Evidence and implications of an extensive early Mesozoic rift basin and basalt/diabase sequence beneath the southeast Coastal Plain

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ABSTRACT

Regional seismic reflection profiles across the Georgia and South Carolina Coastal Plain provide a detailed view into the internal structure and stratigraphy of the buried Triassic-Jurassic South Georgia basin. Reflection data indicate that the basin is a complex composite of smaller, individual basins which vary drastically along strike. These basins are relatively wide along north-south profile (maximum >100 km) but appear to be more restricted along strike. In cross section, the basins are asymmetric, being typically bounded on their south sides by an interpreted north-dipping master normal fault. The thickness of interpreted basin fill below the Cretaceous-Tertiary overlap also varies drastically, locally reaching 6 km.

Analysis and correlation of the reflection profiles, when integrated with drill-hole and offshore reflection data, suggest the presence of an areally extensive basalt flow and/or diabase sill sequence of probable Early–Middle Jurassic age, covering a large part of the Triassic-Jurassic South Georgia basin. The sequence is traceable on seismic reflection profiles across much of the South Georgia basin and may extend as far as from western Georgia to offshore South Carolina. The implied areal extent of this sequence would be more than 100,000 km^2, ranking it among the great basalt flows and/or sills of the world. On seismic reflection profiles over the South Georgia basin, the basalt/diabase sequence is also important in marking a "post-rift" unconformity which separates tilted and apparently faulted lower Mesozoic rift-related strata below from a thinner, more widespread, and generally unfaulted sequence above. This configuration is interpreted to mean that basalt extrusion and/or hypabyssal intrusion occurred after the main episode of Late Triassic–Early(?) Jurassic normal faulting and associated localized subsidence ("syn-rift" phase) and prior to a later, Jurassic episode of more widespread uniform subsidence ("post-rift" phase) accompanied by relatively minor normal faulting. This two-stage evolutionary sequence is analogous to that of many rift basins throughout the world and suggests a hypothesis that the South Georgia basin was an area of incipient crustal spreading associated with the early formation of the central Atlantic Ocean.

INTRODUCTION

Early Mesozoic rift-basin formation along the eastern margin of North America typically involved igneous activity manifested as diabase dikes, sills, and/or basalt flows intercalated with rift-basin sedimentary assemblages (Sanders, 1963; Marine and Siple, 1974; Faust, 1975; Van Houten, 1977; de Boer and others, 1988; Manspeizer and Cousminer, 1988). The North Mountain basalt of the Bay of Fundy (Papezik and others, 1988), the Palisades sill and the Watchung basalt flows of New York and New Jersey (Faust, 1975), and the Clubhouse Crossroads basalt flows beneath the Coastal Plain of South Carolina (Gottfried and others, 1983), are well-studied examples. Similarly, limited drill-hole information indicates the presence of basalt and diabase associated with Triassic-Jurassic continental rift-basin strata beneath the Coastal Plain in Georgia, South Carolina, Alabama, and Florida ("South Georgia basin," Gohn and others, 1978; Chowns and Williams, 1983). The scattered drill-hole data, however, only indicate the presence or absence of igneous rock within separate, isolated vertical sections, and hence, the lateral extent and regional geometry of these igneous layers have remained essentially unknown.

Herein, we summarize seismic reflection and relevant drill-hole data for the Georgia Coastal Plain (Figs. 1 and 2; Fig. 2 is folded insert), which indicate that a basaltic igneous sequence at or some distance below the base of the Cretaceous-Tertiary Coastal Plain sequence is a characteristic feature of the South Georgia basin in southern Georgia. This sequence is identical in all essential respects to the "J" basalt layer previously recognized beneath the Coastal Plain of South Carolina and the adjacent offshore region on the basis of reflection and refraction surveys and drill holes. Lacking appropriate tie lines, we are unable to correlate this layer unequivocally between reflection profiles in southwestern Georgia, southeastern Georgia, and South Carolina (Fig. 1). The data, however, certainly suggest the possibility that the "J" horizon is extensive over much of the South Georgia basin of southern Georgia, as well as South Carolina and the adjacent offshore region. The reflection data further suggest that this very prominent layer marks the previously unrecognized "post-rift" unconformity within the South Georgia basin, separating a lower, graben-filling sequence from a thinner, basin-overlapping one above. Identified in this way, the post-rift unconformity in the South Georgia basin variously occurs as either a separate horizon well below the base of the Cretaceous-Tertiary Coastal Plain sequence or coincident with it. The "J" basaltic igneous layer thus may provide a datable, and reliably correlatable, marker for use in analyzing the Mesozoic evolution of the basin.

RECOGNITION OF THE "J" BASALT REFLECTOR

Seismic reflection surveys by the COCORP (Consortium for Continental Reflection Profiling) (Schilt and others, 1983), the U.S. Geological Survey (U.S.G.S.), and the Virginia Polytechnic Institute and State Uni-

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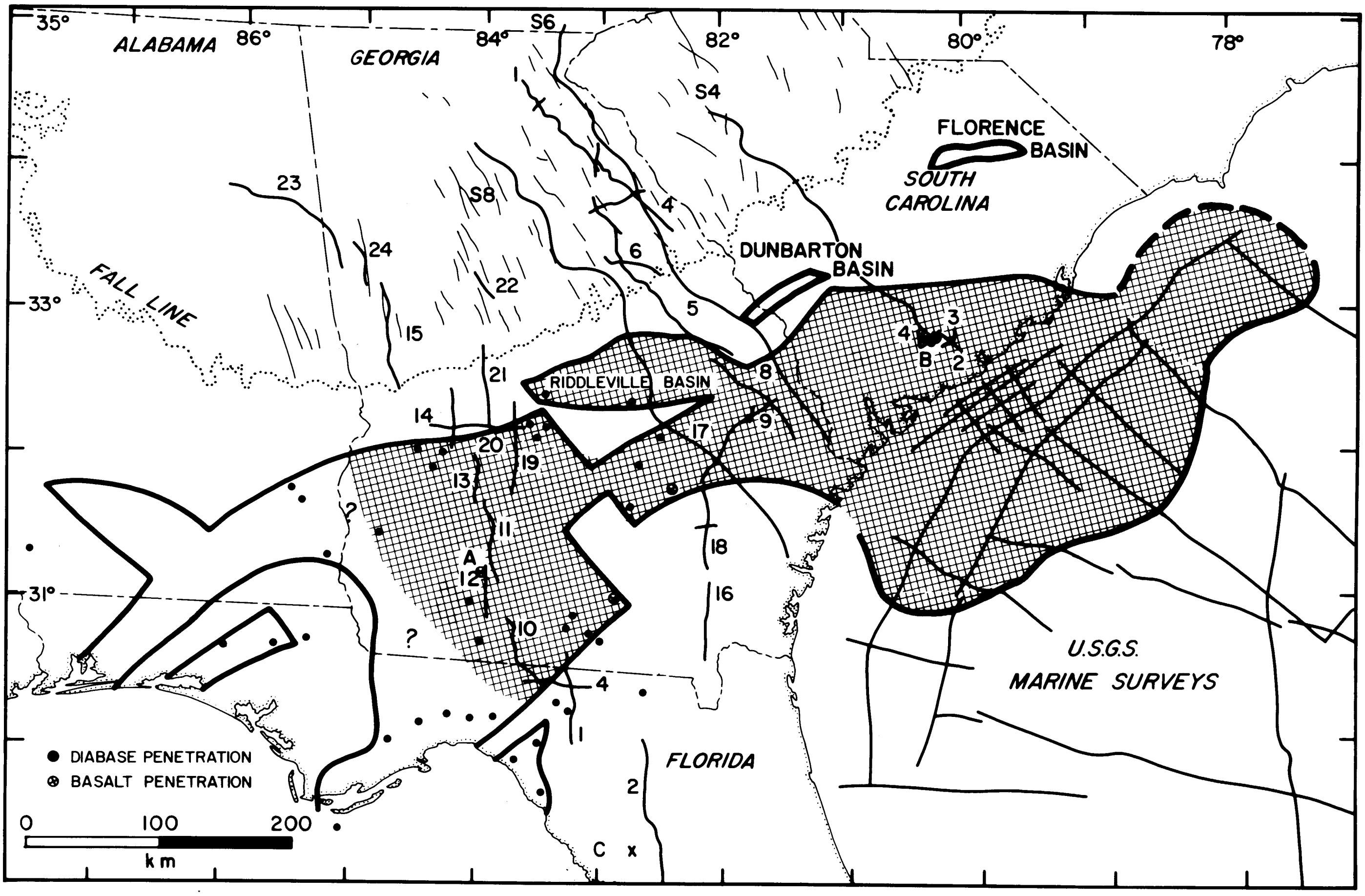

Figure 1. Map of study area, showing postulated extent of subsurface basalt/diabase ("J") reflector (offshore region from Dillon and others, 1983) (cross-hachured). Additional basalt/diabase penetrations in drill holes where reflection data are lacking or inconclusive may mean that this extent is larger than that shown. As discussed in text, reflector may be locally missing due to faulting and erosion. Heavy line outlines region of Triassic-Jurassic subcrop (Chowns and Williams, 1983). Dots indicate drill holes penetrating Jurassic-age mafic igneous rock. Thin lines represent exposed diabase dike outcrops in the Piedmont (from Dooley and Wampler, 1983). Numbered lines refer to Consortium for Continental Reflection Profiling (COCORP) surveys; lines S4, S6, and S8 to data acquired by the U.S. Geological Survey (U.S.G.S.) and reported in Behrendt (1986); and lines offshore to marine surveys acquired by the U.S.G.S. and reported in Behrendt and others (1983) and Dillon and others (1983).

versity (Yantis and others, 1983; Hamilton and others, 1983) over the Coastal Plain near Charleston, South Carolina, have previously imaged a strong, smooth reflector beneath the Coastal Plain of southeastern South Carolina (Fig. 1). This feature, originally termed the "J" reflector by Schilt and others (1983), has been correlated (Fig. 3) with a series of tholeiitic basalt flows encountered in the Clubhouse Crossroads drill holes near Charleston, South Carolina (Gottfried and others, 1983). The "J" reflector has also been traced offshore beneath the continental shelf for more than 150 km on U.S.G.S. seismic reflection and refraction lines (Behrendt and others, 1983; Dillon and others, 1983; Dillon and McGinnis, 1983), where it covers an area of more than 60,000 km^2 (de Boer and others, 1988). Throughout this region, the "J" reflector lies beneath the Cretaceous-Tertiary Coastal Plain sequence and at or just above the post-rift unconformity. Behrendt (1986) has also identified a similar strong reflector beneath the Coastal Plain sequence in South Carolina and eastern Georgia on commercial seismic lines acquired by the U.S.G.S. On the basis of ^{40}Ar/^{39}Ar, basalts correlated with the "J" reflector in the Clubhouse Crossroads drill holes have been dated as early Middle Jurassic (184 ± 3.3 Ma) (Lanphere, 1983).

Where imaged on reflection profiles from on- and offshore South Carolina, the "J" basalt reflector has a very distinct seismic character. Schilt and others (1983), Hamilton and others (1983), and Yantis and others (1983) described the basalt "J" reflector in the Charleston area as a laterally continuous, high-amplitude, low-frequency, and two-cycle reflection. The unusual high-amplitude character of the reflection was argued by Schilt and others (1983) to result from constructive interference from the top and bottom of the basalt layer together with the large contrast in seismic velocity and density of the basalt compared to sedimentary rocks above and below, a conclusion supported by synthetic seismograms (McBride, 1987, Fig. 2.3, p. 63; see also Krollpfeifer and others, 1988). The "J" reflector is also characterized by a prominent refraction, visible on individual shot records (Ackermann, 1983), possessing velocities ranging as high as 6.3 km/sec (Dillon and McGinnis, 1983). The refraction velocity associated with the "J" reflector has proved to be a particularly useful

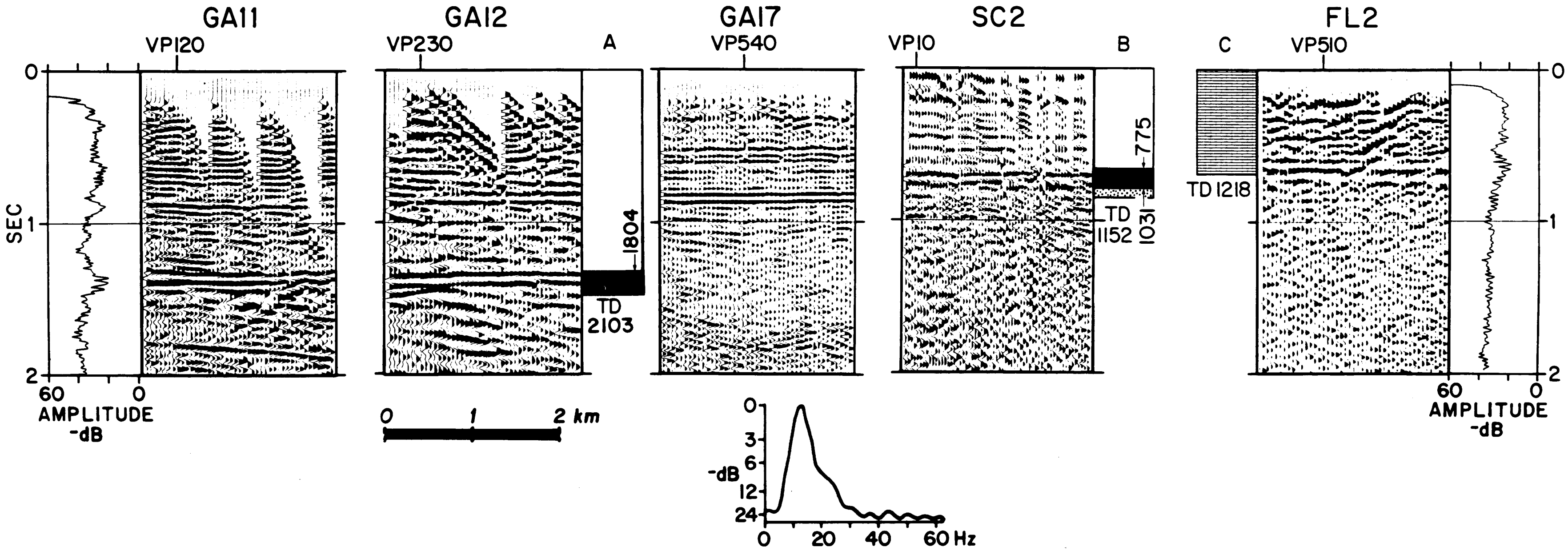

Figure 3. Four portions of stacked sections from Georgia lines 11, 12, and 17 and South Carolina line 2, showing the characteristic reflection associated with basaltic igneous layers in drill holes along with seismic characteristics of reflection frequency and amplitude. Time-depth correlations based on interval velocity conversion. Also shown is a section from Florida line 2 where basalt or diabase is not indicated. Simplified drill-hole sections taken from A: Horace Parker No. 1, Houston Oil and Minerals Corporation. B: Clubhouse Crossroads No. 3. C: J. T. Goethe No. 1, Sun Oil Corporation. Depths are in meters. Blank, Cretaceous-Tertiary Coastal Plain strata plus (?) locally Jurassic Cotton Valley strata. Black, interval of basalt/diabase and intercalated clastic sedimentary rock. Open stipple, Triassic(?) red-bed clastic strata. Blocks, Coastal Plain sequence strata, here predominantly carbonate rock. See Figure 1 for location.

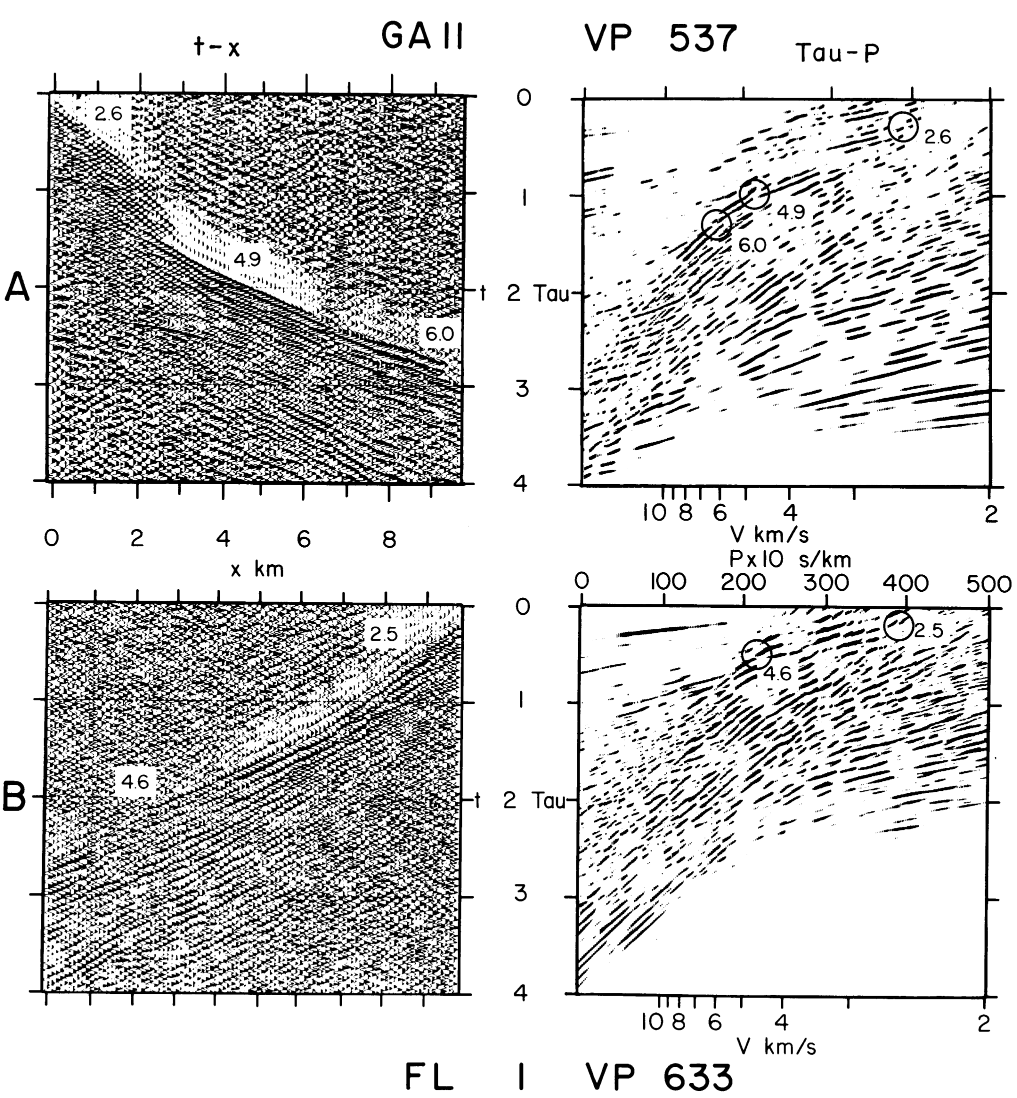

Figure 4. (A) Vibrator point record and corresponding tau-p transform (that is, zero-offset intercept traveltime versus slowness of wave; for example, Carrion, 1988) showing the typical high-velocity refraction associated with basalt/diabase reflector and lower velocities within and at the base of the Cretaceous-Tertiary Coastal Plain sequence. (B) Record for data from Florida line 1 where basalt/diabase is not indicated.

criterion throughout the Southeast for corroborating the presence of a basaltic igneous interval elsewhere beneath the Coastal Plain. Seismic velocities measured from refracted waves within Triassic-Jurassic sedimentary rocks in the Southeast tend to be no more than about 4.5–5.0 km/sec; Piedmont basement velocities are higher, typically as much as 6.0 km/sec or more; and Coastal Plain strata velocities are much lower, 2.0–3.0 km/sec (Bonini and Woollard, 1960; Antoine and Henry, 1965; Costain and Çoruh, 1988; Stephenson and Chapman, 1988; this study, Fig. 4). Thus, the high-velocity refraction associated with a basaltic layer tends to stand out where it is located above lower-velocity Triassic-Jurassic sedimentary strata. A high-velocity refractor also occurs where Coastal Plain strata rest directly on igneous or metamorphic basement (for example, Georgia line 16, Fig. 2). This, however, is clearly distinguishable from the refraction associated with a basaltic layer within the basin because it is not associated with layered reflections below and is not in very many cases associated with such a distinctive two-cycle reflection.

Analysis of reflection data collected over the Coastal Plain of Georgia and northern Florida suggests that the basaltic layer encountered in the Clubhouse Crossroads drill holes, or an equivalent layer at the same stratigraphic level, occurs over a larger part of the South Georgia basin than previously known. This interpretation is based on the lateral continuity of reflections on profiles tied to basaltic rocks encountered in drill holes, velocity determinations from relevant refractions, and the strikingly similar seismic character and consistent relative stratigraphic position of these reflections across the South Georgia basin subsurface.

SEISMIC REFLECTION DATA IN SOUTHERN GEORGIA AND NORTHERN FLORIDA (SOUTH GEORGIA BASIN)

Reconnaissance deep seismic profiles in southern Georgia and northernmost Florida comprise two major transects of the South Georgia basin (Fig. 1). The western transect consists of Florida line 1 and Georgia lines 10, 11, 12, 13, 14, and 19. The eastern transect consists of Georgia lines 16 and 17. In order to clearly present the main observations of the transects, the upper portions of the seismic sections are shown in line-drawing format in Figure 2. These lines are in addition to COCORP profiles collected previously over the South Georgia basin in easternmost Georgia (Georgia lines 8 and 9, Fig. 1) (Cook and others, 1981; Petersen and

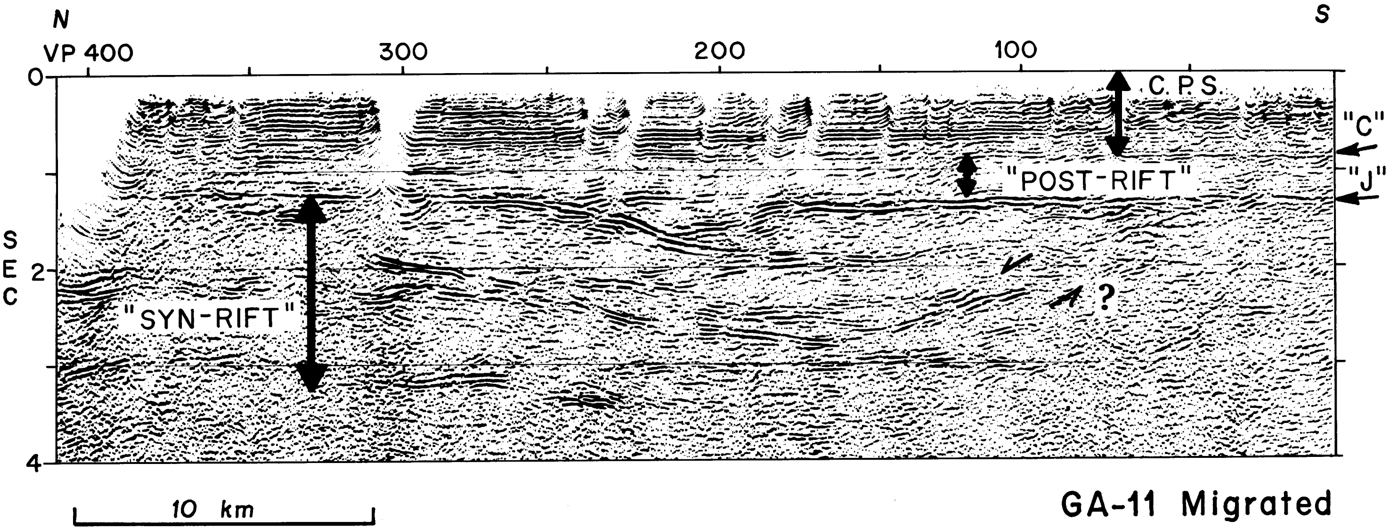

Figure 5. Wave equation–migrated (variable velocity) Vibroseis CDP-stacked section (processing including muting, velocity analysis, pulse deconvolution, trace amplitude balance, and coherency filter) of southern portion of COCORP Georgia line 11 (Figs. 1 and 2). Fold is nominally 48. Section displayed with variable area, no wiggle, and zero trace bias = 40% and at a vertical exaggeration of 2:1, using a conversion velocity of 3 km/sec. C.P.S.: Cretaceous-Tertiary Coastal Plain sequence. "Post-rift": Thinner and less reflective interval of basin (broad, uniform subsidence phase). "Syn-rift": Thicker, lower, and reflective interval of basin (more localized graben-forming phase), although locally some pre-rift material may be included. "J": Basalt/diabase reflector. "C": Interpreted base of Cretaceous-Tertiary Coastal Plain sequence. As known for other areas of the South Georgia basin (Smith and Foley, 1988), some of the deeper and brighter reflections may be from earlier-formed igneous flows or sills.

others, 1984) and in the vicinity of Charleston, South Carolina (South Carolina lines 1–4, Fig. 1) (Schilt and others, 1983). After reporting the initial results of the western Georgia transect (Nelson and others, 1985), we discussed the over-all structure of the South Georgia basin as inferred from the seismic data along both transects in McBride and others (1987) and developed a genetic model for deep crustal structure in McBride and Nelson (1988). This study emphasizes the regional stratigraphic and tectonic implications of basalt/diabase units within the lower Mesozoic rift sequence.

South of the Fall Line (landward edge of Cretaceous-Holocene overlap), all of the sections show strong and highly continuous subhorizontal reflections from 0 to approximately 1 sec (seconds, reflection time) (Figs. 2–6). This reflection sequence thickens gradually southward from the Fall Line, reaches a maximum traveltime near the southern end of Georgia line 11 of about 0.90 sec, and thins, slightly, southward into northern Florida. Drill-hole data from throughout the region indicate that most of the upper part of this sequence consists of Lower Cretaceous to upper Tertiary Coastal Plain sediments (Popenoe and Zietz, 1977; Chowns and Williams, 1983), composed primarily of interlayered limestone and weakly consolidated clastic sedimentary strata (Cramer, 1974; Gohn and others, 1978; Chowns and Williams, 1983). The well-layered, uniform character of this seismic stratigraphic sequence throughout the region distinguishes it from underlying lower Mesozoic basin strata and from pre-Mesozoic basement (McBride and others, 1987).

Beneath the base of the Cretaceous-Tertiary Coastal Plain sequence, the reflection data reveal a prominent series of internally complex layered reflections locally extending as deep as 4 or 5 sec. The areal extent of this series generally coincides with the map limits of the Triassic-Jurassic South Georgia basin as defined by scattered drilling (Chowns and Williams, 1983) and potential field analysis (Daniels and others, 1983) (that is, as shown in Figs. 1 and 2). This sequence is generally highly reflective in contrast to relatively unreflective Suwannee basin Paleozoic strata (Smith, 1982) beneath the Coastal Plain sequence in northern Florida and similarly unreflective metamorphic and igneous rocks beneath the Coastal Plain to the north (Nelson and others, 1985; McBride and others, 1987). Shallow drilling within the South Georgia basin indicates that at least the upper part of this reflective package is composed of continental clastic deposits inferred to be equivalent in age to the Middle Triassic–Middle Jurassic Newark Supergroup, exposed in fault-bounded basins farther north in the Appalachians (Van Houten, 1969; Maher, 1971; Cornet and others, 1973; Gohn and others, 1978; Chowns and Williams, 1983; Froelich and Olsen, 1985; Schamel and others, 1986). We thus refer to this entire seismically defined assemblage as the "South Georgia basin sequence," which we likewise infer to be of Middle(?) Triassic to Middle(?) Jurassic age, although actual age constraints on the deeper part of the sequence are lacking.

Along the western Georgia transect, the South Georgia basin sequence reaches a maximum inferred thickness of about 6 km (based on interval velocity conversion) near the northern end of Georgia line 11 (VP 450) (Fig. 2). From there, it thins gradually to the north and pinches out beneath the Coastal Plain sequence just north of Georgia line 14. To the south on Georgia line 11, the lower two-thirds(?) of the South Georgia basin sequence is truncated against a north-dipping reflector (fault?), which separates the reflective basin sequence from unreflective basement to the south (VP 50) (Figs. 2 and 5). Farther south on Georgia lines 12 and 10 and the northern part of Florida line 1, the South Georgia basin sequence is generally thinner and appears to include a number of small fault-bounded basins (McBride and others, 1987). Georgia line 19 is located about 40–50 km east of the main western Georgia transect and spans the northern boundary of the South Georgia basin as defined by drill-hole data (Chowns and Williams, 1983) (Fig. 1). On Georgia line 19, the South Georgia basin sequence defines a large asymmetric basin approximately 40

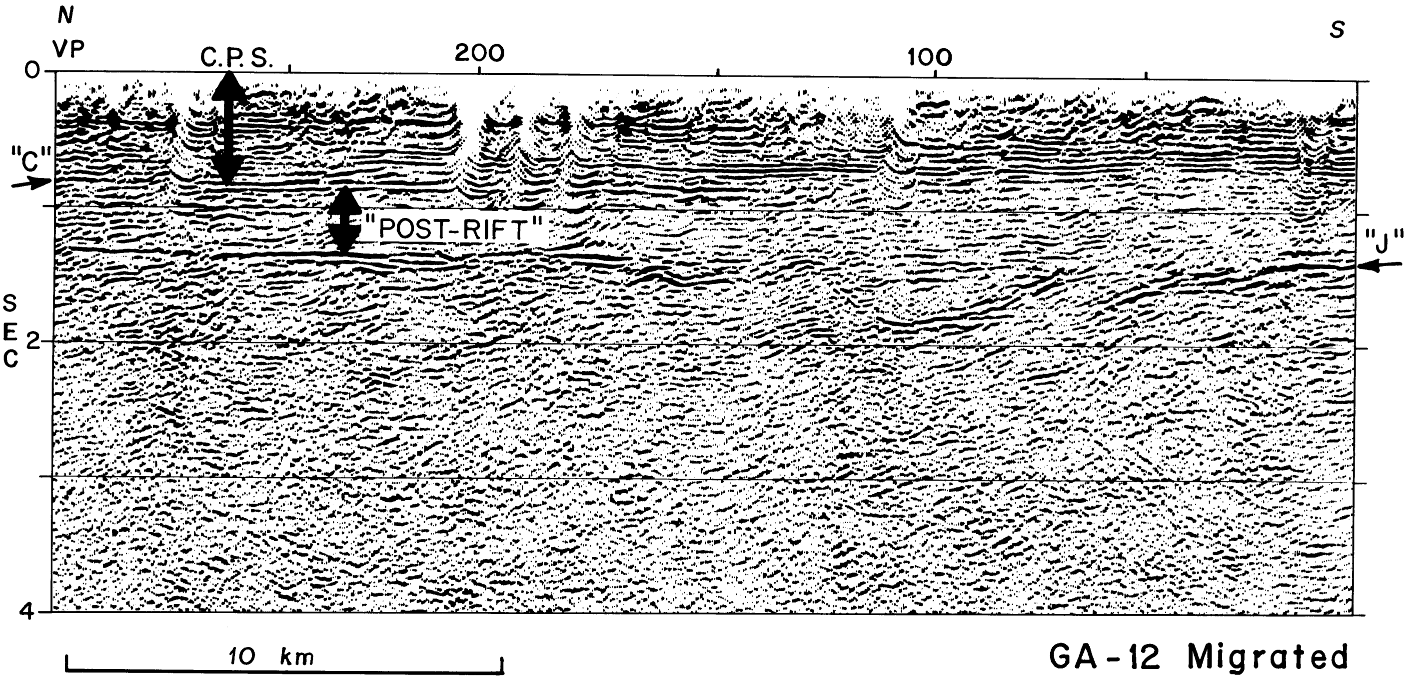

Figure 6. Wave equation–migrated (variable velocity) Vibroseis CDP-stacked section (processing including muting, velocity analysis, pulse deconvolution, trace amplitude balance, and coherency filter) of southern portion of COCORP Georgia line 12 (Figs. 1 and 2). Fold is nominally 48. Section displayed with variable area, no wiggle, and zero trace bias = 40% and at a vertical exaggeration of 2:1, using a conversion velocity of 3 km/sec. C.P.S.: Cretaceous-Tertiary Coastal Plain sequence. "Post-rift": Thinner and less reflective interval of basin (broad, uniform subsidence phase). "J": Basalt/diabase reflector. "C": Interpreted base of Cretaceous-Tertiary Coastal Plain sequence. Note local faulting of "J" reflection overlain by nontilted reflections.

km wide and having an estimated maximum depth of 7.5 km (Fig. 2). As argued in McBride and others (1987), the distinct asymmetry of the reflection package on line 19 suggests a half-graben bounded on its southern side by a north-dipping master normal fault similar to the case of line 11 to the west. The great dissimilarity in basin morphology imaged on lines 11–13 and on line 19 (roughly symmetrical on lines 11–13 and strongly asymmetrical on line 19) indicates a strong along-strike disparity in basin architecture.

Georgia lines 16 and 17 of the eastern Georgia transect together extend over and beyond the eastern part of the basin. Here, reflections assigned to the South Georgia basin sequence appear to be restricted to Georgia line 17, where, in marked contrast to the western Georgia transect, they define only a relatively thin assemblage immediately beneath the Coastal Plain sequence (maximum apparent thickness about 1 km). No large basins equivalent to those in western Georgia are observed in this area. To the south on Georgia line 16, the Cretaceous-Tertiary Coastal Plain sequence lies directly on unreflective Eocambrian felsic volcanic rocks (Maher, 1971; Chowns and Williams, 1983). To the north on Georgia line 8, the South Georgia basin sequence thickens locally in the Riddleville basin (Petersen and others, 1984).

A striking feature of the seismic profiles within the South Georgia basin is the almost ubiquitous occurrence of a high-amplitude, two-cycle reflection ("J" in Figs. 2–6) at or a short distance below the Cretaceous-Tertiary Coastal Plain sequence base ("C" in Fig. 2). On the western Georgia transect, this distinctive reflection can be traced continuously from at least as far south as the south end of Georgia line 12 to the middle of Georgia line 14, where it pinches out beneath the Coastal Plain sequence, a distance of about 150 km. A drill hole immediately adjacent to VP 310 on Georgia line 12 (Figs. 2 and 6) demonstrates that at that locality, this very distinctive reflection originates (based on interval velocity conversion) from a 299-m-thick section of intercalated diabase and/or basalt (both basalt and medium-grained pyroxene?-bearing mafic igneous rock reported) and clastic sedimentary rock, the top of which is 289 m below the base of the Cretaceous (or about 1,804 m below surface) (Houston Oil and Minerals Corporation, Horace Parker No. 1; McFadden and others, 1986). Between the base of the Cretaceous and the top of the basaltic interval is an undifferentiated section of continental clastic strata clearly distinct from overlying layers (McFadden and others, 1986). Like the "J" basalt in the Charleston area, this prominent reflector coincides throughout its extent with a distinctive high-velocity (⩾5.5 km/sec) refraction (Fig. 4). Although traceable south of Georgia line 12 onto Georgia line 10 and Florida line 1, the reflector loses continuity in this region. Scattered drill-hole penetrations, however, do indicate the presence of Jurassic basalt or diabase in the subsurface as far south as northern Florida (Fig. 1). Furthermore, drill holes in the vicinity of Florida line 1 penetrate a basalt-diabase interval near the level of a prominent two-cycle reflection on Florida line 1 (Fig. 2). As elsewhere in the South Georgia basin, the strong reflection on Florida line 1 corresponds to a high-velocity (5.4 km/sec) refraction. The broken and sporadic appearance of the reflection on Georgia line 10 may be related to imaging problems arising from the increased proportion of cavernous limestones in the Tertiary section to the south (Cramer, 1974), to local erosion and/or faulting of the basaltic interval, or to diminished magmatism in this area of the basin.

Georgia line 19 also exhibits a strong, smooth two-cycle reflection that occurs at or just beneath the base of the Cretaceous-Tertiary Coastal Plain sequence and that caps the distinctive basin sequence imaged on this line. Although there is no immediately adjacent well control as in the case of lines 11 and 12, several drill holes in the vicinity of line 19 penetrate basalt and/or diabase at about the depth of this reflector. Furthermore, like the prominent two-cycle reflection observed elsewhere in the South Georgia basin, this horizon is associated with a high-velocity refraction.

In eastern Georgia, the upper 1 sec of Georgia line 17 shows a reflection sequence similar to that of line 19. This line also shows a prominent two-cycle reflection separating the Coastal Plain sequence from the underlying discordant reflections of the South Georgia basin sequence. A similar reflection is observed on U.S.G.S. line S8, which crosses line 17 near VP 200 (Behrendt, 1986). As on line 19, there is no immediate well control on this reflector; however, drill holes farther west in the basin (Fig. 1) encountered basalt and/or diabase at approximately the depth of the reflector, and the reflection is likewise associated with a high-velocity refraction (here, as high as 6.3 km/sec). Certainly, the striking similarity between the reflector on Georgia line 17 and that originally identified as the "J" basalt reflector along South Carolina line 2 is suggestive of a correlation (Fig. 3). A high-velocity refraction is also observed at the base of the Coastal Plain sequence farther south on Georgia line 16; however, in that region, the refraction is not associated with the distinctive two-cycle reflection, and it does not overlie dipping basinal strata. Furthermore, drill-hole data as mentioned above indicate a felsic igneous basement directly below the Coastal Plain sequence.

SYN-RIFT AND POST-RIFT SEQUENCES INTERPRETATION

Along the western Georgia transect, the basaltic igneous reflector ("J") appears to vertically separate the South Georgia basin sequence into two distinct seismic stratigraphic sequences below the base of the Cretaceous-Tertiary Coastal Plain sequence. This is particularly well illustrated on Georgia line 11 (Fig. 5). On this section, the "J" interval clearly occurs above a thick sequence of complexly dipping, and thus presumably fault-bounded, reflectors and below a thinner, less reflective sequence of flat-lying reflectors, which in turn lies immediately beneath the base of the Coastal Plain sequence. We thus interpret the lower and upper sequences below the Coastal Plain sequence as marking the "syn-rift" and "post-rift" phases of basin development, respectively, analogous to the developmental sequence documented for the offshore Atlantic margin (Sclater and Christie, 1980; Behrendt and others, 1983). In western Georgia, the thinner less reflective post-rift interval is clearly distinct from the overlying Coastal Plain sequence (as defined in Fig. 2 and as observed in the Houston Oil and Minerals Corporation well) and is a broad dish-shaped seismic stratigraphic sequence reaching its maximum thickness on Georgia line 12. It is possible that this upper, anomalous package may include or even be the Upper(?) Jurassic equivalent to the Cotton Valley Formation (Gray, 1978), penetrated in a few drill holes in southwestern Georgia (Chowns and Williams, 1983). As discussed by Chowns and Williams (1983), this package is locally nonmarine but passes laterally into marine layers to the south and west. These workers tentatively assigned this layer to the basal Coastal Plain sequence and noted that it appears to be separated from the underlying rift-basin/basalt/diabase sequence by an angular unconformity. *If* this assignment is used, then all or part of the interpreted post-rift sequence (that is, between "C" and "J," Fig. 2) would be lumped with the Coastal Plain sequence.

Farther east, on Georgia lines 19 and 17, the thinner intervening post-rift sequence appears to be absent, so that the Coastal Plain sequence may lie directly on the "J" reflector (as is the case for South Carolina lines 1–4, Fig. 3). In some areas, such as the southern end of Georgia line 12 (Fig. 6), the basaltic layer is broken and tilted, implying some post-rift fault offset. In these areas, however, the immediately overlying strata appear to be flat lying and disconformable on the basalt/diabase layer. If the reflection and drill-hole data are taken as a whole, it appears that basalt flows and/or diabase sheets were extruded/intruded over much of the South Georgia basin at or near the end of the main episode of basin formation. Hence, to a first approximation, this horizon marks the post-rift unconformity within the South Georgia basin.

DISCUSSION

A prominent reflection associated with basaltic igneous rocks is observed on regional seismic reflection profiles in southwestern Georgia, southeastern Georgia, and South Carolina, as well as on U.S.G.S. profiles in South Carolina and the adjacent offshore region. Everywhere, these reflections exhibit a distinctive two-cycle character and a similar predominant frequency of about 13–15 Hz (Fig. 3) and are associated with a high-velocity refraction. On all the profiles, these reflections lie at or a short distance (maximally ~0.5 sec) below the base of the Cretaceous-Tertiary Coastal Plain sequence and essentially coincide with the post-rift unconformity within the South Georgia basin. Although seismic tie lines between the various areas are lacking, the available data certainly suggest the possibility that these distinctive reflections represent the same basalt/diabase layer. The implied areal extent of this layer between western Georgia and offshore South Carolina is more than 100,000 km^2 (Fig. 1). This is comparable in areal extent to the Columbia Plateau flood basalts (220,000 km^2) and the Deccan traps of India (500,000 km^2) (for example, Williams and McBirney, 1979).

According to the compilation of drill holes bottoming in Triassic rock in Georgia by Chowns and Williams (1983, p. L19), almost all drill holes penetrating to the depth of this reflector (generally about 1.3 sec, maximum) encountered basalt or diabase in association with Triassic-(?)Jurassic nonmarine sedimentary strata. Available drill-hole data throughout the South Georgia basin also suggest that this interval is composed of several closely spaced basaltic layers intercalated with sedimentary strata. Except for the basalt flows identified in the Clubhouse Crossroads drill holes and the drill hole adjacent to Georgia line 12, however, we are presently unable to determine whether, in general, the prominent reflections originate from basalt flows, diabase sills, or some combination of both. We note that some individual diabase sills are known to extend for great distances as horizontal, concordant intrusions as, for example, the Palisades sill, which is about 80 km long by 305 m thick, or the mid-Jurassic Peneplain diabase sill of Antarctica, which covers an area of more than 20,000 km^2 and has a thickness of 250 to 400 m (Gunn, 1962). Basaltic igneous rocks encountered in drill holes over the Southeast Coastal Plain have variously been identified as basalt flows or diabase sills (for example, Gohn and others, 1978; Chowns and Williams, 1983), sills being distinguished from flows on the basis of coarser texture and the presence of metamorphic aureoles (Chowns and Williams, 1983). We suggest that the "J" reflector identified on the COCORP and U.S.G.S. seismic profiles may consist of flows in some areas and hypabyssal sills confined to the upper part of the syn-rift sequence in others or to some combination of both in a vertical sequence.

Regardless of the precise emplacement nature of this reflector, its age and structural position within the lower Mesozoic sediments below the Coastal Plain are of key significance for the timing of rift faulting across the South Georgia basin, as well as for the timing of possible mantle interactions with the crust at various stages in the rift sequence. Tholeiitic basalts sampled in drill holes in both the Georgia and South Carolina Coastal Plain generally yield Early–Middle Jurassic ages (Gohn and others, 1978; Lanphere, 1983; Smith and Foley, 1988). The position of the basaltic igneous sequence separating the syn-rift and post-rift stratigraphic sections (Fig. 5) of the basin, together with limited age dating of the basalts, implies that initial Mesozoic rifting in the South Georgia basin is pre–Early to Middle Jurassic (that is, pre-basalt) and that the upper broad and generally unfaulted sequence directly below the Cretaceous Fall Line unconformity in western Georgia represents a younger uniform-subsidence stage, which preceded deposition of the Cretaceous Coastal Plain sediments. In South Carolina and perhaps in eastern Georgia, the intervening younger post-rift phase is apparently absent (Hazel and others, 1977) and may have been removed by erosion prior to deposition of the Coastal Plain sequence, as suggested by the fact that the basalt encountered immediately beneath the Coastal Plain sequence in the Clubhouse Crossroads drill hole is weathered and eroded (Gohn, 1983), although total nondeposition is also possible.

The post-rift unconformity is perhaps the single most important and traceable horizon for comparing evolution and timing of rifting between on- and offshore basins. Over the offshore margin, the post-rift unconformity is also the deepest horizon that can be continuously mapped from seismic data (Klitgord and others, 1988). All along the Atlantic margin, as in the North Sea, this unconformity is considered to mark the end of rifting (Early or Middle Jurassic) and the beginning of regional subsidence and active sea-floor spreading (Ziegler, 1982; Klitgord and others, 1988). As stressed by Manspeizer and Cousminer (1988), the offshore post-rift unconformity is time correlative with the onshore volcanic sequences. Early Mesozoic basins are generally well preserved (that is, with a post-rift unconformity) only seaward of the hinge zone with at most the lower levels remaining farther landward—a previously recognized exception being the South Florida basin, which has Upper Jurassic post-rift sediments preserved (Ascoli and others, 1984; Gohn, 1988). The South Georgia basin is therefore anomalous among most onshore East Coast basins in preserving a complete record of inland rifting *and* later uniform subsidence. Beneath offshore South Carolina, the "J" reflector rests on or just above the post-rift unconformity (Behrendt and others, 1983; Dillon and others, 1983). The continuation of the "J" reflector onshore into South Carolina and Georgia at the post-rift unconformity therefore implies that the extrusive/intrusive episode across the South Georgia basin began as sea-floor spreading commenced in the central Atlantic.

The evolutionary sequence deduced here for the South Georgia basin is similar to that reported for exposed Mesozoic basins farther north in the Appalachians. Basaltic volcanism around the eastern margin of North America and the northwestern margin of Africa is thought to have occurred about 75 m.y. after initial crustal thinning and at least 20 m.y. after the beginning of rift sedimentation in the middle Carnian (Manspeizer and others, 1978; Manspeizer and Cousminer, 1988). From the western Georgia reflection data, 5–6 km of syn-rift material accumulated before the onset of volcanism that produced the basalt/diabase interval. A similar concentration of basalt flows and diabase sills stratigraphically above most of the basin fill is well documented all along the East Coast (for example, Faust, 1975; Lindholm, 1978; Manspeizer and others, 1978; Swanson, 1982; Bowman and others, 1987; Manspeizer and Cousminer, 1988). For example, Faust (1975) has noted that most (80%–90%) of the Newark Supergroup sediments filling the Newark basin were deposited before the first major basalt flow. More recently, industry seismic data (Brown, 1986; Grierson and others, 1987) from the Bay of Fundy reveal a like concentration of Lower Jurassic tholeiitic basalt flows (Papezik and others, 1988) above as much as 9 km of syn-rift sediment and below a much thinner post-rift sequence, in a manner strikingly analogous to the South Georgia basin. This magmatic phase postdates the main episode of normal faulting that formed the East Coast basins, as evidenced by diabase dikes cutting through the basins and into the surrounding country rock (Faust, 1975; Popenoe and Zietz, 1977). Although controversy has historically surrounded the precise age of Mesozoic tholeiitic igneous activity along the East Coast, paleomagnetic and radiometric data seem to suggest a range of time, 175–200 Ma (Phillips, 1983; Sutter, 1985; Smith and Foley, 1988), over which several igneous events may have occurred (de Boer and others, 1988). The reflection data in the South Georgia basin and the interpretation of magnetic anomaly patterns (McBride and Nelson, 1988), as well as the studies just mentioned, all support the view that this igneous episode in the Appalachians was related not so much to intracontinental stretching as to the subsequent initiation of sea-floor spreading associated with the early formation of the central Atlantic Ocean.

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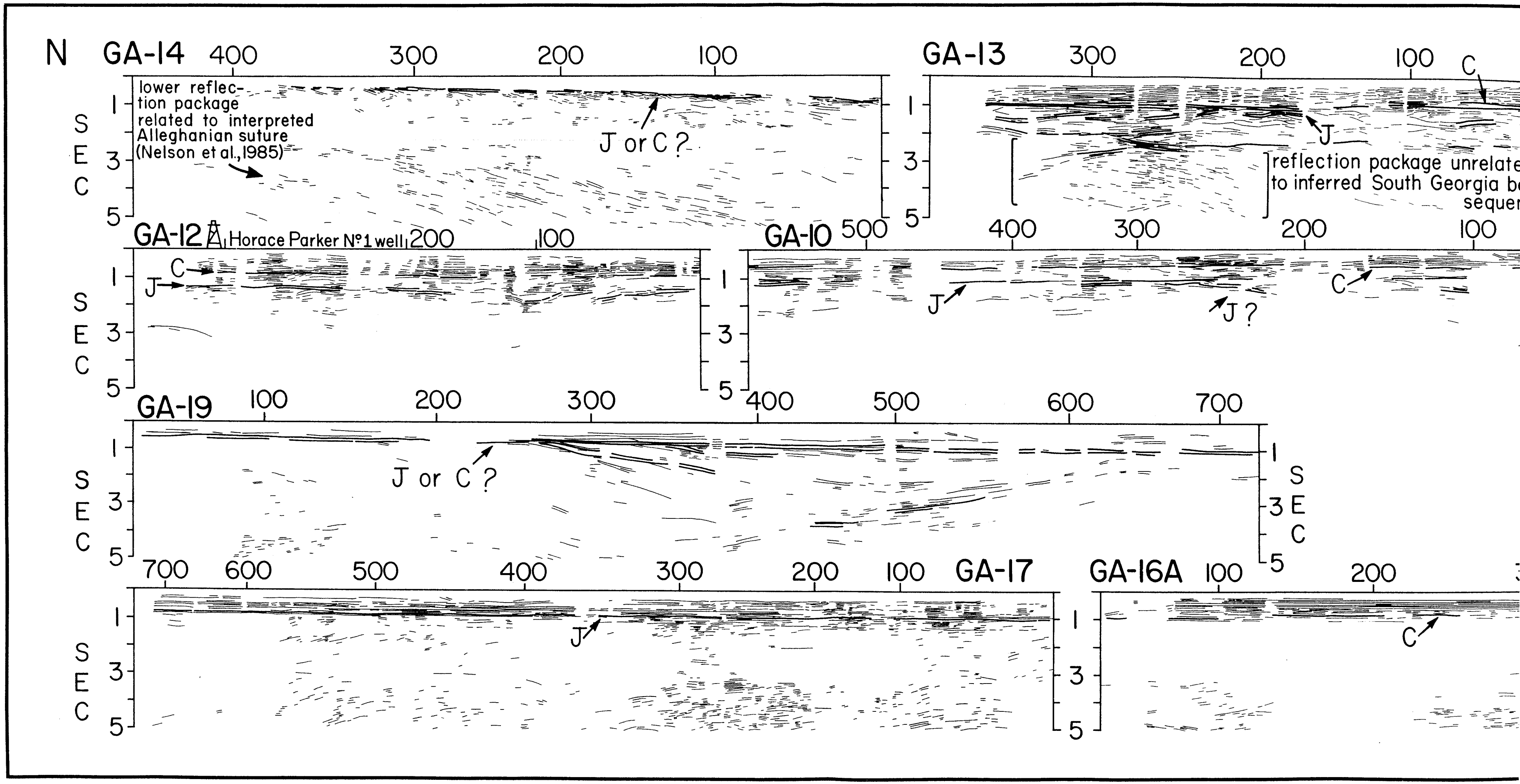

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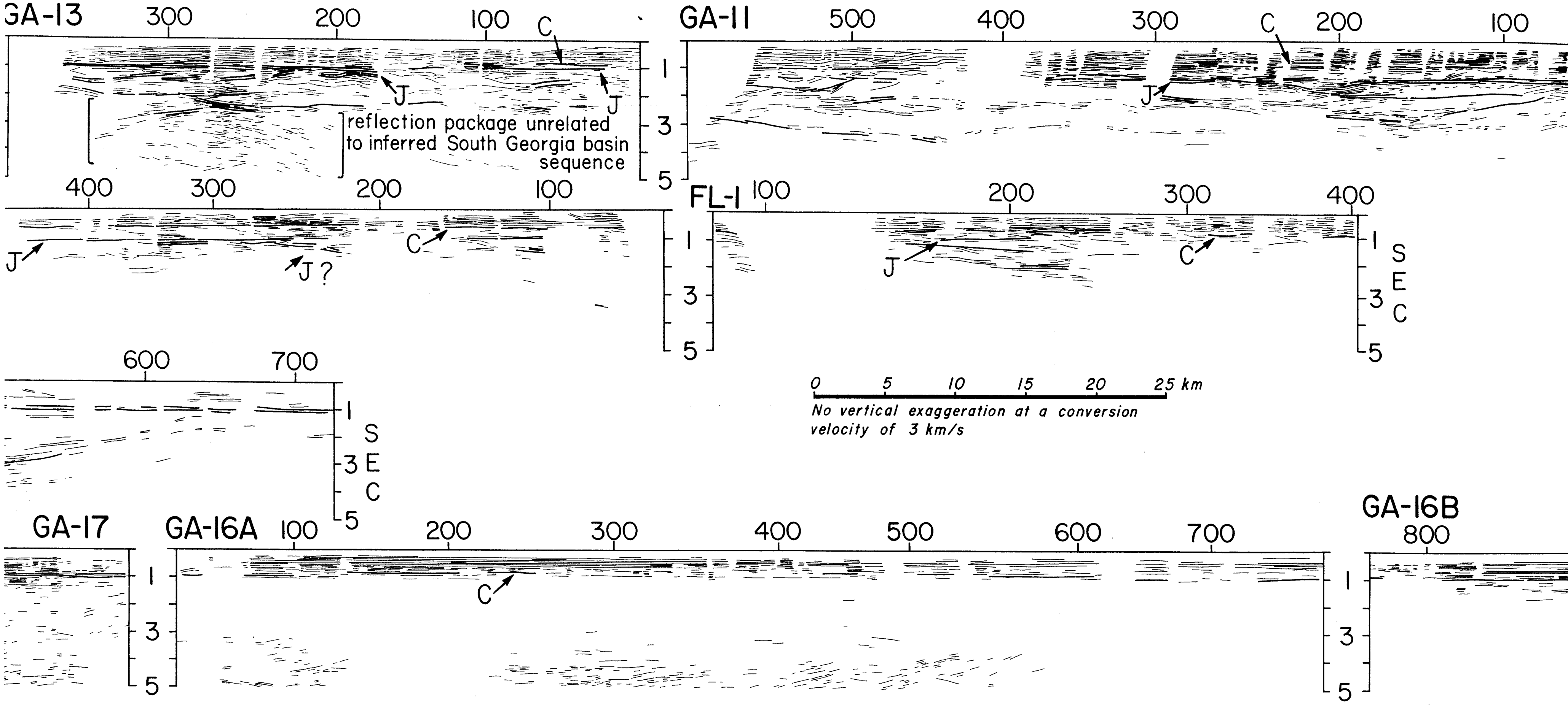
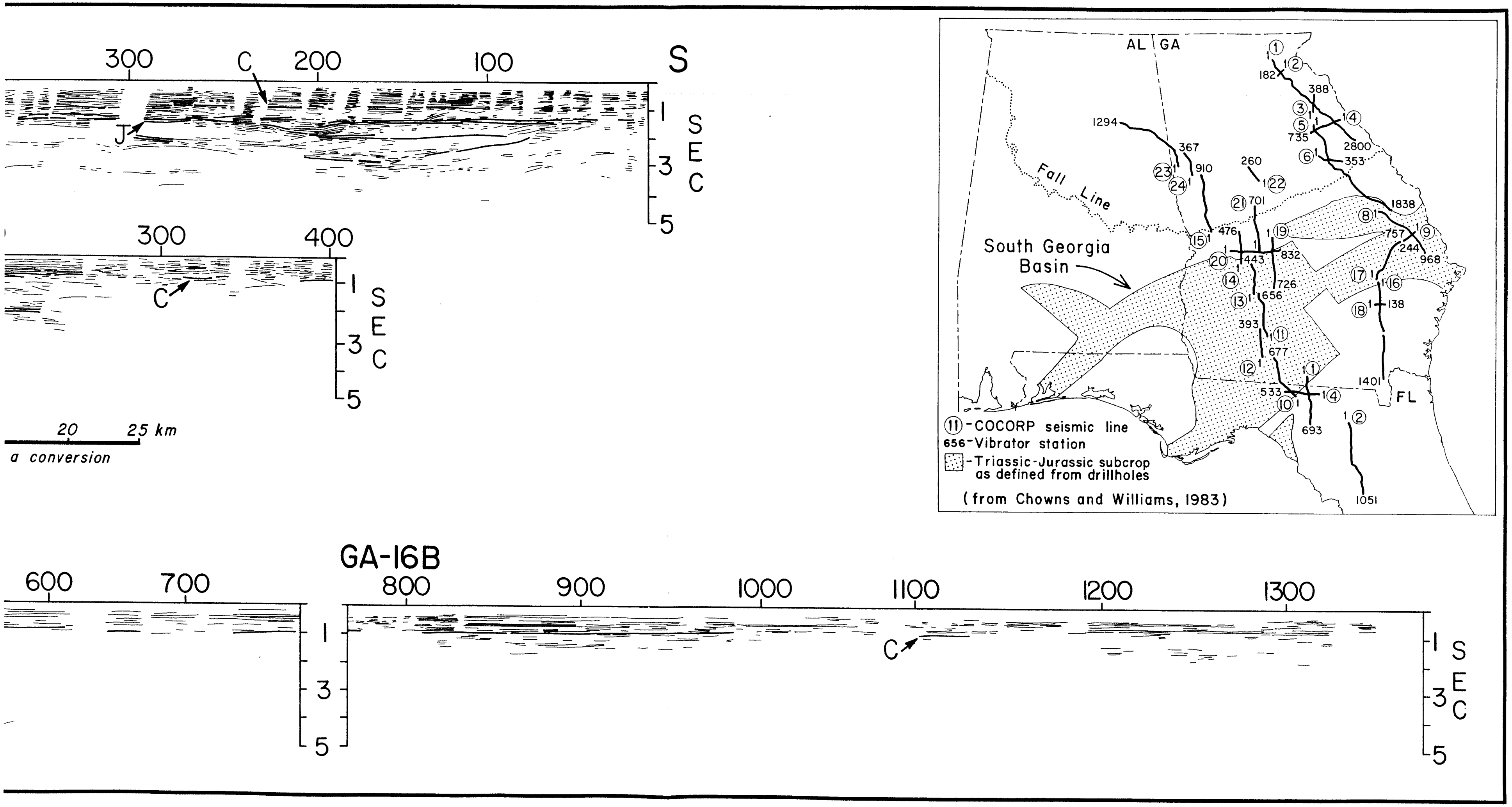


Line-drawing representation of the upper 5 sec of COCORP CDP-stacked seismic reflection sections (unmigrated; see Figs. 5 and 6 for migrated examples) over the Georgia-Florida Coastal Plain. Heavy lines indicate reflections with higher amplitude and/or coherency. Line-drawing format is used in order to clearly reproduce information on sections (original sections available; see Kaufman, 1987). Displayed with no vertical exaggeration, using a conversion velocity of 3 km/sec (typical average for sedimentary rocks). "C": reflection marking base of Cretaceous-Tertiary Coastal Plain sequence. "J": interpreted basalt/diabase reflection.



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