of 150 km wide and 8 km deep in the Namibia margin (Skogseid, 2001) to 25 km wide and 15 km deep in the U.S. East Coast margin (Alsop and Talwani, 1984). The size of the seaward dipping reflector provinces and the thickness of emplaced oceanic crust vary widely in passive margins and are attributed to the driving force in the rifting process (Menzies et al., 2002). The Pelotas and Walvis basins have seaward dipping reflector provinces greater than 200 km wide extending more than 3000 km along the coast on both sides of the Atlantic, formed as basaltic material was emplaced over the extended crust (Talwani and Abreu, 2000; Menzies et al., 2002). The Cuvier margin has an extremely thick oceanic crust adjacent to the margin; attributed to a large amount of volcanism during rifting resulting from a plume driven rifting process (Hopper et al., 1992). The Exmouth margin just west of the Cuvier margin shows an average thickness of oceanic crust from a rifting process interpreted to be driven by far-field stresses (Hopper et al., 1992).

Though all margins show similar and distinct features, the variability between margins make it impossible to determine singular driving forces for individual margins. For example, the Gulf of Mexico has been studied extensively (Mickus et al., 2009; Hall, 1990), but the thick sediment package causes difficulties in determining properties of the ocean-continent crustal boundary. Mapping and analysis of magnetic data has proven to be an effective method of determining subsurface structures. The fabric of these structures can be revealed by analyzing their magnetic signatures (Talwani and Abreu, 2000). The Texas portion of the Gulf of Mexico is an important region due to the suggestion that breakup of Pangaea initiated along the Texas Gulf Coast (Klitgord and Schouten, 1986), and has been studied previously using potential field methods by Mickus and others (2009).

The Texas Gulf Coast margin shows a sharp shelf break with a short zone of crustal thinning and extension. The pre-existing Ouachita orogenic zone acts as a region of increased lithospheric strength rather than a zone of weakened lithosphere, as is the typical case (Menzies et al., (2002). The fold and thrust belt associated with the suture zone shows virtually no extensional deformation (Huerta and Harry, 2012). Extension along this margin is mainly confined to regions seaward of the suture zone (Ewing, 1991).

The Texas Gulf Coast underwent a series of tectonic processes leading up to rifting and continental breakup. It has seen at least two separate cycles of rifting and orogeny: once during the formation of Laurentia, and again during the formation and separation of Pangaea (Thomas, 1991). Laurentia left behind its main craton, which was exposed in the Llano uplift of central Texas approximately 1.4 Ga (Thomas, 1991). At 1.1 Ga the crust was partially deformed during the Grenville orogeny, caused by a partial subduction of Laurentia and the formation of Rodinia (Thomas, 2005). The continent became fairly stable at this time and was left relatively unchanged until rifting began approximately 530 Ma.

Rifting resulted in the breakup of the Rodinia and the formation of the Iapetus Ocean (Thomas, 1991). The Ouachita orogenic belt was formed around 300 Ma when Gondwana and Laurentia collided, forming Pangaea (Thomas, 1991). The formation of Pangaea was a soft collision in which micro-continents and island arcs in the Iapetus Ocean were accreted into the suture zone of the supercontinent. The site of the modern Gulf of Mexico occupied the central region of Pangaea during the existence of the supercontinent. Beginning around 200 Ma, Pangaea split apart forming the modern

Atlantic Ocean isolating the North American, South American, and African continents. The breakup of Pangaea began along the western edge of the modern Gulf of Mexico with the separation of North America from the South American continent and the Yucatan Block (Dunbar and Sawyer, 1987). Rifting continued northward along modern United States East Coast margin separating the North American and African continents. These rifting and orogenic zones are significant pre-existing zones of weakness which could act as reactivation surfaces for newer rifts (Keller and Hatcher, 1999).

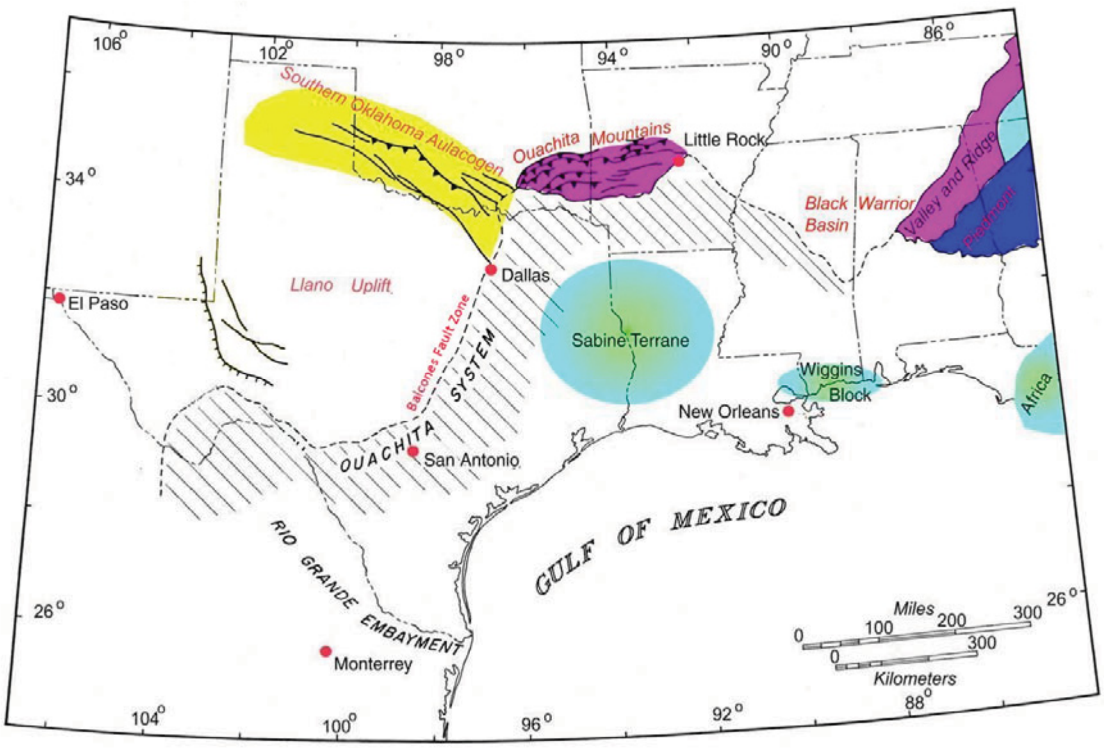


Figure 1. Modern tectonic features of the Texas Gulf Coast margin. Modified from Keller and Hatcher, 1999.

The Texas Gulf Coast margin has been interpreted to be a volcanic rifted margin with a triple junction to the south and a non-volcanic margin to the east, both left over from the breakup of Pangaea (Mickus et al., 2009). Mickus and others (2009) associated a large magnetic anomaly that parallels the Texas Gulf Coast to a volcanic pillow located along one edge of an interpreted failed triple junction left over from the breakup of Pangaea. Current mapping of magnetic intensity data shows that the gulf coast magnetic anomaly is not one anomaly but two distinct anomalies, with one portion trending parallel to the margin before curving northward through central Texas, and then northeastward into the Balcones Fault Zone along the eastern trace of the Ouachita deformation front, and the other following the coastline into Louisiana (figure 2). Previous passive margin studies have defined a single magnetic anomaly along the Texas Gulf Coast that might correspond to the U.S. East Coast anomaly (Hall, 1990) but fail to describe a secondary anomaly branching out of this region. The purpose of this study is to investigate the

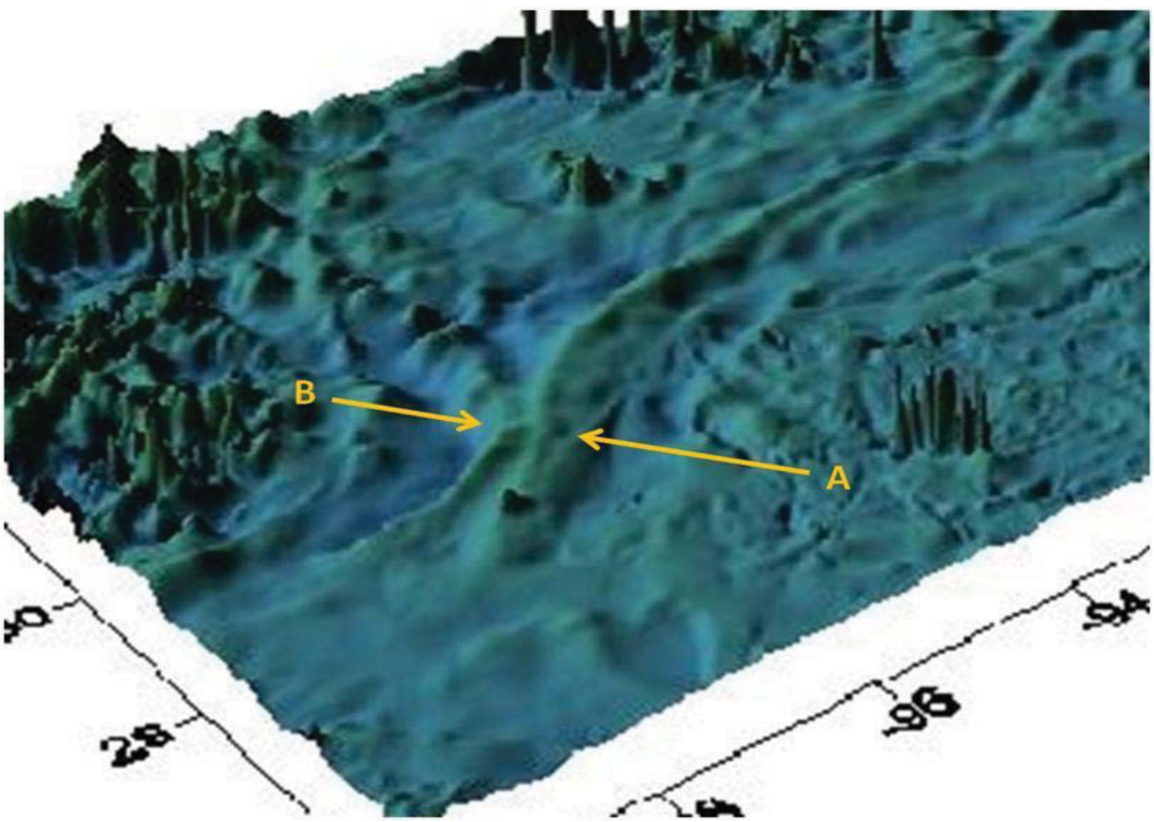


Figure 2. 3D magnetic intensity map of the U.S. Gulf Coast margin. Arrows show the locations of the two main magnetic anomalies as they parallel the Texas coast along the shortest zone of transition from continental to oceanic crust.

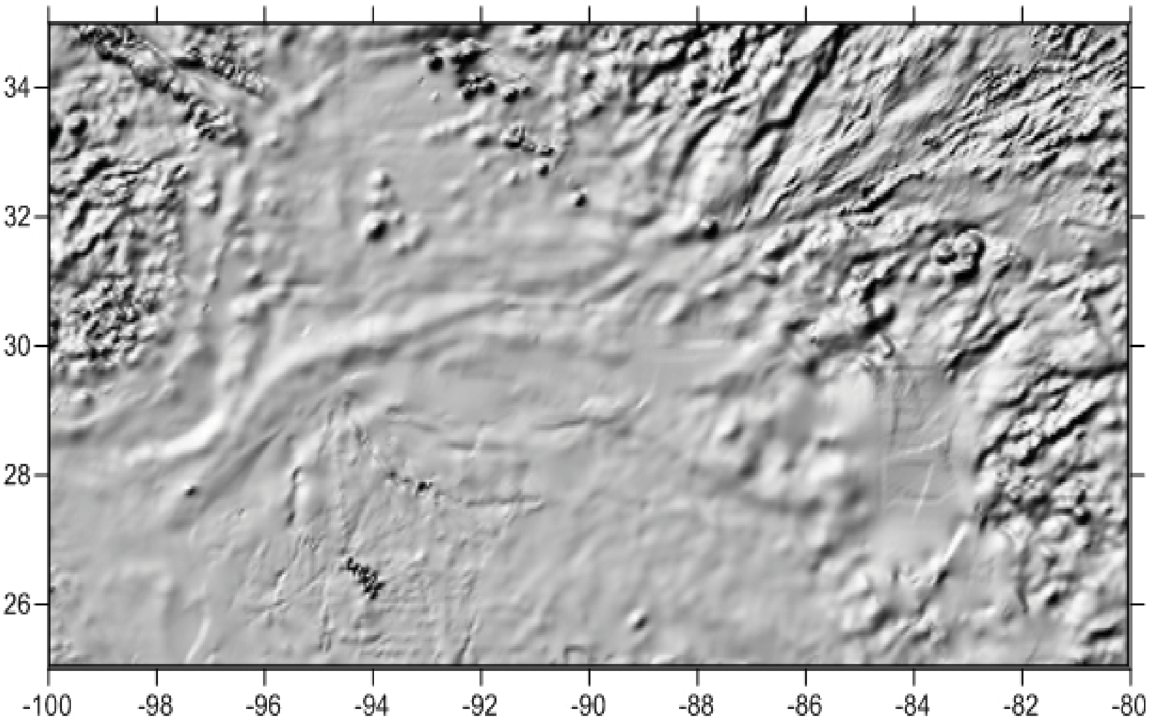
existence of two continuous magnetic anomalies in an effort to better understand the breakup anomaly and the nature of the boundary between transitional and oceanic crust. In considering multiple profiles along strike of the Gulf of Mexico margin, it is possible to determine how the breakup anomaly changes along the margin, how those changes influenced the opening of the Gulf of Mexico, and if the anomaly continues through the Gulf of Mexico into the Atlantic.

CHAPTER TWO

Methods

Aeromagnetic and gravity data are obtained for this study from the GeoNet database compiled by the University of Texas El Paso (Pan-American Center for Earth and Environmental Studies). The data are plotted to create shaded relief and intensity maps to characterize magnetic and Bouguer gravity anomalies (figure 4). The magnetic intensity and shaded relief maps of the region clearly show the Gulf Coast magnetic anomaly is comprised of two sub-parallel magnetic highs along the margin. Three profiles are then extracted from the GeoNet data sets that bisect the Gulf Coast anomaly. The eastern (MK5) and central (GO2) profiles are both 1500 km long and the western (EP) profile is 640 km. All three profiles contain the rift margin magnetic maximum as well as the second, inland magnetic maximum. Profiles are extracted at 2 km spacing by averaging the four closest data points in the dataset to yield each profile data point. The MK5 and GO2 profiles each contain 751 extracted points, while 306 points are extracted to form the EP profile. Locations for the magnetic data are converted to UTM coordinates to determine profile bearings. The magnetic profiles were then projected onto an average of Earth's main field, to isolate the magnetic anomaly for each profile.

Profiles are modeled using a variation of Talwani's magnetic and gravity modeling methods (Talwani and Heirtzler, 1964; Talwani and Abreyu, 2000). The magnetic model uses total intensity, declination, and inclination of Earth's averaged main field. It is assumed all magnetic signatures are induced, therefore no remnant field is calculated.



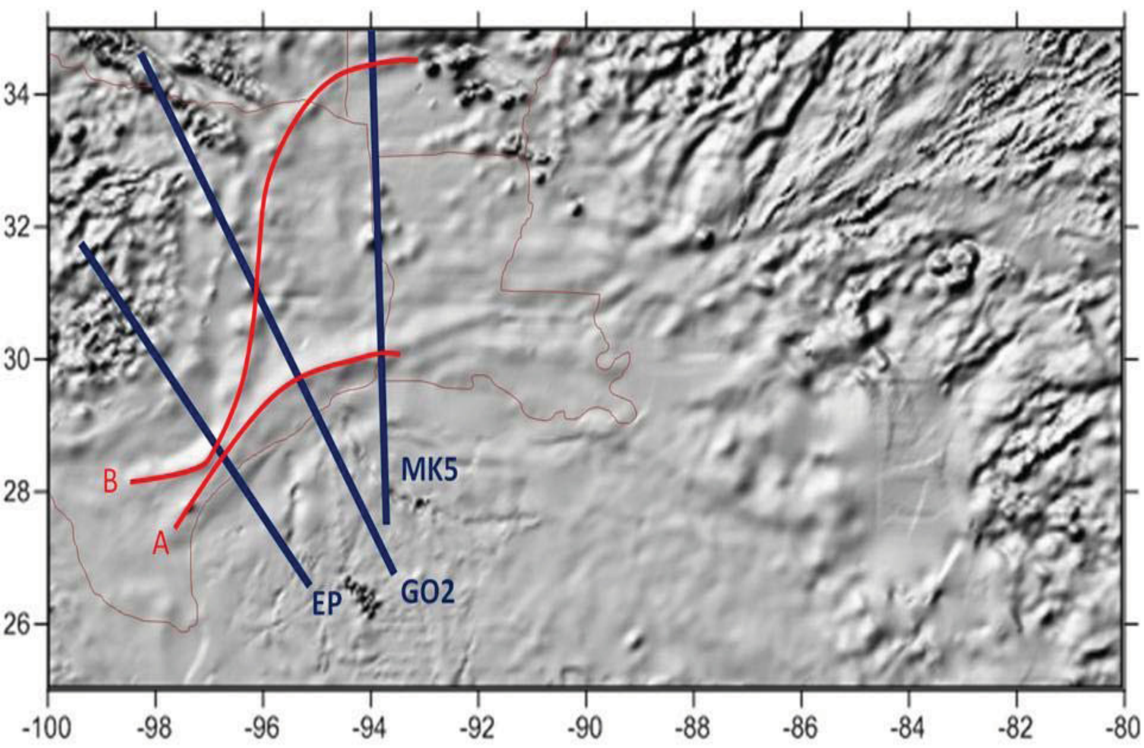


Figure 3. Shaded relief map of magnetic intensity data of the U.S. Gulf Coast Margin. Thick lines represent locations of magnetic profile models. Arrows show the locations of two main anomaly features as they parallel the Texas Coast. Landward anomaly (B) propagates northward through Texas joining to the Balcones Fault Zone and following the Ouachita Orogenic front eastward into Arkansas. The seaward anomaly (A) follows the coastline eastward through Louisiana.

The profiles are oriented perpendicular to the trend of the main magnetic maximum to maintain structural consistency across all modeled profiles. Polygons are created to simulate geologic features of uniform magnetic susceptibility in the subsurface. Susceptibilities and initial shapes of specific bodies are taken from previous margin studies of the Texas Gulf Coast and the United States East Coast passive margins (Mickus et al. 2009; Talwani and Abreu, 2000; Mickus and Keller, 1992). The size and shape of the polygons are then modified to best fit the observed magnetic data.

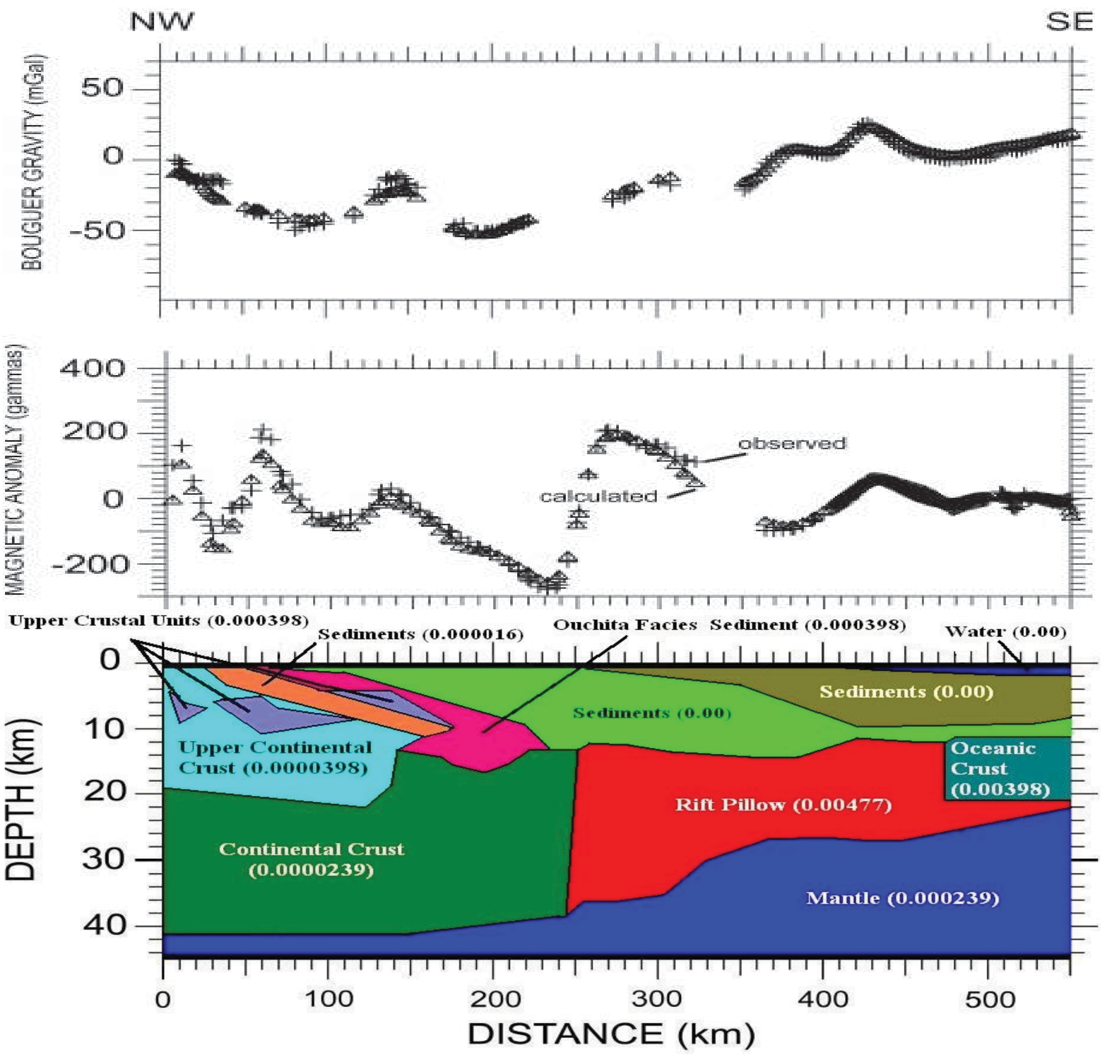


Figure 4. Lithospheric profile modeled from gravity and magnetic data. Location corresponds to the EP magnetic profile. Numbers are dimensionless magnetic susceptibilities in SI. Modified from Mickus et al., 2009.

The EP (figure 4) and MK5 (figure 5) geologic cross-section models are based on previous studies along the same lines (Mickus et al., 2009; Mickus and Keller, 1992). The EP profile extends in both directions beyond the length of the previous study (Mickus et al., 2009) and is modified to incorporate separate magmatic bodies corresponding to the peaks produced by the two distinct magnetic anomalies (figure 4). A separate transitional crust segment is added between the main rift features and the beginning of oceanic crust to fit a third smaller magnetic high. Estimates for the location of the landward edge of oceanic crust are made in previous potential field studies by Bird and others (2005) and Mickus and others (2009). The rift zone extending from the Llano uplift to sea floor along this profile is approximately 250 km, which is the shortest width of transitional crust along the Texas Gulf Coast.

The MK5 profile is created by reproducing the gravity model produced by Mickus and Keller (1992) (figure 5) and modifying the size and shape of the rift pillow, oceanic

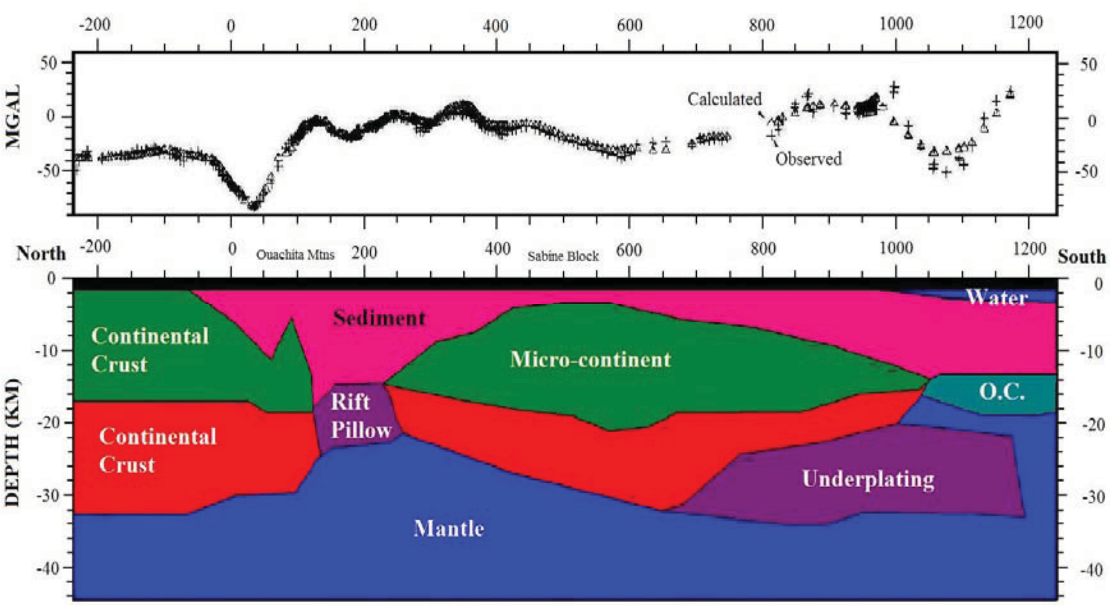


Figure 5. Lithospheric profile modeled from gravity data. Location of this model corresponds to the MK5 magnetic profile line. Modified from Mickus and Keller, 1992.

crust, transition crust and other geologic features to fit the magnetic data (figure 5). A Bouguer gravity profile is created using the same techniques as the magnetic profiles and matched to the Mickus and Keller (1992) study to ensure the model profile locations are accurate.

Gravity profiles are not modeled in this study because they lack the anomalous features that are seen in the magnetic profile data. Transitional crust is added between the rift anomaly and oceanic crust to match features of the observed magnetic data.

The GO2 model is created by modifying features from the MK5 profile, adding oceanic and transition crust from the EP profile, and introducing a micro-continent similar to the micro-continent seen in the model of Mickus and Keller (1992). Small surface features similar to those seen in the MK5 profile are added to fit peaks and troughs in the observed data. All three models are extended beyond the study region to eliminate edge effects in the calculated data. No attempt is made to model fluctuations in the observed data in the ocean basin and continental craton.

CHAPTER THREE

Results

The shaded relief maps of magnetic intensity in the region show a clear anomaly that parallels the coast line through Texas into Louisiana before trending offshore. This anomaly correlates spatially with the inferred location of the boundary between transitional and oceanic crust, and so is called the breakup anomaly. A second anomaly parallels the landward side of the breakup anomaly where the transitional crust and oceanic crust boundary is the shortest along the Texas Coast. To the east the second anomaly diverges from the breakup anomaly, curves north, and turns parallel to the seaward edge of the Ouachita deformation zone through Central Texas. It then joins with a third magnetic high bordering the Balcones Fault Zone through Texas and the Ouachita mountain system in Arkansas.

The magnetic intensity along the EP profile shows a clear second peak adjacent to the breakup anomaly associated with the opening of the Gulf of Mexico (figure 6). The anomalous features reach a magnitude of almost 300 nT when combined, and extend to a width of approximately 180 km. Due to the superposition of the features it is difficult to measure the width of the magnetic high associated only with the rift anomaly, but the half width of the feature measure just over 50 km suggesting the entire width to be approximately 100 km. The modeled rift pillow is split into two bodies placed next to one another to comprise a composite rift. The seaward body is interpreted to be a rift pillow associated with the Jurassic breakup and opening of the modern Gulf of Mexico.

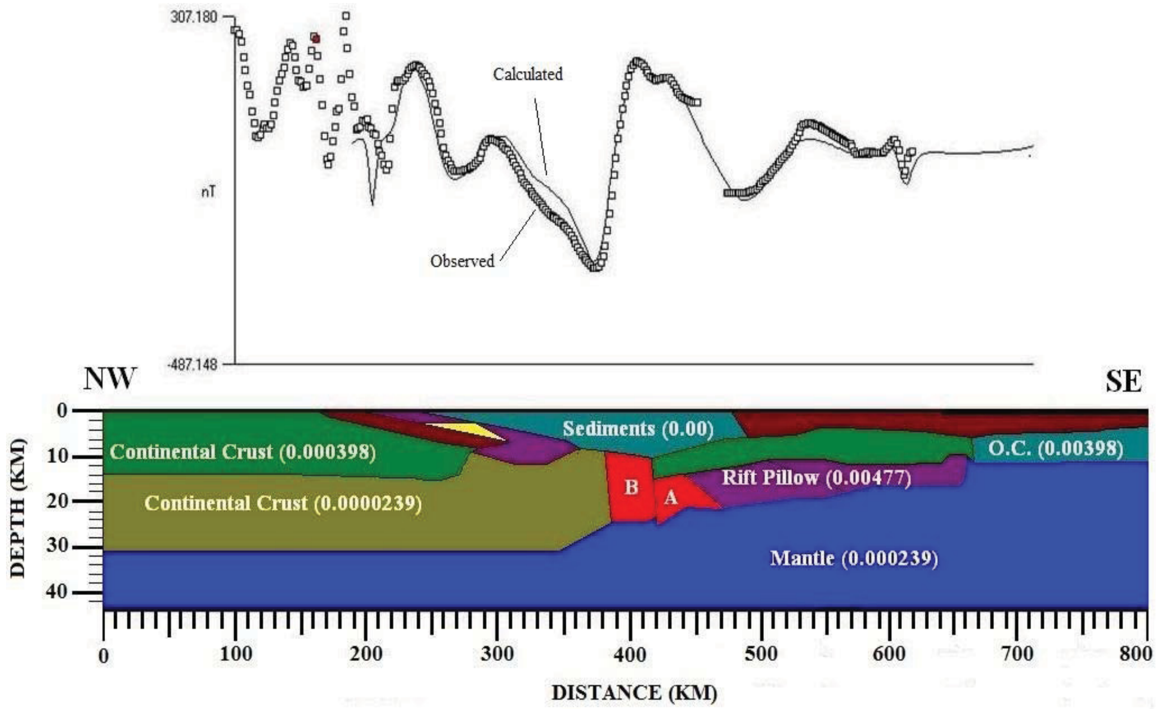


Figure 6. EP cross-section with associated calculated and observed magnetic anomaly data. Numbers are dimensionless magnetic susceptibility. Letters are: (A) Gulf Coast rift anomaly, (B) unnamed rift anomaly. Magnetic susceptibilities for A and B are 0.00477.

The landward body is interpreted to be an older remnant from a past rifting event, which pre-dates the opening of the Gulf of Mexico. There is little difference in modeling two smaller magmatic bodies compared to a single large body in this profile, though it results in two separate peaks, which separate further in successive models. The third smaller magnetic high on the seaward side of the model shows a good fit by the addition of transitional crust between the composite rift features and oceanic crust. The small magnetic low just landward of the oceanic crust in the data is matched well by a slight separation of transitional crust and the start of true oceanic crust.

The GO2 profile is characterized by two magnetic highs in the center of the profile, separated by approximately 200 km, and a small magnetic low on the seaward side of the profile (figure 7). The magnetic highs are separate, smooth anomalies that do not show the double-hump feature seen in the EP data. These two large magnetic highs are fit well by two magnetic bodies that are similar in size, shape and depth to those modeled in the EP model. The magnetic low on the seaward side of the model is fit by a small separation between the transitional and oceanic crust consistent with the low seen in the EP model.

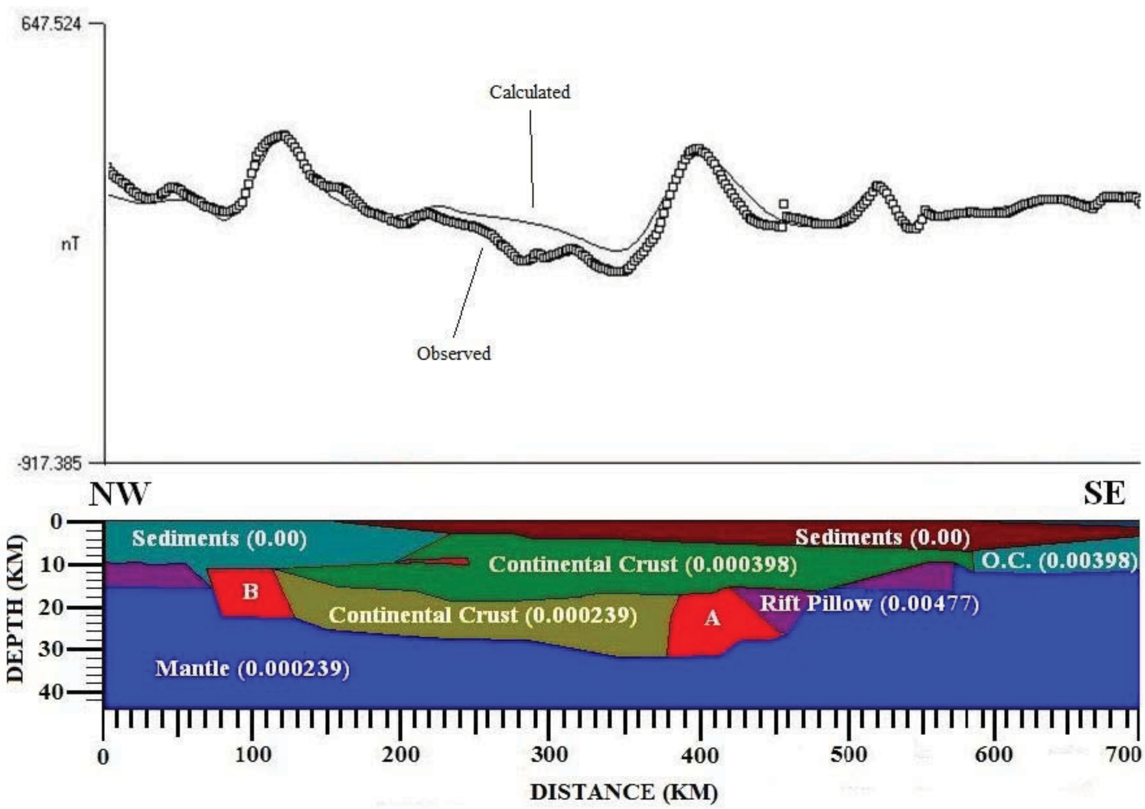


Figure 7. GO2 cross-section with associated calculated and observed magnetic anomaly data. Numbers are dimensionless magnetic susceptibility. Letters are: (A) Gulf Coast rift anomaly, (B) unnamed rift anomaly. Magnetic susceptibilities for A and B are 0.00477.

The MK5 model is characterized by two magnetic highs in the center of the profile separated by approximately 400 km (figure 8). The small magnetic low seen on the EP and GO2 profiles is less pronounced in this profile, but is still present, approximately 100 km seaward of the composite rift feature. The magnetic highs in the observed data are fit by modeling the same rift features as seen in the GO2 model and doubling the separation distance between them. The seaward side magnetic low is fit by a smoother junction between the transitional and oceanic crust. Smaller magnetic highs between the main bodies are fit with smaller, shallower versions of the magnetic bodies used on the models of the other profiles.

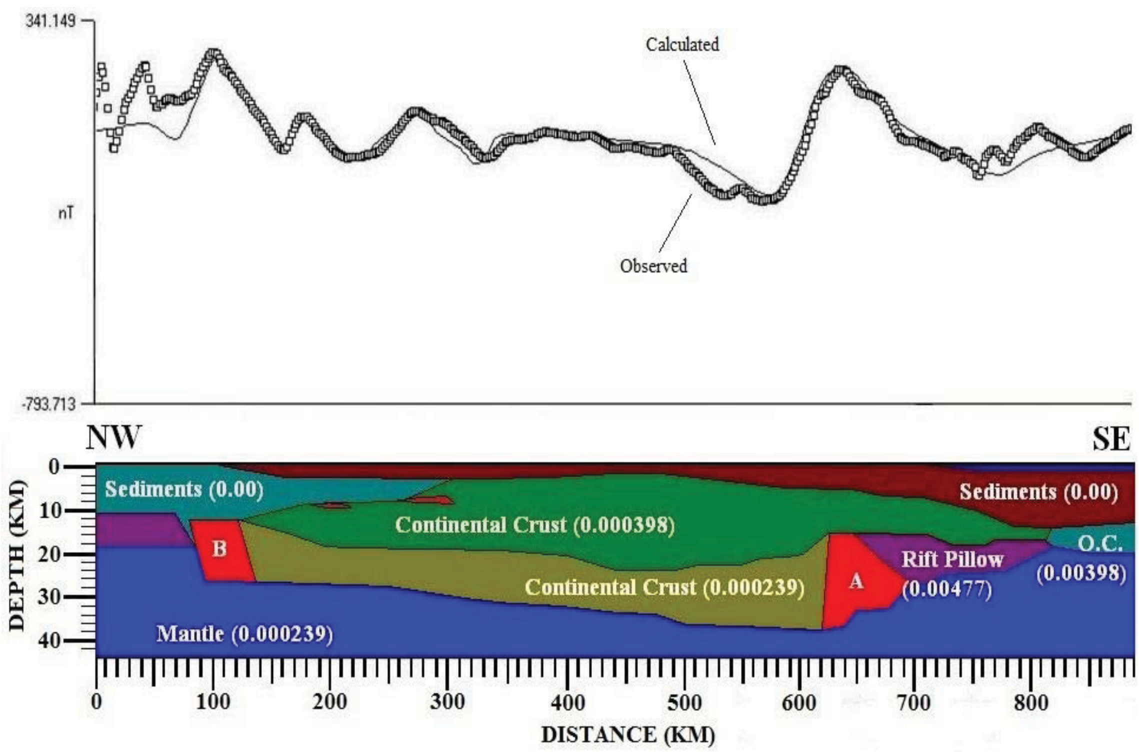


Figure 8. MK5 cross-section with associated calculated and observed magnetic anomaly data. Numbers are dimensionless magnetic susceptibility. Letters are: (A) Gulf Coast rift anomaly, (B) unnamed rift anomaly. Magnetic susceptibilities for A and B are 0.00477.

All of the models consistently show the presence of two main bodies that correspond to magnetic highs in the observed magnetic data. The best fit for the observed data includes a transitional crust body seaward of the main rift body next to oceanic crust. The formation of a micro-continent between the main magmatic features trending to the east is consistent with the earlier model produced by Mickus and Keller

(1992). All models maintain a consistent sediment thickness of 15-20 km in depth from the surface. Individual sediment layers were not modeled in this study. The secondary magmatic anomaly on the continental side of the micro-continent maintains a consistent distance to the continental craton. The combination of the magnetic intensity and shaded relief maps shows that the magnetic maximum previously associated with the opening of the Gulf of Mexico is actually two continuous magnetic highs that parallel one another along the southern portion of the Texas Gulf Coast and diverge eastward.

CHAPTER FOUR

Discussion

Mechanisms for rift formation are contained within the definition of a complete Wilson cycle, as there are strong associations between existing mountain belts and the zone of continental breakup (Wilson, 1966). Collision of continents during the closure of oceanic basins causes orogenic belts that are potentially favored sites of future rifting, due to weakened lithosphere from crustal faulting and the existence of a crustal root. The crustal root decreases lithospheric strength by thickening the zone of relatively weak felsic material in the lower crust that occupies space that would otherwise be filled with stronger ultramafic mantle (Dunbar and Sawyer, 1989; Chery et al., 1990). Variations in lithospheric thickness, density, crustal thickness, and extent of magmatic intrusions found in rift zones around the world result in the diversity that is observed among rifts (Merle, 2011).

The separation of the double hump feature seen in the magnetic data in the western Gulf of Mexico suggests the superposition of a pre-existing crustal feature and a normal breakup anomaly. It is inferred that the pre-existing rift feature caused a weakness in the continental lithosphere that controlled the orientation and location of rifting during the early stages of the breakup of Pangaea. The rift zone shifted south of the pre-existing feature as the rift propagated to the east, perhaps due to lithospheric weaknesses caused by the soft collision of Laurentia and Gondwana during the formation of Pangaea. The smaller width of this rift anomaly suggests that there was less volcanic activity in this location during the rifting process than is seen in other passive margins, such as the U.S. East Coast, and the Cuvier margins (Menzies et al., 2002).

The inferred location of the rift pillow is consistent with a Mesozoic “rift pillow” or “rift margin” inferred in similar models of the U.S. Gulf Coast margin (Huerta and Harry, 2012; Harry and Londono, 2004; Mickus et al. 2009; Mickus and Keller, 1992). The inferred location of a magmatic body underneath the extended micro-continent is consistent with underplated margins seen in other parts of the Gulf Coast margin (e.g. Mickus 1992; Mutter et al., 1984). There might have been several stages of volcanism along the Gulf yielding a wide zone of underplating, similar to the multi-stage volcanism seen on the U.S. East Coast (Alsop and Talwani, 1984).

The magmatic pillow on the continental side of the micro-continent arc parallels the main rift feature along the shortest continental-oceanic transition, then follows the northern portion of the Ouachita deformation front north through Texas across northern Louisiana. The size and shape of the inferred magmatic body in the MK5 profile matches the interpreted Paleozoic oceanic crust in previous models (Huerta and Harry, 2012; Harry and Londono, 2004). The central Texas portion of the anomaly may be a younger feature associated with faulting on the Ouachita system, or an older feature associated with the accreted micro-continent wedged between Laurentia and Gondwana. We interpret it here to be a pre-existing crustal feature older than the rift anomaly. The presence of a magmatic high in all of the profiles modeled in this study suggest that it is a continuous feature, and it is possible that it is a remnant feature due to suturing as part of the formation of Pangaea.

The width of the extended crust along the seaward side of the model ranges from 500 km along the western Texas margin to almost 400 km along the eastern portion of the study region, which is consistent with previous studies (Dunbar and Sawyer, 1989; Driskill et al., 1988; Pindell, 1985). The zone of extension is underplated by a Mesozoic rift pillow and bounded on the seaward side by the oceanic crust of the Gulf of Mexico. The previous mass balancing study shows the majority of thinning and extension during rifting was contained to the seaward region of the pre-existing suture zone (Huerta and Harry, 2012), though extension likely occurred as far inland as the Balcones Fault Zone. The Ouachita system lacks a thick crustal root typically seen in Wilson cycle margins, but is instead underlain by a shallow mantle due to a well preserved ancient subduction zone (Huerta and Harry, 2012) which strengthens the continent.

The micro-continent in the models is interpreted to be a Paleozoic feature that was accreted onto the southern edge of the Laurentian continent during the formation of Pangaea. The micro-continent itself ranges from non-existence on the western most profile to a width of more than 800 km in east Texas. During the rifting of the continent, the micro-continent was subjected to thinning and extension, leaving the Pangaea suture zone and the Ouachita orogenic zone relatively unchanged. The extension of the micro-continent caused the formation of a large salt basin just to the east of the study area (Huerta and Harry, 2012), and potential salt diapirs may be the cause of the isolated magnetic highs between the Mesozoic and Paleozoic ocean crust (Grow and Sheridan, 1988).

Similar potential field anomalies are found in other passive margins throughout the world, such as the Voring plateau, U.S. East Coast, Cuvier and Exmouth margins

(Talwani and Abreu, 2000; Pedersen and Skogseid, 1989; Mjelde et al., 2007). The U.S. East Coast magnetic anomaly is a magnetic high approximately 200 km wide (Sheridan et al., 1993) that extends parallel to the East Coast of the United States for 2000 km (Hall, 1990); (figure 9). Previous studies along the Southern Baltimore Canyon Trough reveal a Moho depth of approximately 30 km and a high velocity seismic zone (7.5 km/sec) that is interpreted to be underplating (Sheridan et al., 1993; Holbrook et al., 1994; Talwani and Abreu, 2000), both of which are similar to the Texas Gulf Coast margin anomaly. West of the main rift anomaly is the Brunswick magnetic anomaly, which is a magnetic low that has been interpreted as a pre-rift suture zone left over from the formation of Pangaea (Klitgord and Schouten, 1986). The Brunswick anomaly and the East Coast anomaly are parallel and superpositioned along much of their length offshore of Virginia, North Carolina, and South Carolina similar to the two anomalies seen on the Texas Gulf Coast. It is possible that the suture zone provided a weakness in the lithosphere that determined the site of rifting during continental breakup in this location. East of the main rift anomaly is the Blake Spur magnetic anomaly that has been identified as an old spreading center jump, and has been used to determine the pole of rotation in the breakup of Pangaea (Klitgord and Schouten, 1986).

The existence of two superimposed anomalies on the Texas Gulf Coast can be interpreted that rifting along the western portion of the gulf was controlled initially by weaknesses in the lithosphere due to the suture zone left from the formation of Pangaea. The parallel anomalies in the EP profile infer rifting occurred with less strain than would be required if the lithosphere were not weakened by the orientation of the anomalies along strike of the margin. The main rift feature diverges from the suture zone along the

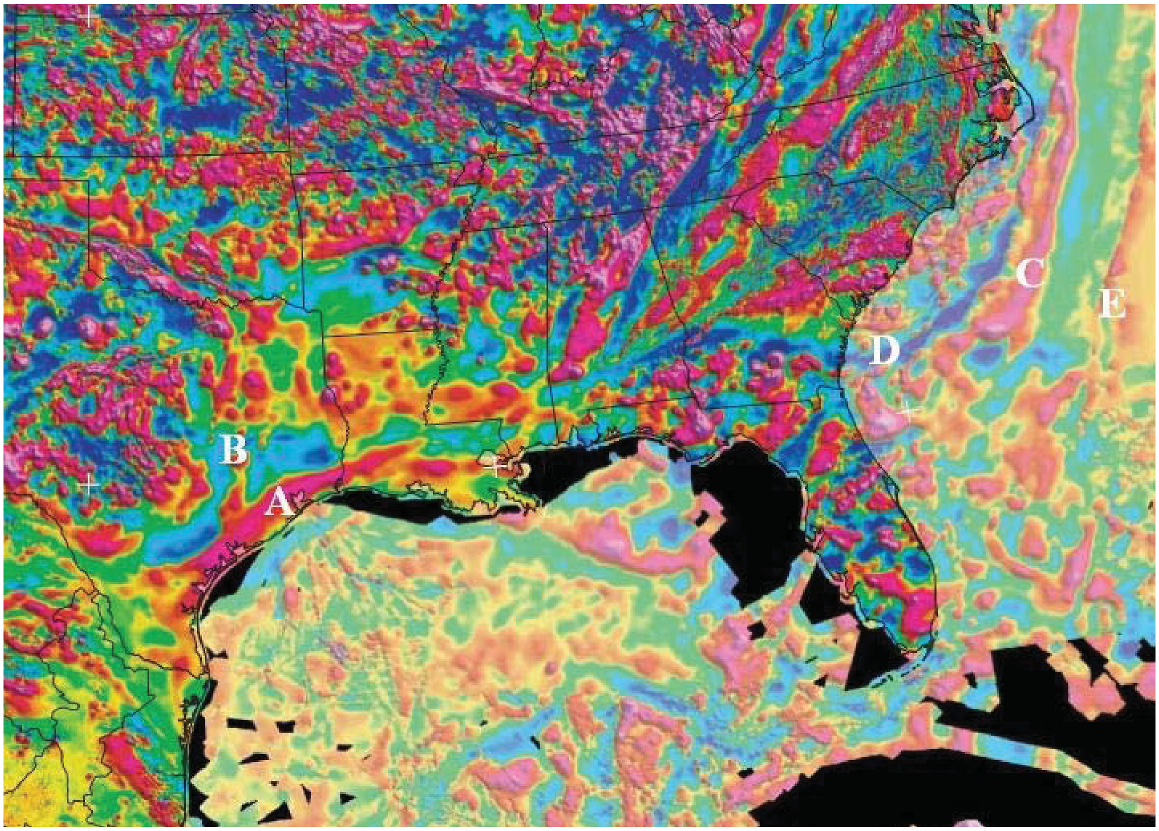


Figure 9. Magnetic intensity map. Red are positive anomalies, blue are negative anomalies. Anomalous features shown are: (A) Texas Gulf Coast anomaly, (B) Unnamed anomaly, (C) East Coast anomaly, (D) Brunswick anomaly, (E) Blake Spur anomaly. Modified from Blankey et al., 2002.

Ouachita trend in Texas and follows the coast into Louisiana before curving south and progressing offshore. Suggestions of a different crustal weakness trend or rift mechanism through this region have been made. Previous studies interpret the offshore portion of the main rift anomaly as a continuous feature that propagates through central Florida and may continue up the East Coast of the United States, making the East Coast anomaly an extension of the Gulf Coast anomaly (Hall, 1990).

Closures calculated by Klitgord and others (1988) show a pole of rotation 67°N 12°W and an angle of -75.5° implying that the initial breakup of Pangaea occurred on the western portion of the Gulf of Mexico with the detachment of the Yucatan Block from

North America around 175 Ga. The North Atlantic Ocean opened as a result of the separation of Africa and South America from the North American continent. Africa and South America continued to drift as one continent until 110 Ga when they separated, yielding the Walvis and Pelotas Basins (Thomas, 1991). The opening of the northern Atlantic Ocean and the Gulf of Mexico was driven by far field that acted as the mechanism for passive rifting seen in the western Gulf of Mexico, initiating the breakup of Pangaea.

CHAPTER FIVE

Conclusion

Potential field data show two clearly defined magnetic highs that parallel the Texas Gulf Coast margin. The two anomalies are continuous and separate to the east, with one portion following the coastline into Louisiana, and the other portion trending north along the Ouachita orogenic belt. The landward anomaly is interpreted as a crustal feature that pre-dates the breakup of Pangaea and is likely left over from the suturing of a micro-continent in the collision zone between Laurentia and Gondwana. The seaward anomaly is interpreted to be a typical rift feature for a passive rifted margin and is consistent with the idea that the Gulf of Mexico margin ends in a triple junction to the south, and continues on as an extensional boundary to the east, as suggested by Mickus and others (2009). A pre-rift crustal feature is inferred to have determined the location and orientation of rifting during the early stages of continental breakup and localized the point of initiation for the opening of the Gulf of Mexico and the Atlantic Ocean.

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