Integration of COCORP deep reflection and magnetic anomaly analysis in the southeastern United States: Implications for origin of the Brunswick and East Coast magnetic anomalies

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ABSTRACT

Integration of magnetic anomaly analysis with COCORP deep reflection data from the southeastern United States provides three new constraints on the interpretation of the Brunswick and East Coast magnetic anomalies, as well as on the reflection data. These are as follows. (1) The source of the Brunswick anomaly lies within the deep crust. This anomaly is not caused by a Mesozoic rift basin, as proposed by some workers. (2) A simple, seaward-dipping, high-susceptibility slab model can explain both the Brunswick and East Coast magnetic anomalies. The along-strike change in character of the two anomalies results largely from a change in azimuth of the source body. (3) Beneath the southeastern United States, this source body dips south, lies immediately on the south flank of the prominent southward-dipping reflective zone revealed on COCORP surveys, and was previously associated with the Alleghanian suture between North America and Africa. These results imply that a dipping, highly magnetized zone in the upper plate of the Alleghanian suture is responsible for both the Brunswick and East Coast magnetic anomalies. The high-susceptibility material responsible for these anomalies might be mafic lower continental or oceanic crust thrust upward during Alleghanian continental collision, or mafic igneous material intruded into the upper plate of the suture zone during subsequent Mesozoic rifting, or both. The latter hypothesis implies that the Alleghanian suture acted as a zone of weakness (a repository ?) which was reactivated to control the site of ultimate Atlantic rifting and possibly initial sea-floor spreading.

INTRODUCTION

In this study, the interpretation of deep seismic reflection data collected by the Consortium for Continental Reflection Profiling (COCORP) over the Alleghanian suture buried beneath the Georgia Coastal Plain (Fig. 1) is integrated with that of magnetic-anomaly data for the Coastal Plain and adjacent Atlantic margin. The dominating feature of the magnetic-anomaly field of the southeastern United States and adjacent margin is the Brunswick magnetic anomaly (BMA) and its apparent offshore continuation, the East Coast magnetic anomaly (ECMA) (Zietz, 1982) (Fig. 2). Although originally defined as a single continuous anomaly (Taylor and others, 1968), the BMA and ECMA subsequently have been considered to represent two separate features (that is, sources) (Hutchinson and others, 1982; Higgins and Zietz, 1983). Although the origin of the ECMA is not understood in detail, it is generally thought to be associated with the continental/oceanic crustal transition beneath the United States Atlantic margin (Alsop and Talwani, 1984). The BMA, however, because it lies entirely within continental crust (Alsop and Talwani, 1984), has been considered to have a different origin. Two hypotheses for the BMA, advanced in the literature, are that the anomaly results from either a buried Mesozoic rift basin (Popenoe and Zietz, 1977; Higgins and Zietz, 1983) or a late Paleozoic suture (Chowns and Williams, 1983; Daniels and others, 1983). Prior to the completion of recent COCORP surveys, it was not possible to distinguish these possibilities.

This report considers the problem of the relationship of the BMA to the ECMA as well as their relationship to deep crustal structure. We utilize the new COCORP data to conclude that the Brunswick anomaly is not caused by a Mesozoic rift basin but rather must have a "deep" source within the basement. Using magnetic modeling, we then examine the likely geometry of this source and show that it has a systematic spatial relationship to prominent dipping reflections displayed on the COCORP profiles, which probably mark the Alleghanian suture beneath the southeastern United States. We show that the same basic magnetic source model can reproduce both the BMA and the ECMA. Thus, there is no *a priori* reason to believe that these two anomalies have, geologically, distinctly different sources. Lastly, we discuss the possible geologic implications of our results for both anomalies.

DEEP REFLECTION DATA OVER BRUNSWICK ANOMALY

As shown by Taylor and others (1968) and defined by Klitgord and Behrendt (1979), the BMA is the negative portion of the ECMA over the Carolina platform and trough. Here, at its southern extremity, the ECMA swings abruptly westward and continues onshore at Brunswick, Georgia (Taylor and others, 1968; Pickering and others, 1977) (Fig. 2). In this area, the anomaly changes character as its inner, negative branch becomes better defined and the outer high is broken into elongated discontinuous anomalies. The aeromagnetic map compilation for the southeastern United States (Zietz, 1982) reveals that the main magnetic low of the BMA persists across the Georgia Coastal Plain, continuing into central Alabama with a maximum width of about 55 km (Higgins and Zietz, 1983), and is flanked on the south by discontinuous highs. Some recent workers have separated the high and low segments of the anomaly and attributed

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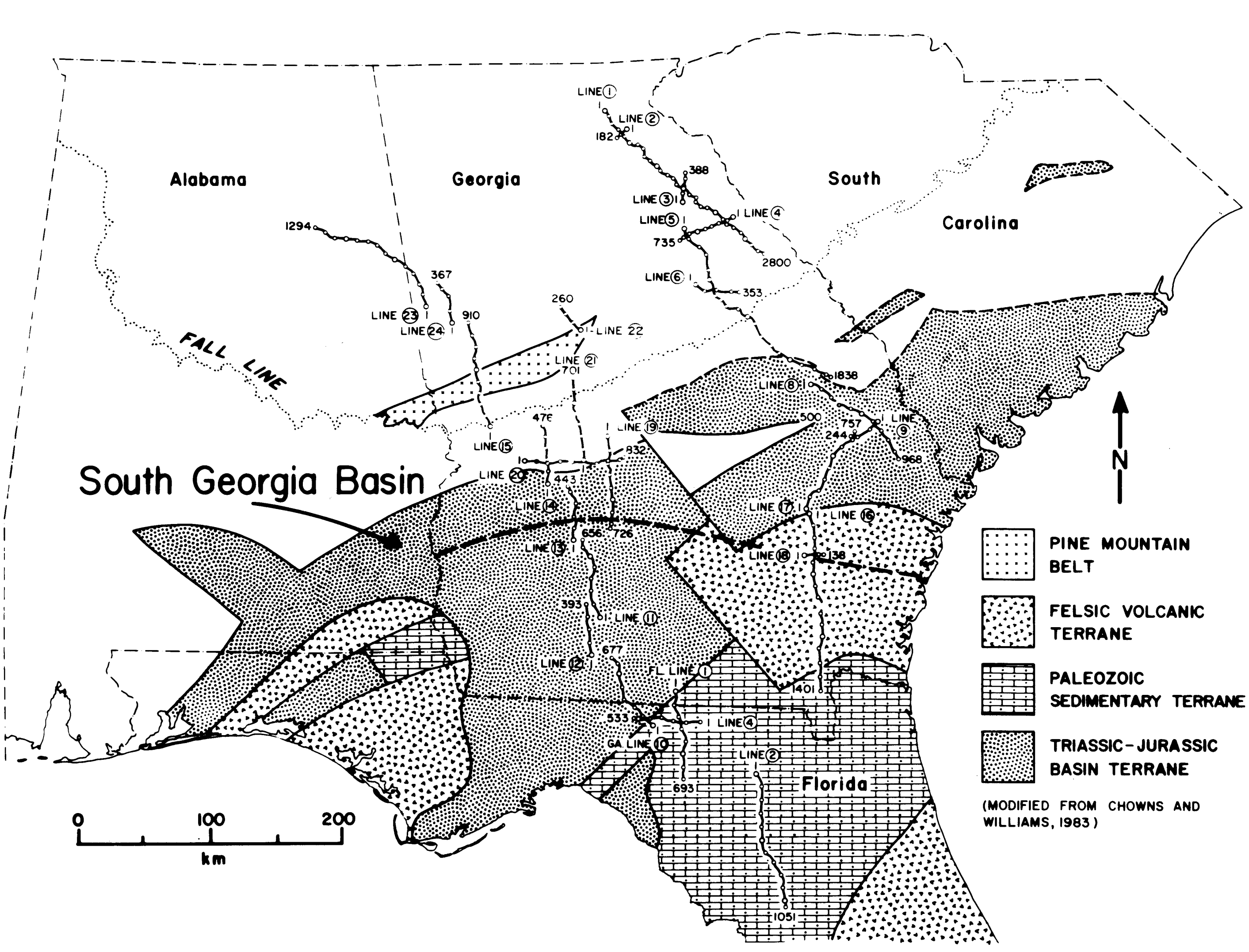

Figure 1. Location map showing COCORP survey lines and basement terranes as determined by drillhole data (from Chowns and Williams, 1983). Heavy dashed line indicates southern limit of dipping reflection zones (see Fig. 3) inferred to be related to the Alleghanian suture.

them to different sources. For example, the inner, negative and outer, positive branches have been respectively referred to as the Altamaha and Brunswick anomalies (Higgins and Zietz, 1983). As we demonstrate subsequently, however, the high-low pair is probably related to a single source, and so we will maintain the original terminology of Klitgord and Behrendt (1979) and refer to the segment where the negative branch is more prominent as the BMA, and where the positive branch dominates, as the ECMA.

COCORP has completed three deep seismic reflection traverses across the BMA in Georgia: lines 13–15, lines 19–21, and lines 16–18 (Figs. 2 and 3). In all three crossings of the BMA, the middle-to-lower crust beneath the anomaly low is dominated by a prominent, mainly south-dipping reflective zone extending to the base of the crust. This zone, which is inferred to trend east-west for a distance of 300 km, widens from about 70 km in western Georgia to more than 80 km in southeastern Georgia. Perhaps more importantly, the reflection package within the broad dipping zone is clearly distinct in prominence and dipping character from relatively less reflective crust to the north and south. This prominent zone of dipping reflections has been suggested to be related to the Alleghanian suture between North America and Africa (Suwannee terrane; see Smith, 1982) for the following reasons (Nelson and others, 1985a). (1) The zone of dipping reflections on the three COCORP transects is unique as the only major crustal-penetrating feature imaged between known African-affinity crust, underlying the Suwannee basin Paleozoic sequence of northern Florida, and known North American basement (Grenville), exposed in the Pine Mountain window of west-central Georgia (Schamel and others, 1980) (Fig. 1). (2) The position and dominant orientation of reflections in this zone are appropriate for it to represent the root zone for the inner Piedmont nappes. (3) The zone lies distinctly north, on the two western transects, and south, on the eastern transect, of the inferred depositional axes of the South Georgia basin and is thus not obviously related to post-Paleozoic rifting. (4) The reflective zone corresponds to the BMA which has previously been recognized as separating two distinct regional magnetic terranes (Daniels and others, 1983). (5) A well drilled on the anomaly in Alabama has encountered serpentinite (Neathery and Thomas, 1975; Martin and others, 1986).

In addition to showing the spatial correspondence between the BMA and prominent deep

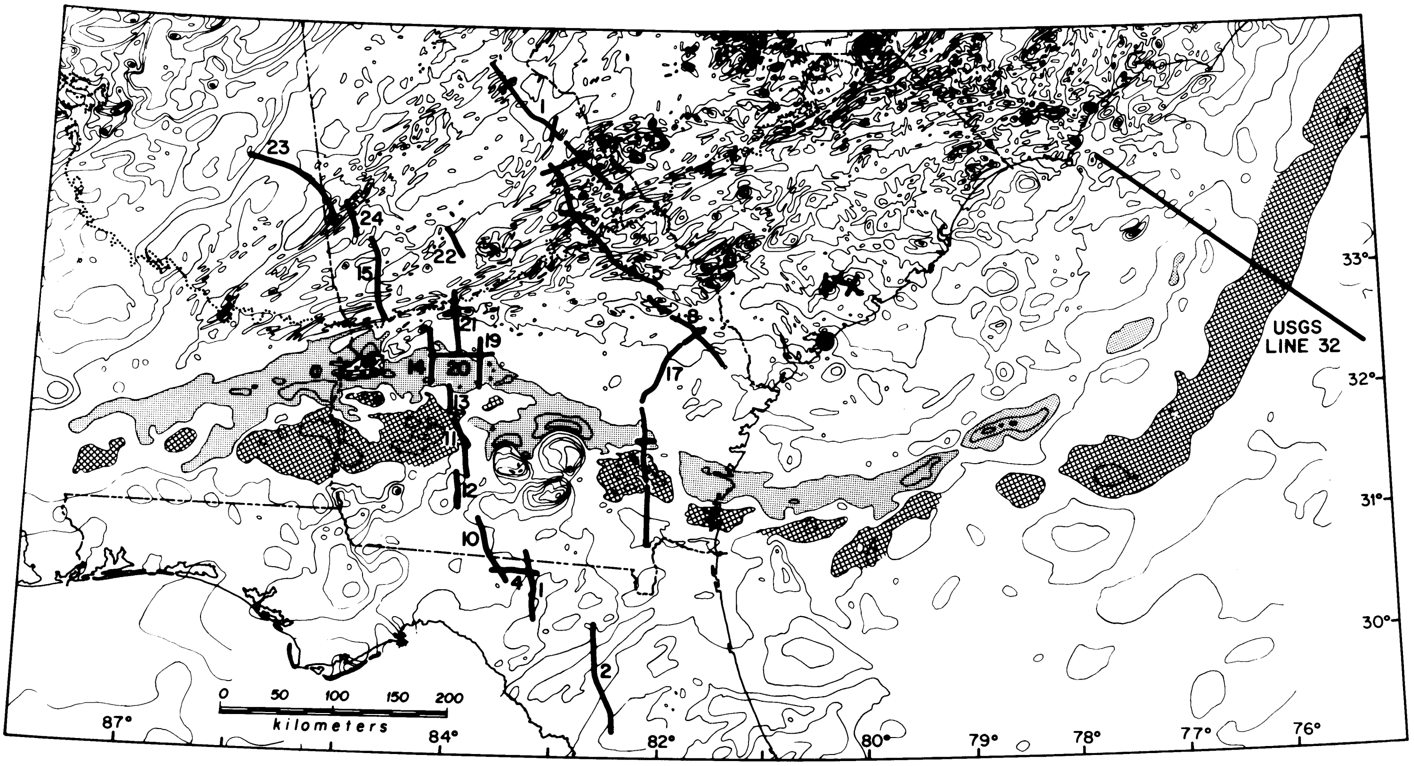

Figure 2. Location and magnetic anomaly map showing position of survey lines of COCORP and U.S. Geological Survey. Stipple: magnetic anomaly minimum. Grid: magnetic anomaly maximum (Zietz, 1982). Contour interval is 200 nT.

reflections, the COCORP data further demonstrate that the anomaly cannot be caused by a shallow rift basin. On the western Georgia transect (10–15), South Georgia basin sediments are shown by the profiling to exist from the northern end of line 13 southward to northern Florida (Fig. 3a), and the maximum thickness is reached more than 50 km south of the anomaly minimum. Therefore, along the westernmost transect, the basin depocenter is not associated with the prominent low of the BMA. On the line 19–21 transect (Fig. 3b), ~50 km to the east, there is an individual asymmetric basin whose depocenter, as on the westernmost transect, is displaced south of the BMA minimum. Finally, the anomaly low on the eastern transect (Fig. 3c) rests over the central portion of line 16 on which no basin was imaged, an observation corroborated by well data (Fig. 1). In summary, the COCORP data show that the BMA coincides with a major, crustal-scale feature and not with a Mesozoic rift basin. Consideration of the likely susceptibility contrast between Mesozoic basin fill and surrounding pre-Mesozoic basement beneath the Coastal Plain provides further support for this view.

BRIEF SUMMARY OF BASEMENT DRILLING RESULTS OVER BMA

Near the eastern COCORP transect, drilling over the Coastal Plain in the vicinity of the BMA indicates a "basement" of felsic igneous rocks, including porphyritic rhyolites, vitric crystal tuffs, and tuffaceous arkoses of Proterozoic Z to Cambrian age (Maher, 1971; Chowns and Williams, 1983) (Fig. 1). The very low estimated magnetic susceptibilities of such general rock types (Dobrin, 1976; Nettleton, 1976), together with the fact that they cover a much broader area than does the BMA (Chowns and Williams, 1983), exclude them as a possible source of the BMA. The "basement" of felsic rocks may actually be only a thin veneer a few kilometres thick, such as is known to occur in the Proterozoic granite-rhyolite province of the eastern mid-continent (Bickford and others, 1986). In this region, for example, large-scale magnetic anomaly patterns have been observed which are attributed to a deeper and more magnetic underlying crust (Lidiak and others, 1985).

Along the western COCORP transect, no drillholes are known which penetrate the basin sedimentary section into basement near the BMA (Chowns and Williams, 1983). Basement-penetrating drillholes north of the BMA in Georgia, South Carolina, and Alabama, however, encounter metamorphic and felsic-intermediate plutonic rocks (Chowns and Williams, 1983) which are the southward extension of Piedmont metamorphic units below the Coastal Plain. For example, a drillhole located over the up-dip projection of the south-dipping reflective zone, near the northern end of COCORP line 19, has penetrated about 0.5 km of granitic gneiss (proprietary data). South of the BMA in western Georgia, wells as far north as Early County (southern end, line 11) penetrate Paleozoic Suwannee basin sequence (Arden, 1974; Barnett, 1975; Chowns and Williams, 1983) beneath the Mesozoic-Cenozoic cover. In summary, pre-Phanerozoic rocks beneath the Georgia Coastal Plain appear to be predominantly felsic in composition, at least on a regional scale, and would be expected to possess relatively low values of suscepbitility (average = 0.00065 c.g.s.; Nettleton, 1976; Dobrin, 1976) (see also Hutchinson and others, 1982, p. 145) and thus not likely to be a source for the BMA.

Drillholes penetrating Triassic-Jurassic sedimentary rocks of the South Georgia basin (Fig. 1) often also encounter mafic igneous dikes, sills, and flows (Chowns and Williams, 1983). Where these rocks occur as inclined sheets surrounded by much less magnetically susceptible country rock, they might produce very high frequency (compared to, for example, the BMA) and high-amplitude anomalies (Popenoe and Zietz, 1977; Daniels and others, 1983). Daniels and others (1983) investigated the possibility of correlating areas of mafic igneous rock penetrated in drillholes to magnetic anomalies over the Southeast Coastal Plain. The lack of correlation was attributed to the thin, nearly horizontal sheet structure of these rocks which would not generate a large-amplitude anomaly except at a sharp vertical edge. It therefore appears that the Triassic-Jurassic basin section contains no anomaly-producing lateral susceptibility con-

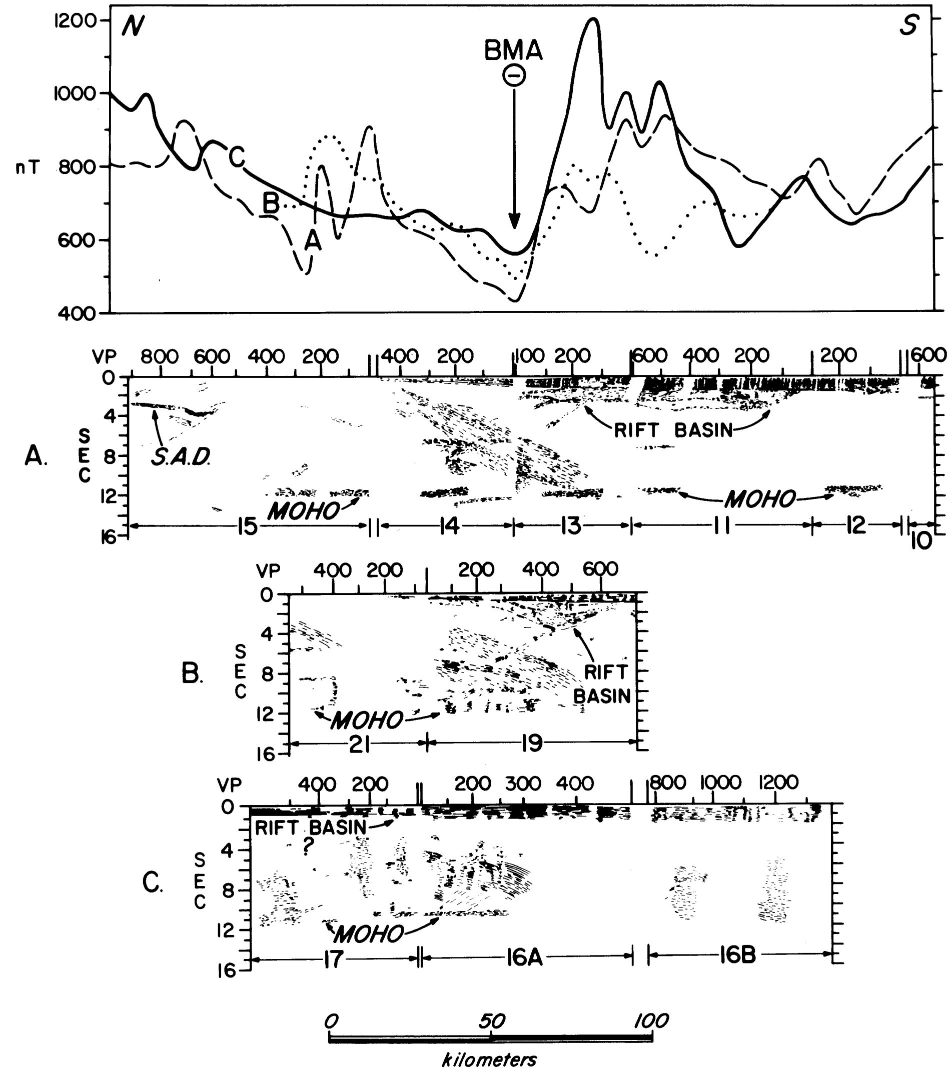

Figure 3. Interpretive line drawings of three COCORP transects together with three associated magnetic intensity profiles. All profiles arranged so as to have BMA minimum coincident. Total magnetic intensity data from Zietz and others (1980). See Figures 1 and 2 for line locations.

trasts, except for easily recognizable high-frequency anomalies.

MAGNETIC MODELING RESULTS

Relationship of BMA to South Georgia Basin

Figure 4 shows a profile through the western COCORP transect depicting the Mesozoic-Cenozoic section geometry, together with the observed magnetic field and the calculated anomaly arising solely from the basin-basement susceptibility contrast. A contrast of 0.00400 c.g.s. was required to produce the synthetic anomaly with an amplitude approaching that of the observed anomaly. The above example demonstrates clearly two points. (1) The basin depocenter on the western transect lies well to the south of the BMA and does not have a calculated anomaly at all similar to that observed. (2) The required susceptibility contrast for an anomaly with the necessary amplitude is prohibitively high. The value of 0.00400 c.g.s. used in Figure 4 is far beyond the average for even mafic igneous rocks (Dobrin, 1976; Telford and others, 1976; Carmichael, 1982). As explained above, a mafic composition crust is not expected for the majority of the Southeast Coastal Plain area (Hutchinson and others 1982; Chowns and Williams, 1983).

Relationship of BMA to COCORP Data

On the magnetic field map (Fig. 2) and the magnetic profiles across the BMA (Fig. 3), a basic, long-wavelength component of asymmetry is a persistent feature of both the BMA and the ECMA, although more prominent for the BMA. This asymmetry is a strong clue to the source-body geometry. The south-dipping component of the reflection data provides a strong suggestion for an intracrustal magnetic source which is tabular and south-dipping. The general asymmetric anomaly character of a gradient flanked by a minimum and a maximum is typical of an inclined contact or tabular source body (Koulomzine and others, 1970). A dike-like shape for the source of the BMA has, for example, been suggested by Chowns and Williams (1983). The characteristic anomaly for an inclined magnetized slab striking east-west in the middle latitudes of the northern hemisphere is shown in Figure 5. From this figure, it should be obvious that a tabular body with an east-west strike has more of an antisymmetric anomaly character for a south dip than for a north dip. It is provocative that the BMA in Georgia has an antisymmetric component similar to the south-dipping slab anomaly in Figure 5 and that the broad reflective zone on the two COCORP transects also dips south from beneath the anomaly low on the north, toward the high on the south. These relationships tentatively suggest a south-dipping magnetized slab whose axis follows the inflection point of the BMA.

Figure 6 shows magnetic models with superimposed reflection-line drawings (Nelson and others, 1985a). An interactive computer modeling program (Saltus and Blakely, 1983) was used to create the models. Because of the linear character of the anomaly, we assumed a two-dimensional source. We have also assumed that magnetization is wholly induced, which is consistent with, for example, the interpretation of Hutchinson and others (1982) for the ECMA. The capacity of a rock to retain remanent magnetization is approximately inversely proportional to the grain size (Merrill and McElhinny, 1983). Tectonic or magmatic processes of emplacement of the source body for the BMA and ECMA might have involved the production of a large grain size either through regional metamorphic recrystallization or primary crystallization associated with deep, slowly cooling intrusions. Thus, the assumption of induced magnetization is perhaps not unwarranted. Although no information is available for the Curie depth in this region, it is probably no greater than about 30 km (Haggerty, 1978; Garland, 1979). Regardless, changing the Curie depth within reasonable limits (that is, so as not to make the slab source appear as a thin plate) does not significantly alter the calculated model. The susceptibility of the sedimentary cover is considered to be negligible. The shape and thickness of the sedimentary cover shown in Figures 6a and 6b are from McBride and others (1987a) and in Figure 6c, from Hutchinson and others (1982). In this study, we focus on the longer-wavelength components of the BMA and ECMA and therefore do not attempt to account for the shorter-

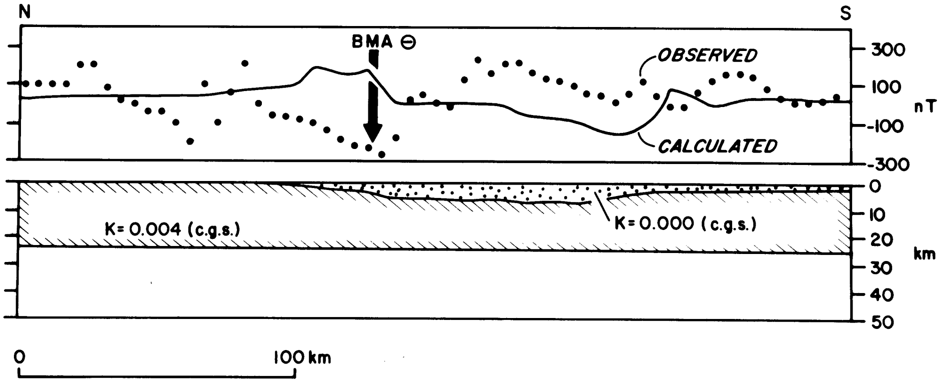

Figure 4. Hypothetical magnetic anomaly for basin, as defined along the western COCORP transect, assuming no other sources and assuming a susceptibility contrast (0.00400 c.g.s.) high enough to reproduce the observed anomaly amplitude.

wavelength anomalies which are due to shallower sources.

Along the western transect (Fig. 6a), the modeling results suggest a through-going slab resting on the southern, down-dip flank of the reflective zone. The slab is ~15 km thick, dips 25° southeast, and is ~25 km south of the southern edge of the reflective zone. The susceptibility value, 0.0033 c.g.s., is close to the average of 0.0026 c.g.s. given for mafic and ultramafic rocks (Nettleton, 1976), although the total range for these rock types is large (0.000044–0.009710 c.g.s., Telford and others, 1976). As argued in the preceding section, the absolute value for continental crust in this region may be very low, and we have accordingly used a value of 0.00020 c.g.s. (compare with Telford and others, 1976, p. 121). The top of the slab subcrops 4 to 6 km beneath the surface on lines 11 and 13. The greater depth of burial of the slab, compared to the eastern Georgia transect, may be acting to subdue the higher frequency edge effects evident in the calculation shown. A south-dipping slab would have its north and south top edges coincident with the minimum and maximum of the anomaly, respectively (Koulomzine and others, 1970; Telford and others, 1976), thus making the use of these extreme points very stable constraints on the modeling.

Over the eastern transect (Fig. 6b), the southern flank of the peak of the BMA is not as well defined, although the basic regional features are well expressed. The somewhat higher frequency character of the anomaly here may indicate a shallower source. The length of the region of the gentle gradient north of the trough is about twice that of the western transect. This is undoubtedly related to the greater distance across thickened Mesozoic-Cenozoic cover (Daniels and others, 1983), as shown in the model. The misfit north of the trough in this area may be related to a thicker basin-fill than that revealed by reflection profiling or the presence of very low susceptibility crystalline rocks beneath the basin. South of the BMA, the poor fit may be similarly due to anomalously low susceptibility basement, possibly corresponding to the felsic igneous terrane mapped by Chowns and Williams (1983). The BMA itself is here characterized by a steeper gradient and a smaller peak-trough separation. This behavior is reflected in the steeper inclination (35°) of the modeled slab. Susceptibility values of sediments, continental crust, and the slab are nearly identical to those for the western transect model (Fig. 6a). At this point, one may be tempted to use the "derived" magnetic susceptibility values to suggest specific lithologies for the source body. However, it should be kept in mind that the susceptibilities used to produce the models are not absolute values. A second problem is the usual nonuniqueness of associating a particular rock type with a certain value (or range of values) of magnetic susceptibility. Because of these uncertainties, it may be misleading to propose anything more specific than that the rock type of the source body is probably mafic or ultramafic.

Along the trend of the BMA, anomaly patterns in the gravity field are not as definitive and "two-dimensional" as they are in the magnetic field (Fig. 7). Density contrasts from within the Triassic-Jurassic basin sedimentary section, which have no effect on the magnetic anomaly field, may complicate the gravity field. Also, the Appalachian (or Piedmont) gravity gradient, the dominating feature of the gravity field of central Georgia (Cook and Oliver, 1981; Hutchinson and others, 1983; Long and Dainty, 1985), may mask or at least complicate the effects of the BMA source, especially in west-central Georgia. Because of these problems, as simple a model for the gravity field as made for the magnetic model is probably not possible. Nevertheless, a trend of discontinuous positive gravity anomalies closely parallels the inflection of the BMA (Lyons and O'Hara, 1982) (Fig. 7). The region of the gravity anomaly maxima rests over the high of the BMA. Such a positive correspondence between gravity and magnetic anomalies usually implies the presence of a mafic or ultramafic source (Popenoe and Zietz, 1977; Lidiak and others, 1985).

Relationship Between BMA and ECMA

In Nelson and others (1985b), we proposed that the ECMA is the northward continuation of the BMA, and together they represent the position of the Alleghanian suture. Although deep reflection data for the Carolina trough and platform are lacking, we have attempted to model a section through the BMA and ECMA in a manner consistent with the previous onshore transects. The observed values shown in Figure 6c, together with depths to magnetic

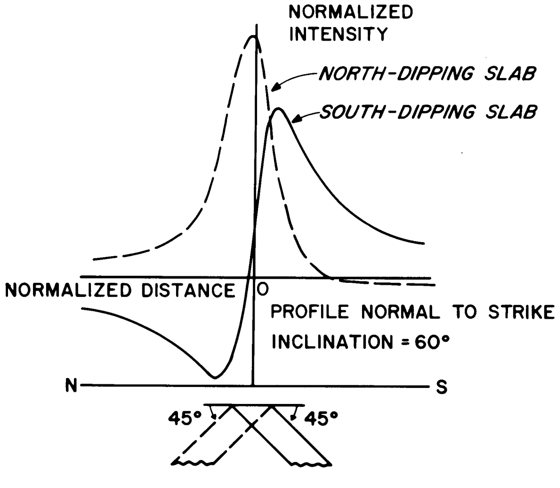

Figure 5. Magnetic model calculations for a slab oriented east-west showing the dependence of asymmetry on dip (modified from Telford and others, 1976).

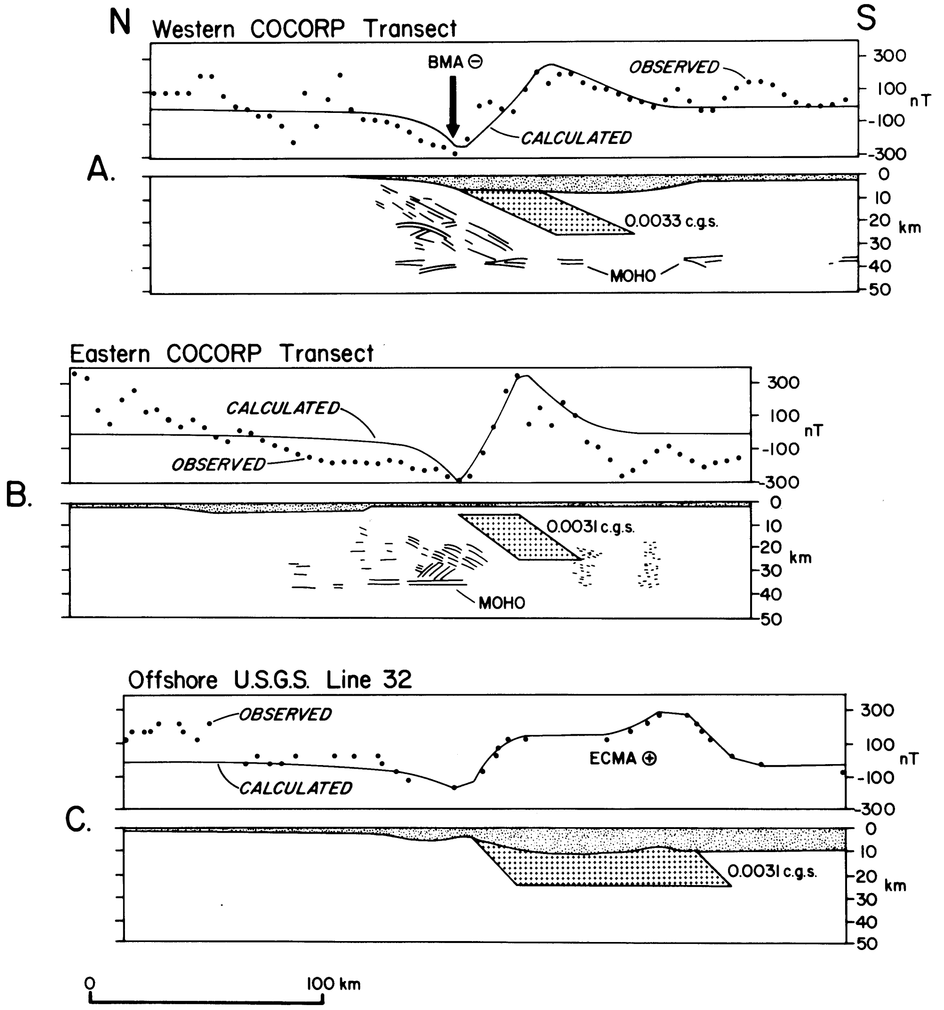

Figure 6. Magnetic anomaly models with susceptibility contrasts (c.g.s.) and simplified line drawings of the reflective portion of the inferred Alleghanian "suture" zone. See Figure 1 for profile locations.

basement, are taken from the vicinity of U.S. Geological Survey profile 32 (Hutchinson and others, 1982). Our model simply illustrates that an interpretation of the ECMA can be made in harmony with the BMA onshore even though the two anomalies have different shapes. As recognized by Hutchinson and others (1982), the flat area in the magnetic field between the peak and trough is due to the eastward deepening of basement subcrop.

That the ECMA and BMA are equivalent, as once proposed (Taylor and others, 1968), is a critical point for our interpretation. Figure 2 shows the trend of the BMA and ECMA with respect to the surface projection of the inferred suture zone and the depositional axes of the South Georgia rift as indicated from the COCORP profiling. As stressed by Hutchinson and others (1982), the inference that the ECMA continues onshore as the BMA implies that the ECMA is not uniquely related to the edge of continental crust. An examination of the magnetic intensity map for the East Coast and continental shelf (Hinze and Zietz, 1985) reveals that where the ECMA is oriented more north-south it has a prominent peak and a subdued flanking low; however, as the high and low begin to change course to the west, the low gains amplitude at the expense of the peak. On land the BMA low becomes larger (Popenoe and Zietz, 1977). For the middle latitudes of the northern hemisphere, this behavior is expected for a magnetized body whose long dimension changes from north-south to east-west (Nettleton, 1976). This relationship can, for example, be expressed by an inclined magnetized slab (Fig. 8) whose strike is changing from north-south to east-west. As can be seen from Figure 8, the change from a north-south to an east-west azimuth is accompanied by a respective change from an antisymmetric (as in Georgia) to a more symmetric (as offshore Carolinas) shape of the anomaly.

Figure 9 shows a synthetic anomaly map for the latitudes of the study area constructed from the simple inclined body shown in Figure 8 for which the only variable is the azimuth of the source-body axis. The purpose of this synthetic is not to reproduce the details of the observed field, but to demonstrate the dominating effect of the azimuth of the source-body axis on the anomaly field for a seaward-dipping slab. The point at which the low of the anomaly begins to lessen markedly on the synthetic matches closely the transition between the negative-dominated BMA and positive-dominated ECMA (compare with Fig. 2). Thus the positive and negative parts of the ECMA and BMA can easily arise from a common source, the change in anomaly character being primarily a function of source-body azimuth.

DISCUSSION

The analysis of magnetic anomalies guided by COCORP reflection data from the Southeast suggests a predominantly south-dipping reflection zone which is flanked seaward by a highly magnetized, but generally unreflective, zone. Although this magnetized zone probably does not have a simple geometry, it can be approximated by a tabular body with an orientation mimicking the reflective zone. The spatial relationship between the magnetic and reflective zones persists along strike. Our analysis rules out the possibility that the BMA is caused onshore by a buried rift basin as has been previously suggested. Not only are the individual basins of the South Georgia rift in an inappropriate position as revealed by the new COCORP data, but it appears that the susceptibility contrast between nonmagnetic sediments and felsic composition basement is too low to produce an anomaly with an amplitude equivalent to the BMA. Furthermore, the interpretation of the BMA is entirely consistent with that of the ECMA and further implies that the two anomalies may be the expression of the same source.

As in the general case, the magnetic modeling cannot uniquely define crustal structure responsible for the BMA and the ECMA. The association of these anomalies, both with the strong dipping reflections attributed to the Alleghanian suture zone, and with subsequent Mesozoic rifting, however, suggests two "end-member" possibilities, which we briefly describe here. As already stressed, the predominantly southward dipping reflection fabric of the inferred Allegha-

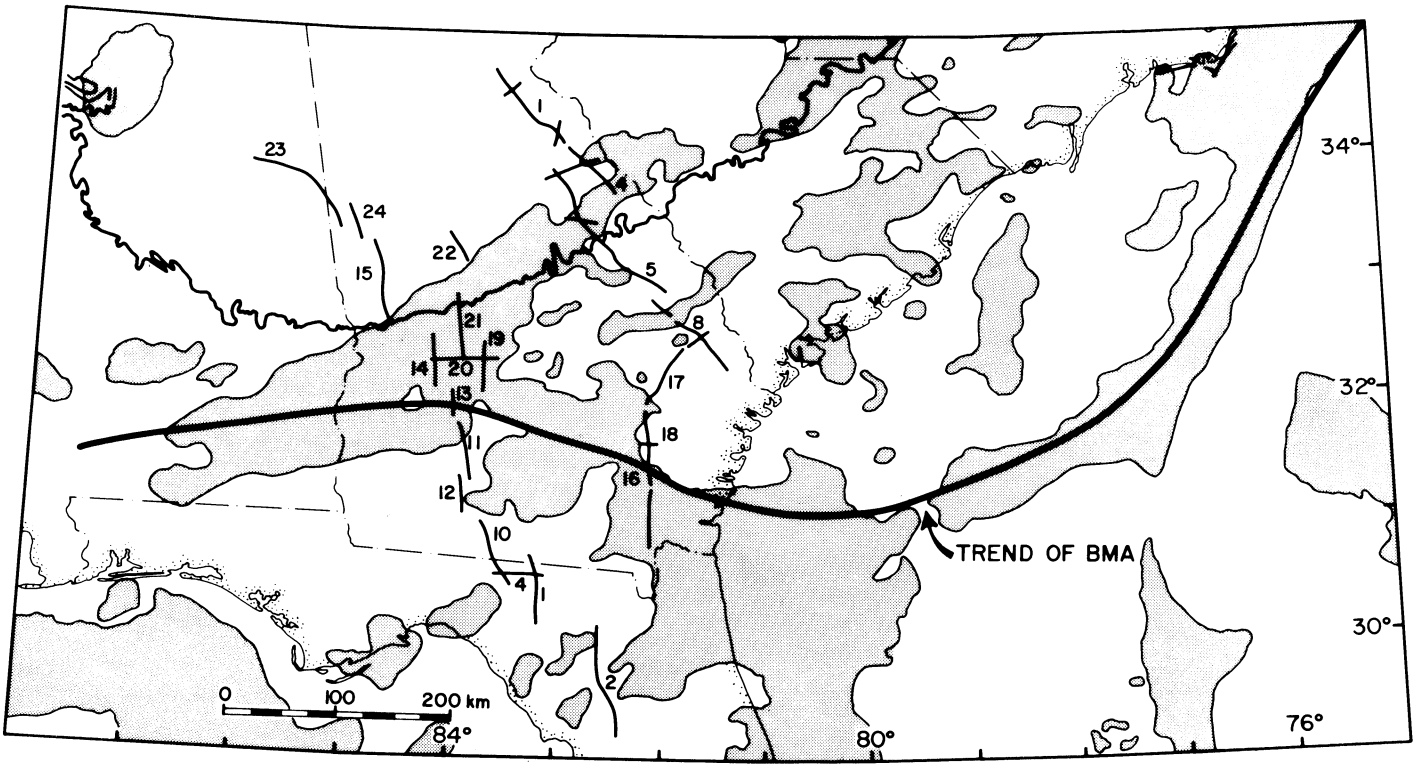

Figure 7. Bouguer gravity anomaly map for study area (same base as for Fig. 2) with zero contour shown only. Heavy line represents the inflection between the negative and positive components of the Brunswick magnetic anomaly (from Lyons and O'Hara, 1982; and Zietz, 1982).

nian suture zone is in an orientation appropriate for it to represent a root zone for Inner Piedmont nappes (Nelson and others, 1985a; Iverson, 1986; Nelson and others, 1986). In the Quebec and northern United States Appalachians, evidence exists for large overthrusted slabs of relict oceanic crust caught up in these root zones (Seguin, 1982; Cook and others, 1983; Ando and others, 1983). Oceanic crust has a very high mafic content relative to more felsic continental crust or geoclinal sediments and, if large enough, could produce a significant magnetic anomaly. On the other hand, a large coherent slab of oceanic crust would not necessarily be expected to be very reflective internally. The position of such obducted oceanic crust (Fig. 10a) would be expected outboard of the paleoshelf edge, possibly separated from the miogeoclinal region by a zone of imbricated thrusting (Cook and others, 1983). The above considerations would also support the interpretation that the ECMA too represents trapped Paleozoic oceanic crust.

A variation on this compressional hypothesis of obducted oceanic crust is that the magnetized zone may represent relict subcontinental mantle which has been trapped as it was obducted in the convergent zone (Fig. 10b). Relict uppermost mantle rocks elevated above the Curie depth would be expected to be highly susceptible relative to surrounding continental crustal rocks. As pointed out by Meissner (1986), serpentinites or serpentinized ultramafic portions of the upper mantle might include metal alloys with a Curie temperature as high as 1000 °C (Haggerty, 1978), suggesting that a very deep source is possible. The geologic model shown in Figure 10b is reminiscent of the Ivrea zone of the southern Alps where relict upper mantle has been thrust over foreland continental crust in the convergent zone and now forms a hinterlandward-dipping slab beneath the Po Plain (Giese and others, 1982). An obvious problem, however, with this model is that, as in the case of the Ivrea zone, a major and distinctive gravity anomaly would be expected. As stressed earlier, although a general trend of gravity anomalies appears to follow the BMA (Fig. 7), no single prominent anomaly is present.

An entirely alternative interpretation (Fig. 10c) is that the anomaly is a consequence of Mesozoic rifting. Hutchinson and others (1982) interpret the ECMA, on the basis of integrating potential field and reflection data, as Mesozoic "rift-stage" crust which divides true oceanic crust seaward from continental crust landward.

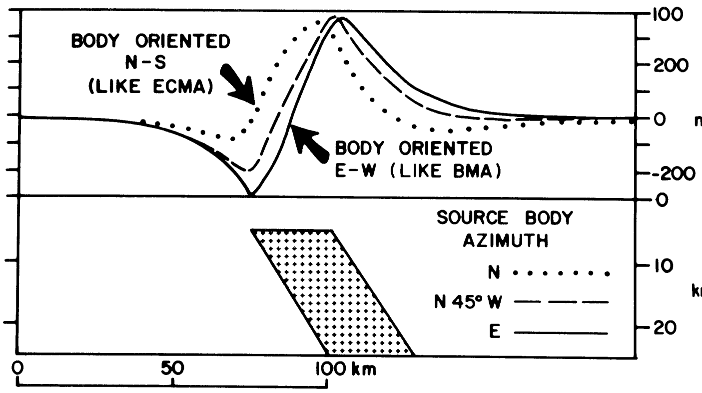

Figure 8. Computed magnetic intensity curves for an inclined slab illustrating the dependence on azimuth.

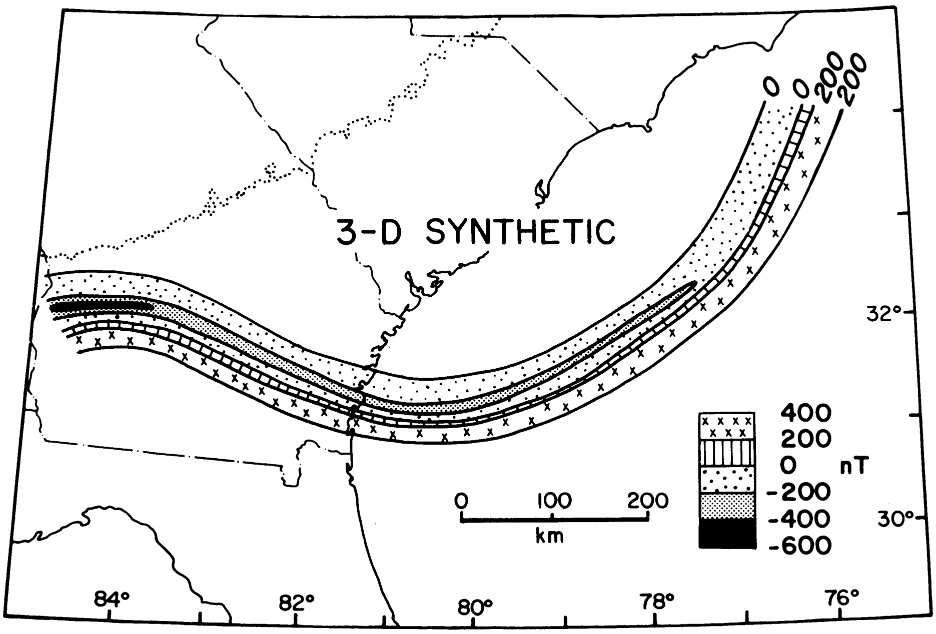

Figure 9. Synthetic magnetic anomaly map for model in Figure 8 showing, in plan view, the changing anomaly character as a function of source body azimuth. Compare with Figure 2.

Rift-stage crust is defined (Falvey, 1974) as having properties of both continental and oceanic crust, including mafic intrusion (this last causing high susceptibilities). A common-source interpretation for the BMA and ECMA, as we have argued, implies that ultimate rifting and subsequent spreading, although successful in the North Atlantic, began but were incomplete on land in the Southeast. The accumulation of as much as 6 km of sediments in fault-bounded basins of the South Georgia rift (McBride and others, 1987a) indicates that significant amounts of normal faulting accompanied incipient spreading. Evidence for a phase of incipient spreading in the region of the BMA is also given by the presence of a major interval of Early to Middle Jurassic tholeiitic basalt/diabase widespread throughout the South Georgia rift and extending offshore (McBride and others, 1987b). Finally, Jurassic incipient spreading has been proposed by Chowns and Williams (1983) on the basis of a pervasive zeolite-grade metamorphic event in the upper portion of the South Georgia rift fill and the bordering Piedmont.

The applicability of either the hypothesis of late Paleozoic obduction or Mesozoic rifting, as outlined above, has broad implications for regional southern Appalachian and Atlantic margin structure and paleogeography. The former hypothesis would imply that an ophiolite belt trends approximately east-west in the crust of southern Georgia and Alabama, following the BMA. The common-source interpretation of the BMA and ECMA suggests that this belt may continue offshore along the ECMA if it has not been destroyed by subsequent rifting. Intuitively, it seems unlikely that an ophiolite belt could persist so uniformly along the entire length of the ECMA.

The latter hypothesis argues that the locus of early Mesozoic rifting and even sea-floor spreading nucleated, in a general way, along the Alleghanian suture (Fig. 11). This hypothesis accords well with the interpretation of the ECMA, which generally tracks the continent-ocean transition, as rift-stage crust emplaced during Mesozoic rifting. Ballard and Uchupi (1972), for example, have suggested that the

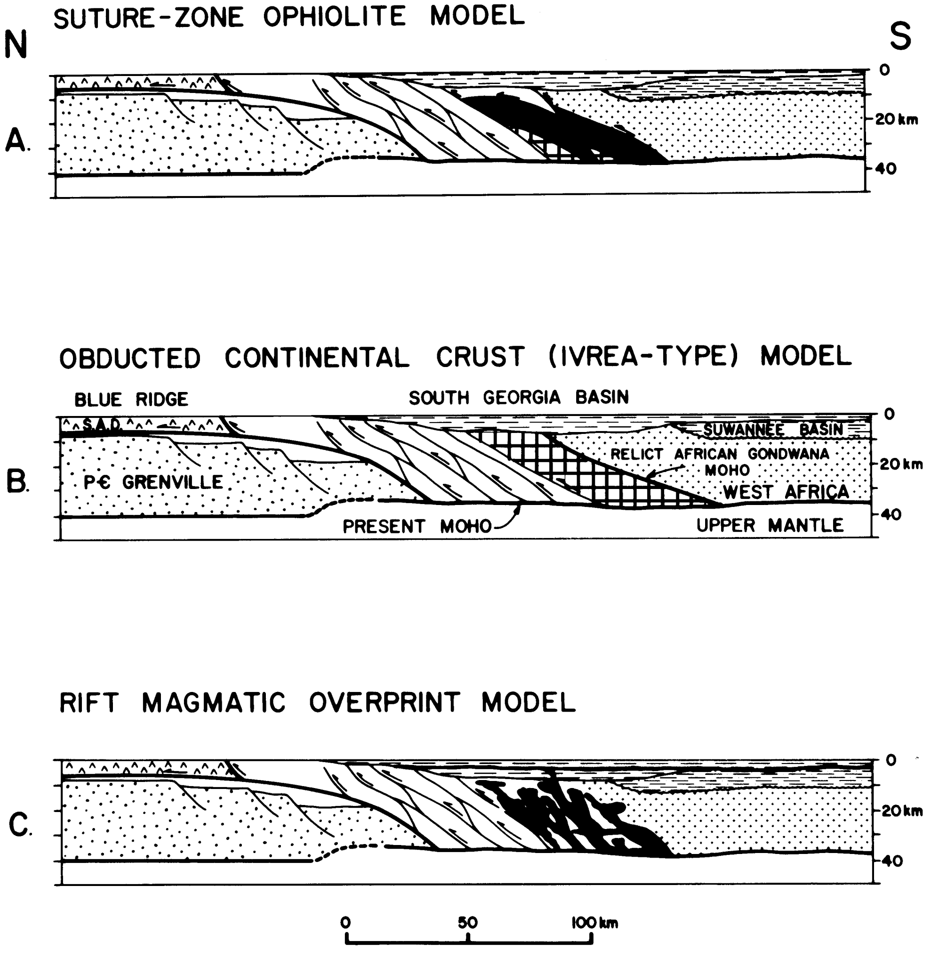

Figure 10. Generalized hypothetical cross sections illustrating three different possible interpretations of crustal structure across the Appalachian Piedmont and Coastal Plain of Georgia. (a) Obducted Paleozoic ocean crust (black) as source for BMA. (b) Obducted relict upper mantle (grid) as source for BMA. (c) Mesozoic rift-stage crust with intrusion of mafic magma (black and white) as source for BMA.

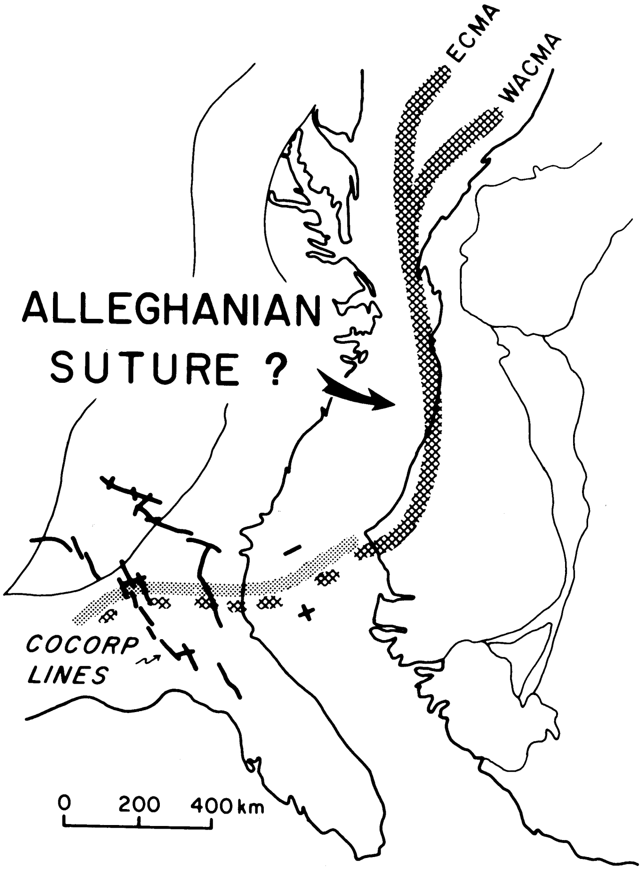

Figure 11. Preopening reconstruction of north-central Atlantic (after Roussel and Liger, 1983). East coast magnetic anomaly (ECMA) and west African coastal magnetic anomaly (WACMA) overlap and appear to be continuous with the Brunswick magnetic anomaly to the west. This composite anomaly may mark the trend of the late Paleozoic suture between North America and Africa, as well as the Early Jurassic rift that subsequently opened to form the Atlantic Ocean (modified from Nelson and others, 1985b).

ECMA is caused by an igneous intrusion possibly associated with the beginning of sea-floor spreading. The coincidence of a mafic intrusive zone along the Alleghanian suture in southern Georgia carries a strong suggestion of reactivation by rift processes. The earlier formation of the Middle to Late Triassic rift system along the East Coast in general appears to have reactivated Alleghanian or older thrust structure (Swanson, 1986). As shown schematically in Figure 11, the rift magmatism hypothesis is attractive in that it brings together the interpretation of the ECMA offshore as Mesozoic rift-stage crust and the interpretation of the BMA onshore as originating from within the zone of late Paleozoic suturing.

CONCLUSIONS

1. The BMA and ECMA, on the basis of their similar analytic form and consistent positions of the gradient and the minimum and maximum, are probably equivalent and arise from a common source.

2. On land, the BMA is not related to a sedimentary basin. COCORP reflection data together with magnetic modeling demonstrate that the depocenters of the South Georgia rift are separated from the BMA. Drillhole information also suggests that the necessary large magnetic susceptibility contrast is lacking.

3. Both the BMA and the ECMA can be modeled consistently as a seaward-dipping magnetized slab. The position of this slab on-strike is consistent with respect to the inferred "suture" zone.

4. Although the magnetized slab has a consistent orientation with respect to the inferred Alleghanian suture as marked by the reflection data, it is not coincident with it.

5. Two hypotheses are possible for the ECMA and BMA. (a) Emplacement of mafic relict oceanic crust or upper mantle by late Paleozoic obduction. (b) Production of Jurassic rift-stage crust accompanied by injection of mafic magma. It is also possible that these two processes may have acted together to varying degrees onshore and offshore.

6. The latter hypothesis implies that the Alleghanian suture acted as a zone of weakness which was reactivated to control the site of ultimate rifting and possibly initial sea-floor spreading.

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