MAPS AND CROSS SECTIONS DEPICTING THE SHALLOW SEISMIC STRATIGRAPHY OF THE CONTINENTAL SHELF AND SLOPE OFF GEORGIA FROM INTERPRETATION OF HIGH-RESOLUTION SEISMIC-REFLECTION DATA

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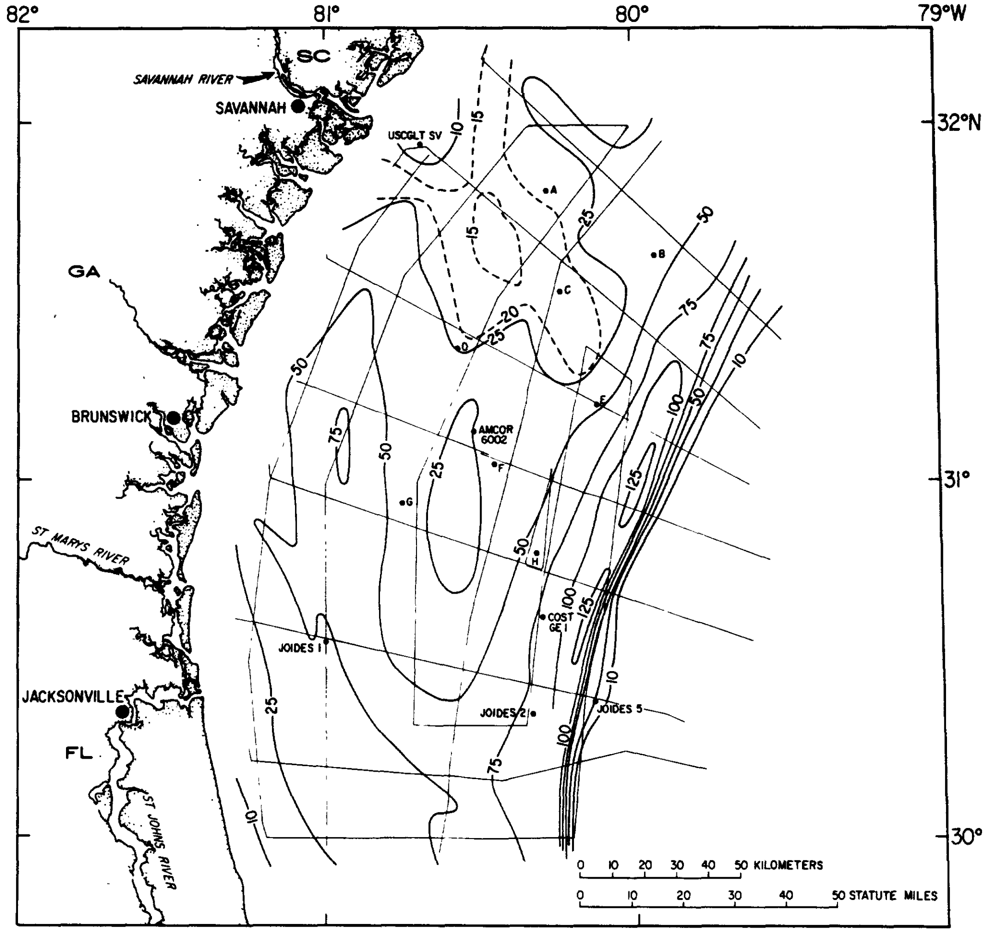

SEDIMENT THICKNESS (METERS) ABOVE MIDDLE MIOCENE STRATA

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Abstract

A seismic-stratigraphic study that used existing USGS high-resolution seismic-reflection profiles was made in the area of the TACTS coreholes. This report presents interpreted cross sections and isopach and structure-contour maps that resulted from that study and some preliminary conclusions. Structure contour maps showing depth below sea level to the upper Eocene, Oligocene, lower Miocene, middle Miocene, lower Pliocene, upper Pliocene, and Quaternary strata are presented. Maps that show the thickness of Oligocene, lower and middle Miocene, middle Miocene, lower Pliocene, upper Pliocene, and Quaternary strata and the total sediment thickness above the phosphatic middle Miocene strata are also shown.

Introduction

The U.S. Geological Survey conducted three high-resolution seismic-reflection surveys in Federal waters off Georgia, South Carolina, and northern Florida for geophysical reconnaissance during 1976 and 1979 {R/V FAY Cruise 017, (Dillon, 1979); R/V FAY Cruise 018 (McGinnis and Locker, 1976); and R/V GILLISS Cruise GS 7903-6 (Popenoe, 1979; 1983)}. These cruises, conducted jointly with the Bureau of Land Management under their Environmental Assessment Program, (a function later assumed by the Minerals Management Service) established a network of cross-shelf and along-shelf traverses spaced at approximately 20 km intervals offshore of Florida, Georgia, and South Carolina.

Because of a need for information on the distribution of phosphate-rich sediments off Georgia, the seismic data were reexamined using new information provided by the TACTS borehole data (Manheim, 1989; 1991). This report presents the maps and cross sections resulting from that analyses and preliminary conclusions. The locations of the TACTS coreholes or offshore wells in relation to the tracklines on which high-resolution seismic-reflection data were obtained are shown in Figure 1.

Previous studies have used parts of this data set. A seismic-stratigraphic analyses was made of data obtained on the FAY cruises in the late 1970's (Edsall, 1979; Paull and Dillon, 1980a; 1980b; Paull and others, 1980). In addition, parts of the FAY and GILLISS data were included in more localized seismic-stratigraphic studies by students of the University of Georgia for both Masters (Foley, 1981; Kellam, 1981) and PhD dissertations (Idris, 1983). The seismic data, supplemented with additional data obtained by the University of Georgia, were used in published papers and maps compiled for previous mineral resource assessments (Kellam and Henry, 1986; Henry and Kellam, 1988). Kellam, Shapiro, and Henry, 1989). Because significant new stratigraphic and mineral resource data was provided by the TACTS cores that was not available for any of these previous studies, I reexamined the shallow seismic-reflection data set off Georgia to both refine the seismic-stratigraphic interpretation and to encompass a larger area than the previous studies. Partial support for the reexamination was provided by the U.S. Minerals Management Service through a contract with the Georgia Geologic Survey.

Methods

Seismic Data Acquisition

A 600-joule (Del Norte)[1] minisparker, fired every 1 second, was used during the R/V FAY 017 and 018 cruises. The incoming signal was collected from a 20 element, 10 m-long streamer, filtered between 250 and 3500 Hz, and the data were displayed on a flatbed (EPC) electrostatic chart recorder at a sweep rate of one-half second.

The R/V GILLISS cruise, which was conducted three years after the FAY cruises, used a 300-joule Uniboom (EG&G) system as a seismic source and an identical recording system to the FAY cruises. Incoming data were generally filtered between 300 and 1400 Hz, and were recorded at a one-forth second sweep rate.

Ship position on all cruises was established by a computer integrated navigation system (Hewlett Packard HP-21 MX) that used both Range-Range and Hyperbolic Loran C (Teledyne), satellite receiver (Magnavox), gyro compass (Sperry), and speed log (Chesapeake). Location fixes were recorded on 9-track magnetic tape with the seismic and other geophysical data. Position accuracy on all data points is within 150 m.

Seismic Data Reduction

Strip photocopies were made of field records. FAY records were copied at full scale, while GILLISS records were copied at one-half scale to make them identical in vertical scale to the FAY data set at line crossings. The location of line crossings and points proximal to well or corehole locations were plotted on all records.

Depths to unconformities established by the well or corehole control were correlated with unconformities seen on seismic records assuming a seismic velocity between 1.5 and 1.6 km/sec. Sequence boundaries were traced on records with different colored pencils depending on the probable age of the underlying unit. As most seismic lines did not pass directly through well or corehole locations, these preliminary correlations were considered approximate, and were adjusted as necessary as interpretation progressed. Sequence boundaries identified from the well data were traced around the grid network between well locations until a suitable fit with stratigraphic data from coreholes and wells was achieved.

Major reflectors were then assigned numbers denoting age, and were digitized. Resulting digital data sets were processed through various software programs developed by the U.S. Geological Survey (Wright and Hosom, 1986) that format the data, merge it with navigation data, and convert the two-way travel time to depths using assigned interval velocities. These velocities, which yielded a good fit with all available well data, were 1500 m/sec for water and Upper Miocene through Holocene sediments, 1550 m/sec for Oligocene through Miocene sediments, and 1600 m/sec for Eocene and deeper strata. The resulting data sets for each line were then machine

[1]. The use of tradenames is for descriptive purposes only and does not convey endorsement by the U.S. Geological Survey.

plotted as cross sections with constant vertical and horizontal scale (Figures 5, 6, 10, 11).

Information on each major reflector was concatenated into a separate computer file. Depth values for each reflector were machine plotted on maps with a scale of 1:500,000 and with a data spacing interval along traverse lines of 1 km. These values were then hand contoured into structure contour maps (Figures 13-19). Well data were compared with contour maps and were used to modify contours, if necessary. Isopach maps (Figures 20-26) were constructed in a similar manner by digitally subtracting depth values between the top and bottom of each major seismic unit, machine plotting these values along traverse lines at 1 km data spacing, and hand contouring the resulting thickness values.

Borehole and Well Data

Biostratigraphic boundaries for the TACTS boreholes were established by Paul F. Huddlestun based on benthic and planktonic foraminifera. These along with the lithology and phosphorite content of the cores is discussed in Manheim (1989; 1991) Data on the COST GE-1 well is from Scholle (1979); as modified herein (discussed later). The stratigraphy in the Savannah Light Tower corehole is discussed by McCollum and Herrick (1964); and Huddlestun (1988). Data on the JOIDES coreholes are from Schlee and Gerard (1965); Charm, Nesteroff, and Valdes (1969); Poag and Hall (1979); Huddlestun (1988); and C. Wylie Poag (personal communication, 1990-1991). The AMCOR drill holes are discussed by Hathaway and others (1979); and Huddlestun (1988).

Discussion of Data

Records obtained by the sparker system used on the FAY cruises were generally of good quality on the outer part of the shelf, slope, and the inner Blake Plateau, but were of poorer quality over the middle and inner shelf (Figures 2, 3, 4). The sparker source produces a complex signal (primary pulse and bubble pulse) that causes a long train of outgoing pulses. This train of pulses is reflected back at strong interfaces, such as the sea floor, obscuring the upper several meters of the sub-bottom, as well as detail of interfaces in the subsurface (Figure 2). Because of this, the most difficult stratigraphic boundary to trace was the top of the Pliocene, since this bounndary often occurred within the long reflected train of pulses from the sea floor and was not a strong reflector.

A strong seismic source in shallow water areas also causes bottom multiples and reverberations, or "ringing". Ringing is the effect of oscillation of short-path multiples in the water column; it is particularly prevalent over areas of hard or compact bottom. The sparker records were thus somewhat difficult to interpret on the mid- and inner-shelf, and previous studies that used these data (Edsall, 1980; Paull and Dillon, 1980), without the additional stratigraphic data from the TACTS cores or the GILLISS Uniboom data, did not attempt interpretation over the middle and inner shelf. The greater part of the FAY data are dip oriented lines (Figures 5, 6).

Although the power, and thus the sub-bottom penetration, of the Uniboom system used on the GILLISS cruise was not as high as that of the sparker system used on the FAY cruises, the clean, high-frequency pulse produced by the Uniboom seismic source yields excellent and easily-interpreted records. These records display considerable detail of sediment and unconformity character at both shallow and deeper depths (Figures 7, 8, 9). The GILLISS data consists mainly of strike oriented lines that tie the dip-oriented FAY sparker records.

In comparing the seismic-stratigraphy with the well or corehole data, nearly all seismic-stratigraphic boundaries were in close agreement with depths recorded from the well or corehole data. In cases, the seismic stratigraphy showed that thin units could be mapped that were not recognized in the boreholes. Given the incomplete recovery of sediment samples from the TACTS cores, this is not surprising.

The only major stratigraphic problem involved fitting the Miocene strata identified in the COST GE-1 well (Poag and Hall, 1979) with seismic-stratigraphic boundaries traced from TACTS coreholes G and H, and from the JOIDES 2 and 5 coreholes (Charm, Nesteroff, and Valdes, 1969). In tracing the middle Miocene (lower Serravallian) boundaries from Borehole H to COST GE-1 along FAY line 25 and GILLISS line 5, both excellent records, the unconformity that marked the top of the lower Serravallian was 25 m higher than the top of the middle Miocene identified in the COST GE-1 well, occurring in the unit identified in COST GE-1 as upper Pliocene. Similarly, in tracing the top of the Oligocene from JOIDES 5 and JOIDES 2 along GILLISS line 5 to the COST GE-1 well, the Oligocene unconformity coincided with the boundary picked as the top of the middle Miocene in the COST GE-1 well.

In an attempt to rectify this problem, I consulted C. Wylie Poag, who had both originally logged the cuttings from the GE-1 well (Poag and Hall, 1979) and had reexamined the JOIDES 2 and 5 cores, although he had not yet published these results. In JOIDES 2 and 5, the Oligocene depth had not changed from the original determination. In JOIDES 2, the unit previously identified as upper Miocene (JOIDES, 1965; Schlee and Gerard, 1965) was shown to be late Pliocene in age by more recent foraminiferal biostratigraphy. This agreed with the seismic-stratigraphy for the Pliocene, but did not rectify the disagreement on the location of the top of the Oligocene or Miocene in the COST GE-1 well.

To further check the COST GE-1 data, Frank T. Manheim and I obtained and examined the unpublished gamma ray log for the shallow subsurface in the well. The unit that I had traced from Borehole H to COST GE-1 as middle Miocene (lower Serravallian) was shown by the log to be highly phosphatic, similar to phosphatic middle Miocene units in the TACTS coreholes (Manheim, 1989; 1991). The unit logged in GE-1 as middle Miocene (Langhian) was non-phosphatic, similar to the Oligocene sections in JOIDES 2 and 5. Based on these results, I concluded that the seismic stratigraphy was correct for the tops of the Oligocene, middle Miocene, and upper Pliocene units at COST GE-1, and used these in preference to the published depths. Wylie Poag has modified his log of the GE-1 well based on our results.

Seismic-Stratigraphic Technique and Interpretive Considerations

Seismic-stratigraphic units are recognized as representing fundamental depositional sequences of stratigraphic significance (Payton, 1977; Brown and Fisher, 1980). On the continental shelf and slope off Georgia, the depositional units identified in the seismic stratigraphy coincide with time-bounded stratigraphic formations mapped onshore and identified in the TACTS cores (this volume). The basic seismic-stratigraphic unit is defined by a set or sequence of conformable strata bounded at the top and bottom by an unconformity or lateral correlatable conformity. The prevailing theory (Payton, 1977; Brown and Fisher, 1980; Jervey, 1988) is that seismic units are deposited during periods of relative sea-level rise that creates space for deposition to occur (accommodation) before a graded shelf surface, in equilibrium with sediment supply and erosional or depositional processes, is reached. Deposition is also strongly dependent on the supply of sediment from the continent, which can overwhelm eustatic effects. The concepts of the seismic-stratigraphic sequence also apply to deep-water deposition, even though this deposition is controlled mainly by the dynamics of the overlying water mass and the sediment supply.

The unconformities that bound seismic-stratigraphic units may be either marine or subaerial in origin. They are recognized on seismic records by discontinuities caused by erosion or truncation of strata, by an onlap or offlap surface, or by a strong reflection that represents a major difference in the physical properties of overlying and underlying units.

Unconformities are believed to be mainly caused by relative falls in sea level. The assumption is that a sea level fall changes the equilibrium of the graded shelf surface, may expose the shelf to subaerial processes, and remove sediments from the shelf by wave-base winnowing and erosion. Excess sediment that cannot be accommodated on the shelf, as well as marine currents, are shifted offshore.

If eustatic falls are of sufficient magnitude to expose the shelf, a condition that appears to have happened several times during the Tertiary off Georgia, a topographic surface may develop that reflects fluvial features on the land surface. These, except some deeper fluvial or tidal channels, are usually removed during the following transgression by ravinement at and near the shore face. Ravinement may cut tens of meters into underlying sediment (the Cliffs of Calvert on the Chesapeake Bay offer an example of Miocene and later strata presently being ravined off). The ravinement surface has a similar dip to a bedding surface and seismic records show that this surface may follow specific resistant stratigraphic layers or horizons, or that several erosional episodes may follow the same horizon, for long distances (Figure 8). Often, this surface can be identified in seismic-reflection records by coastal onlap of overlying strata.

More unconformities and seismic-stratigraphic units are shown on the accompanying cross sections (Figures 5, 6, 10, 11) than are shown on the surface or thickness maps. In the cross sections I have attempted to define particularly prominent disconformity surfaces within the middle Miocene strata, since there is a correlation of these horizons to phosphate-rich zones. These minor and sometimes major breaks, can usually be traced laterally into areas where truncation of underlying strata shows that they are erosional surfaces, rather than merely changes in the physical properties of underlying and overlying sediments (although they are usually both). These units and breaks represent the effects of lower orders of sea-level fluctuations than those breaks that define the major stratigraphic boundaries.

On the outer shelf and slope off Georgia the Gulf Stream is responsible for cutting a number of the rugged unconformities seen on the cross sections. Pinet and others (1981, 1982) have postulated that the Gulf Stream maintains equilibrium by shifting its position landward during sea-level transgressions to impinge on the slope, and seaward during regressions to a position on the central Blake Plateau. This hypothesis is supported by observed rugged unconformities seen in seismic records on the mid- to outer-shelf off Georgia that are parallel to the slope. A north-trending swath of Gulf Stream produced erosion shows on the isopach map of the middle Miocene (Figure 23) where middle Miocene strata have been removed from most of the outer shelf and slope on FAY lines 28, 27, and 26 (Figure 5). These Gulf Stream cut unconformities, presumably cut during the sea level highstands, merge landward with unconformities that show obvious fluvial channels. Thus, the unconformities off Georgia are complex features; a single unconformity reflecting both the high stand and low stand of sea level.

Because of the above processes, Coastal Plain and Shelf sediments represent a fragmentary and largely incomplete sedimentary record. Often, on both the coastal plain and shelf, nearly entire units have been removed and the only evidence for their former presence is preserved in widely scattered outliers that occupy former low areas, such as an erosional channel or sinkhole. This is the case of the upper Miocene strata, which could not be mapped in detail because of two factors: (1) they are discontinuously preserved, occupying mainly low areas on the top of the upper Miocene unconformity, and (2) they are acoustically, texturally, and depositionally identical with the Pliocene strata, which also overlie this unconformity.

The profiles (Figures 5, 6, 10, 11) show apparent folding of middle Miocene and older strata, particularly in the southern part of the surveyed area (Figure 12). This folding is also evident in several both large and small closed depressions seen on the structure contour maps of the top of the Eocene, Oligocene, lower Miocene, and middle Miocene strata (Figures 16, 17, 18, and 19). The folding is a result of downwarping and collapse due to karstification of limestone sections at depth, although it also affects the overlying Miocene strata (Popenoe and others, 1984; Evans and Hine, 1991). The main karstification of the shelf occurred during subaerial exposure of the shelf in late Miocene time, but also may have occurred in the late Oligocene and, at places, during the Pleistocene. Pliocene and younger strata that infill these features show only minor evidence of deformation (Figure 12).

Preliminary Conclusions

It is not the intent of this report to discuss the implications of the data but some preliminary conclusions can be made. Late Paleogene and Neogene deposition in southeastern Georgia and on the Georgia shelf infilled a relict basin (Suwannee Straits) originally cut by currents that flowed from the Gulf of Mexico to the Atlantic across southern Georgia in the Late Cretaceous and Paleocene (Chen, 1965; Popenoe, 1990). In the late Eocene and early Oligocene this basin remained over 100 m deeper off Georgia than the adjacent Florida or Carolina shelves (Figures 18, 19). The basin extended well into the mainland of Georgia as both the Waycross Basin (Popenoe, 1990) and the adjoining Jacksonville Basin of northern Florida (Goodell and Yon, 1960).

Lower Miocene strata are relatively thin under the shelf (generally < 25 m) and are confined mainly to the inner- and mid-shelf areas. These strata are thickest off Brunswick, Ga. (> 40 m) and thin over paleo-bathymetric highs (Figures 5, 6, and 10), as well as both northward and southward onto the margins of the relict low (Figure 17). The top of the lower Miocene strata is a conspicuous unconformity, particularly off southern Georgia, characterized by the discontinuous erosion of a resistant layer (figure 8).

Middle Miocene strata range from zero thickness under the shelf to over 150 m thickness under the slope (Figure 23). The middle Miocene (lower Serravallian) unit is characterized on seismic-reflection records by strongly layered or parallel banded reflectors (Figures 7, 9, 12) over the inner- and mid-shelf. This banding becomes less pronounced toward the slope (Figure 4). Laterally tracing these strong reflectors shows that they locally truncate strata indicating that they represent minor unconformities in the middle Miocene section. A comparison of these strongly-reflective bands with the TACTS corehole data shows a correlation of the strong reflectors with zones of phosphorite enrichment, indicating concentration of phosphorites at the unconformities.

The shallowest subcrop of middle Miocene strata occurs near the Savannah Light Tower where these phosphate-rich sediments are either at or within 10 m of the shelf surface (Figure 24). They become progressively deeper to the south (Figure 24) where they underlie up to 75 m of post-Miocene sand and mud on the inner shelf and 25 m of post-Miocene sediments on the middle shelf.

The top of the middle Miocene is a pronounced erosional unconformity (Figures 5, 6, 7, and 10). Structure contours on the top of the middle Miocene (Figure 16) show that the unconformity has over 50 m of relief across the shelf, due to a broad, 40-km-wide low on the inner shelf (mid-shelf low Kellam and Henry, 1986) that parallels the shoreline from Savannah southward, crossing the shelf to the slope off Jacksonville, Fl. Because of the inner-shelf low, the middle shelf forms a broad high, a feature previously described by Kellam and Henry (1986) and Henry and Kellam (1988) as the outer shelf high. The nature of erosion that formed the broad channel and it's orientation leave little doubt that it originated from fluvial cutting by the combined Savannah and Altamaha Rivers during subaerial exposure of the shelf. The channel is partly filled by prograded late Miocene (Tortonian) strata, dating the major episode of the erosion and subaerial exposure as late Miocene (early Tortonian).

During the subsequent eustatic rise of the early Pliocene the channel was broadened and a now buried escarpment was cut by ravinenent beneath the Sea Islands on the Georgia coast (Kellam and Henry, 1986; Henry and Kellam, 1988). Although our seismic lines did not extend near enough to the coast to see this feature, it's position from Henry and Kellam (1988) is shown on Figures 15 and 16. During the early Pliocene the northern end of the inner-shelf low was filled by southward- and eastward-prograding pro-deltaic shelf sand and mud that appear to emanate from a paleo-Savannah River source (Figure 22). The channel-fill sediments also prograde westward from the mid-shelf high, indicating that as the sea topped this prominent feature, which must have been a peninsula similar to the Delmarva Peninsula, it eroded sediment to be deposited on its western flank. The channel became totally filled by prograded sands and muds during the late Pliocene (Figure 21) producing the smooth and relatively featureless shelf we see today.

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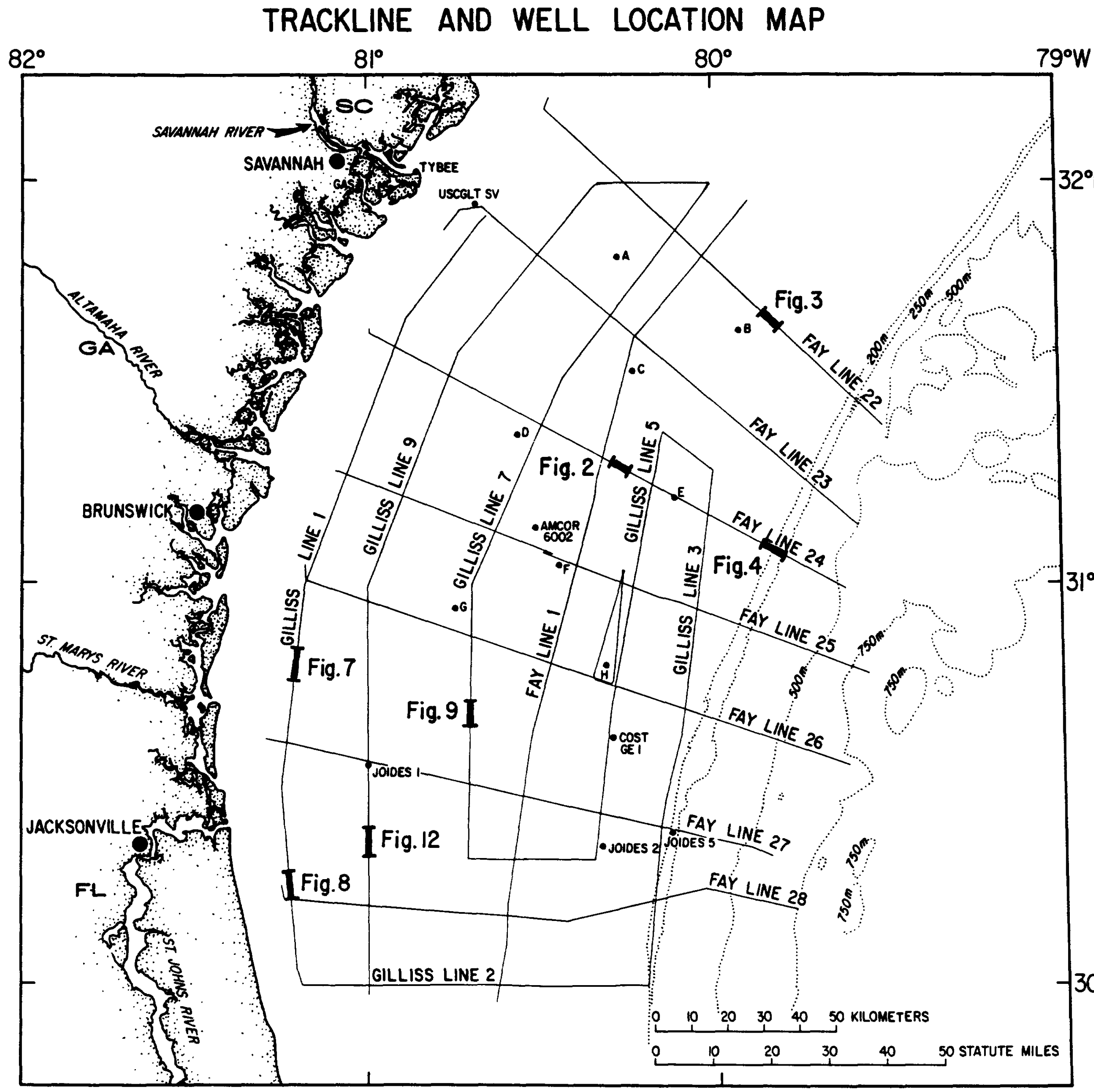

Figure 1. Map of the survey area showing locations of seismic-reflection tracklines and TACTS coreholes A-H; JOIDES 1, 2, and 5; AMCOR 6002; COST GE-1; and U.S.C.G. Savannah Light Tower. Also shown are the locations of Figures.

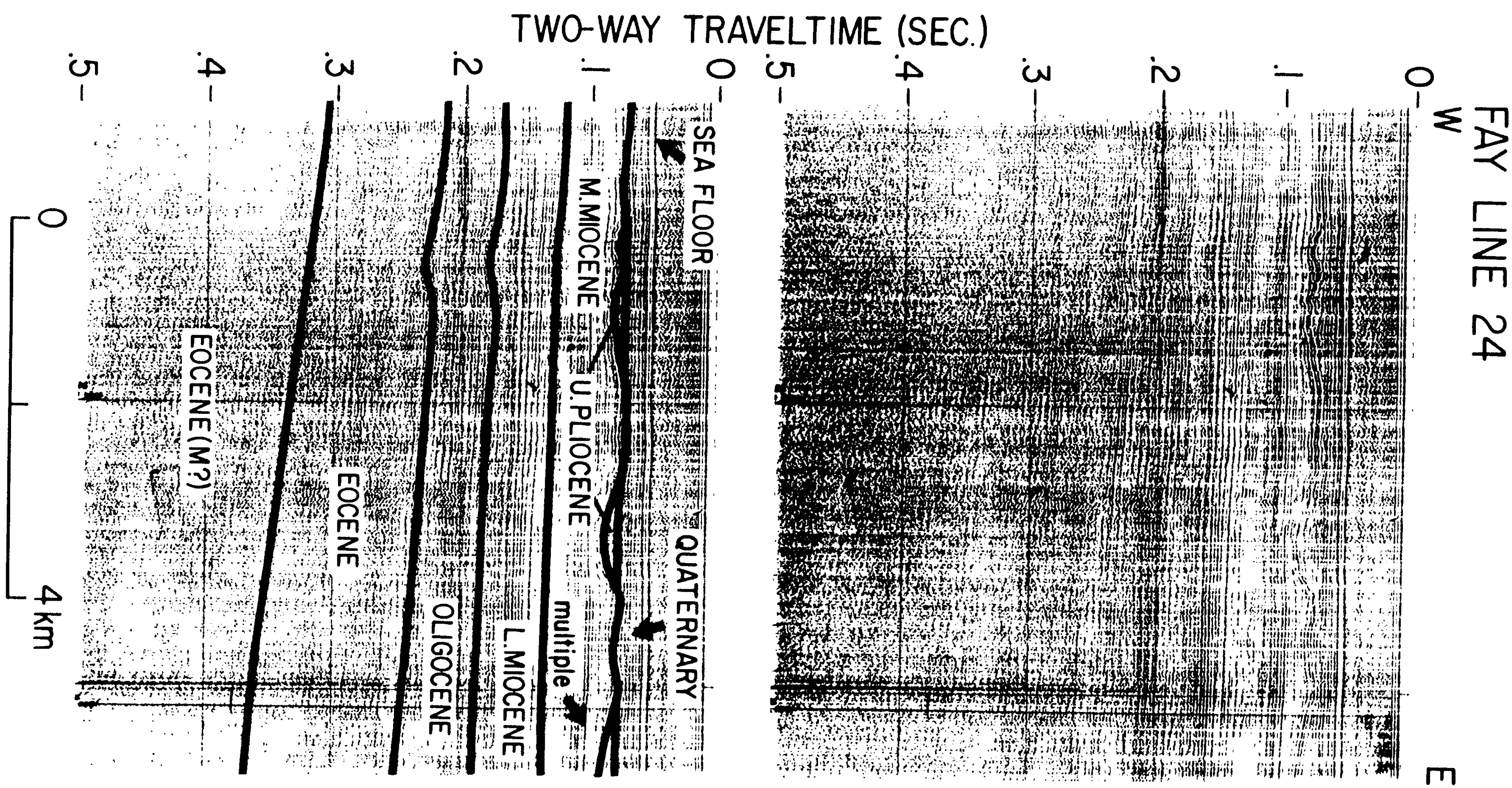

Figure 2. Part of FAY line 24 showing the character of the sparker data collected on the FAY cruises. The undulating unconformity that marks the top of the middle Miocene strata has reflected the entire outgoing sparker signal making the unconformity appear as a layer, rather than a surface.

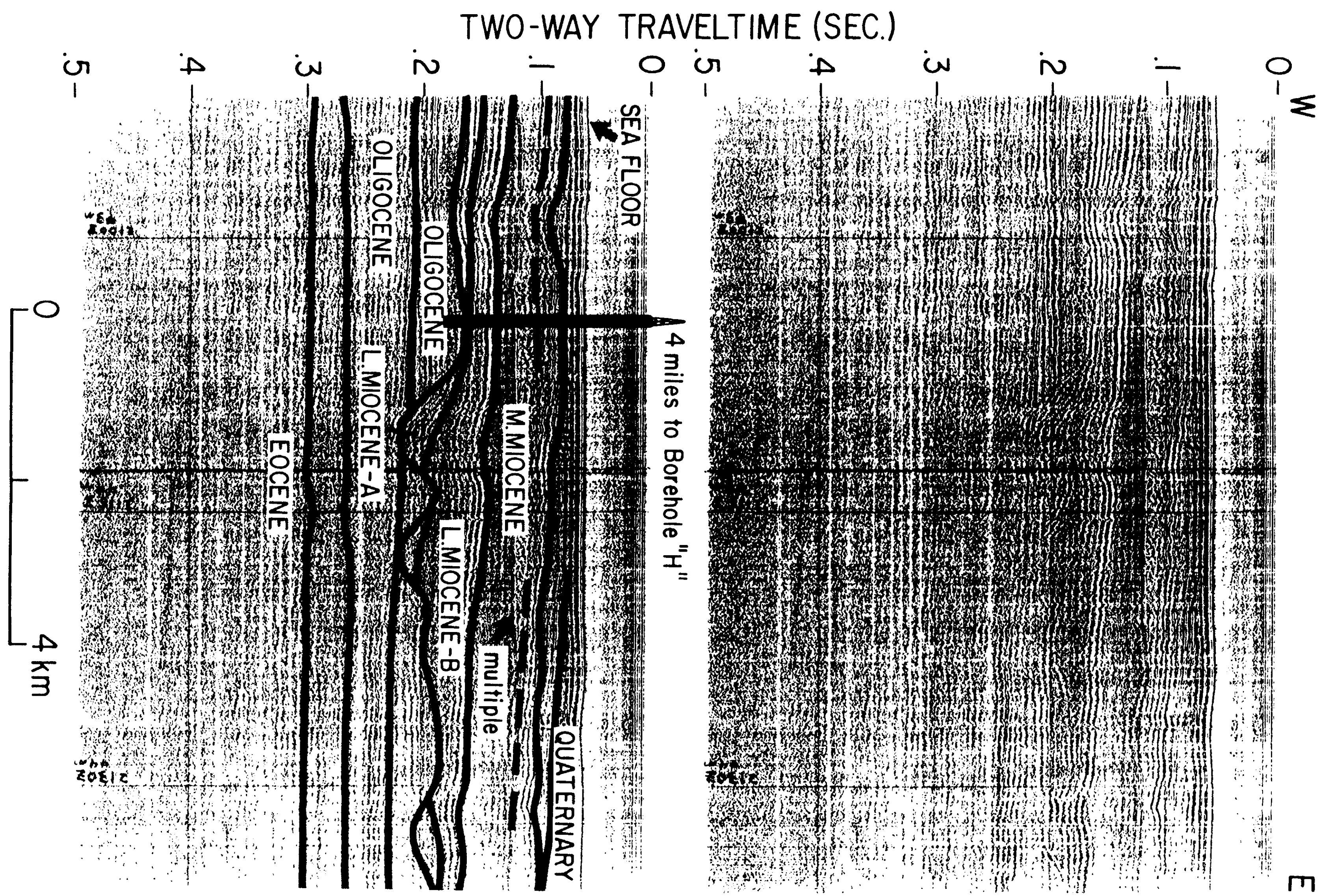

Figure 3. Part of sparker profile FAY line 22 showing deep erosional furrows on the top of Oligocene strata on the outer shelf. Note that the sea floor has reflected the entire outgoing pulse.

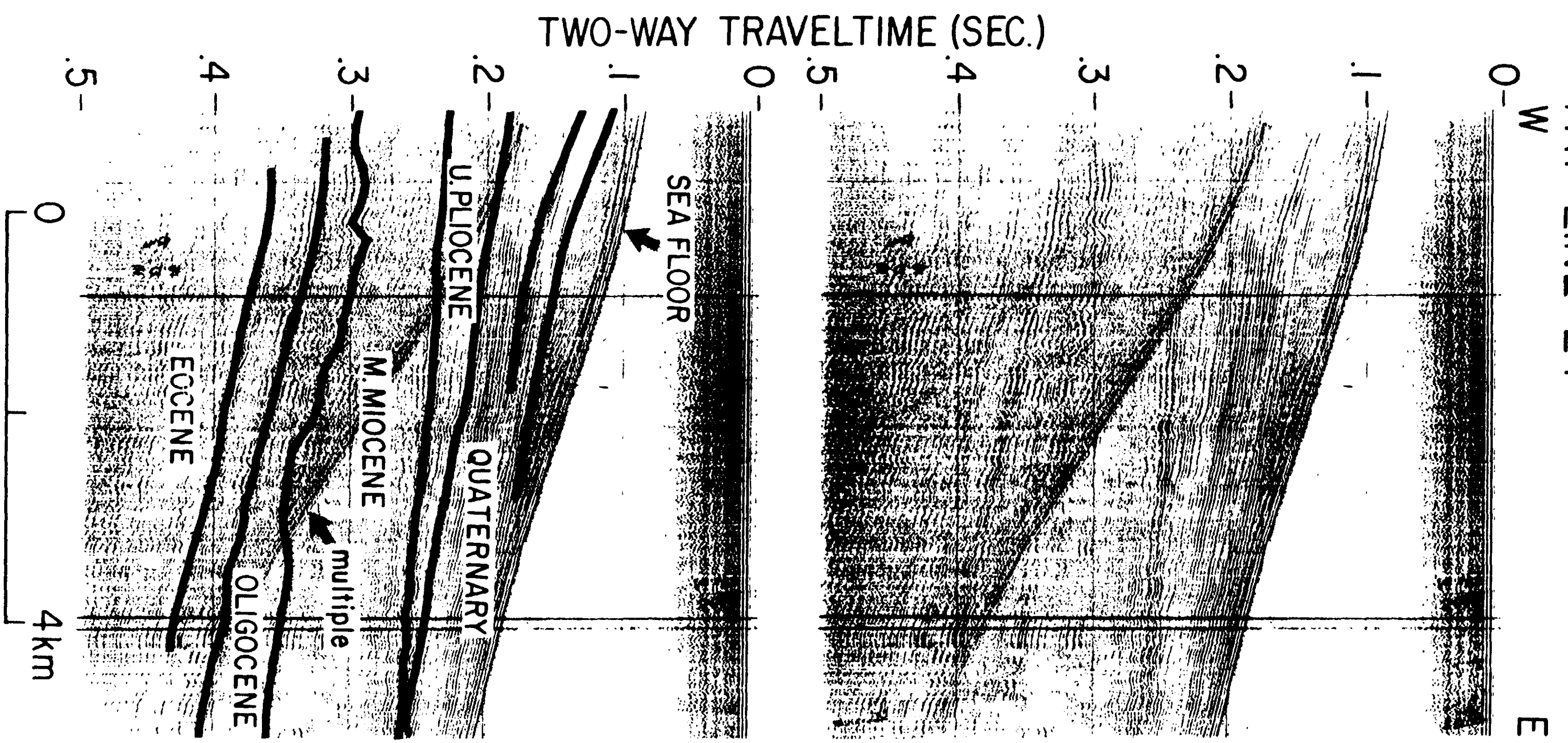

Figure 4. Part of sparker profile FAY line 24 showing the nature of the sparker data over the continental slope. Excellent records were provided by the sparker system in the deeper water of the slope and Blake Plateau.

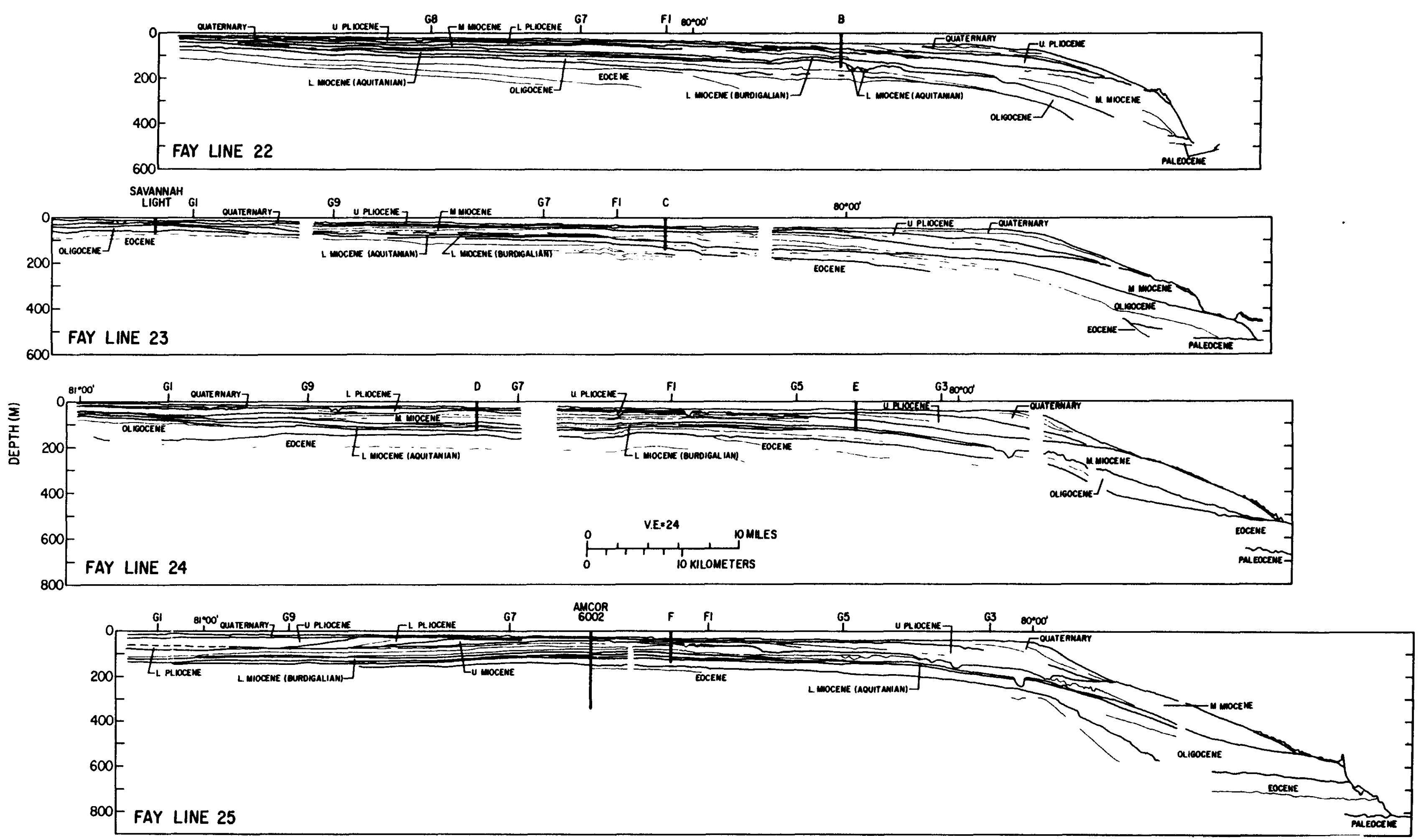

Figure 5. Interpreted scale-adjusted cross sections based on sparker profiles FAY lines 21-25. Locations are shown in Figure 1. Intersections with cross lines and proximity to offshore well or TACTS coreholes are shown above each line. Major boundaries of seismic-stratigraphic units are shown by heavy solid lines and minor boundaries by lighter lines. Dashed lines indicate where boundaries are inferred from cross lines.

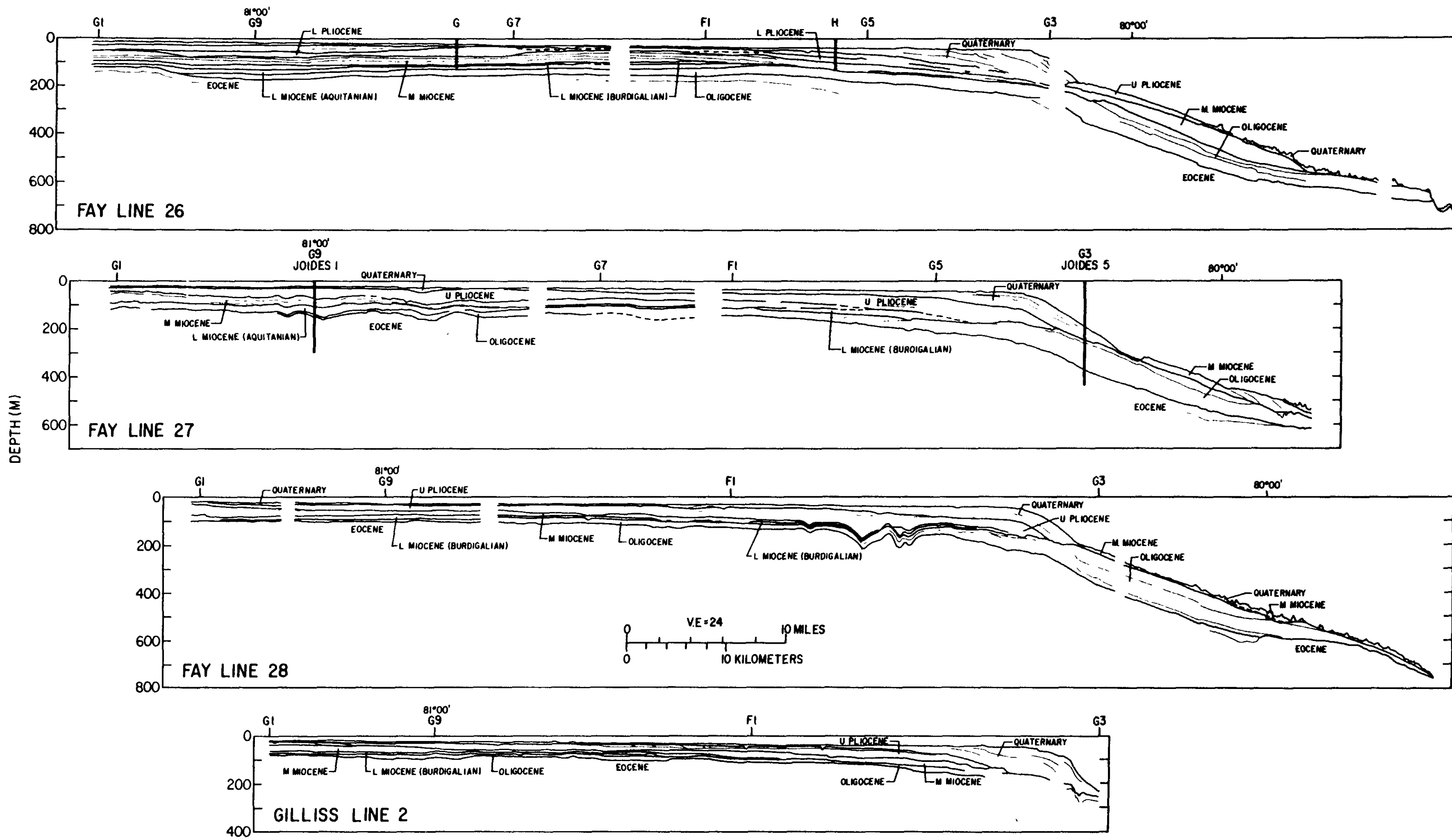

Figure 6. Interpreted scale-adjusted cross sections based on dip-oriented profiles FAY lines 26-28 and GILLISS line 2. Locations are shown on Figure 1. Intersections with cross lines and proximity to offshore well or TACTS coreholes are shown above each line. Major boundaries of seismic-stratigraphic units are shown by heavy solid lines and minor boundaries by lighter lines. Dashed lines indicate where boundaries are inferred from cross lines.

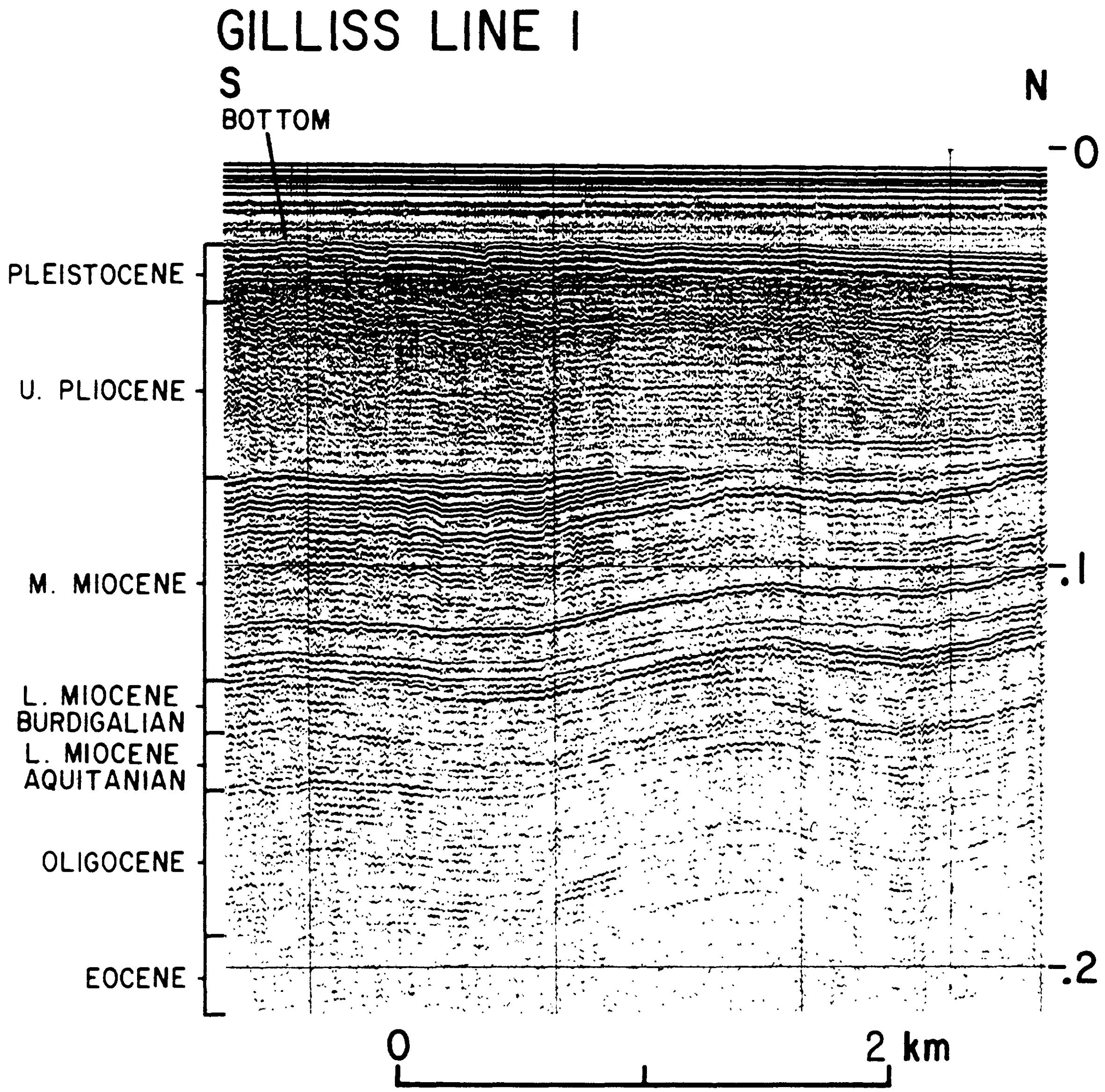

Figure 7. Part of GILLISS line 1 showing a typical record produced by the Uniboom seismic-reflection system. On this record the middle Miocene strata show a parallel-layering or banded appearance characteristic of these strata on the inner and middle shelf. On the outer shelf they are similar in character to the overlying, more acoustically transparent, Pliocene and Pleistocene strata.

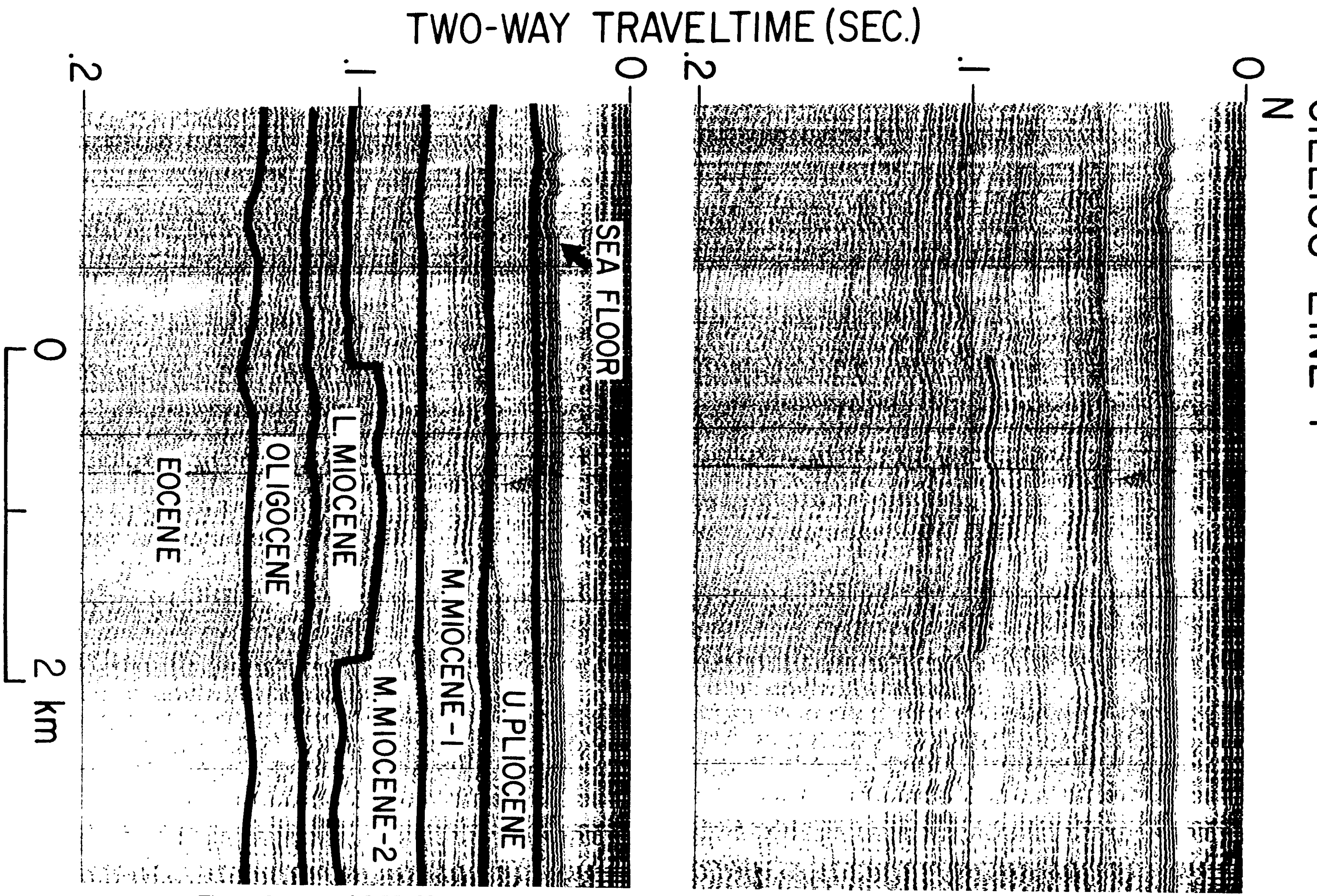

Figure 8. Part of GILLISS line 1 from the inner shelf off southern Georgia. This record shows an erosional remnant layer of strata preserved as an outlier. This type of discontinuous erosion of a resistant layer is characteristic of the top of lower Miocene strata (top of Burdigalian) and may be due to ravinement at the shore face.

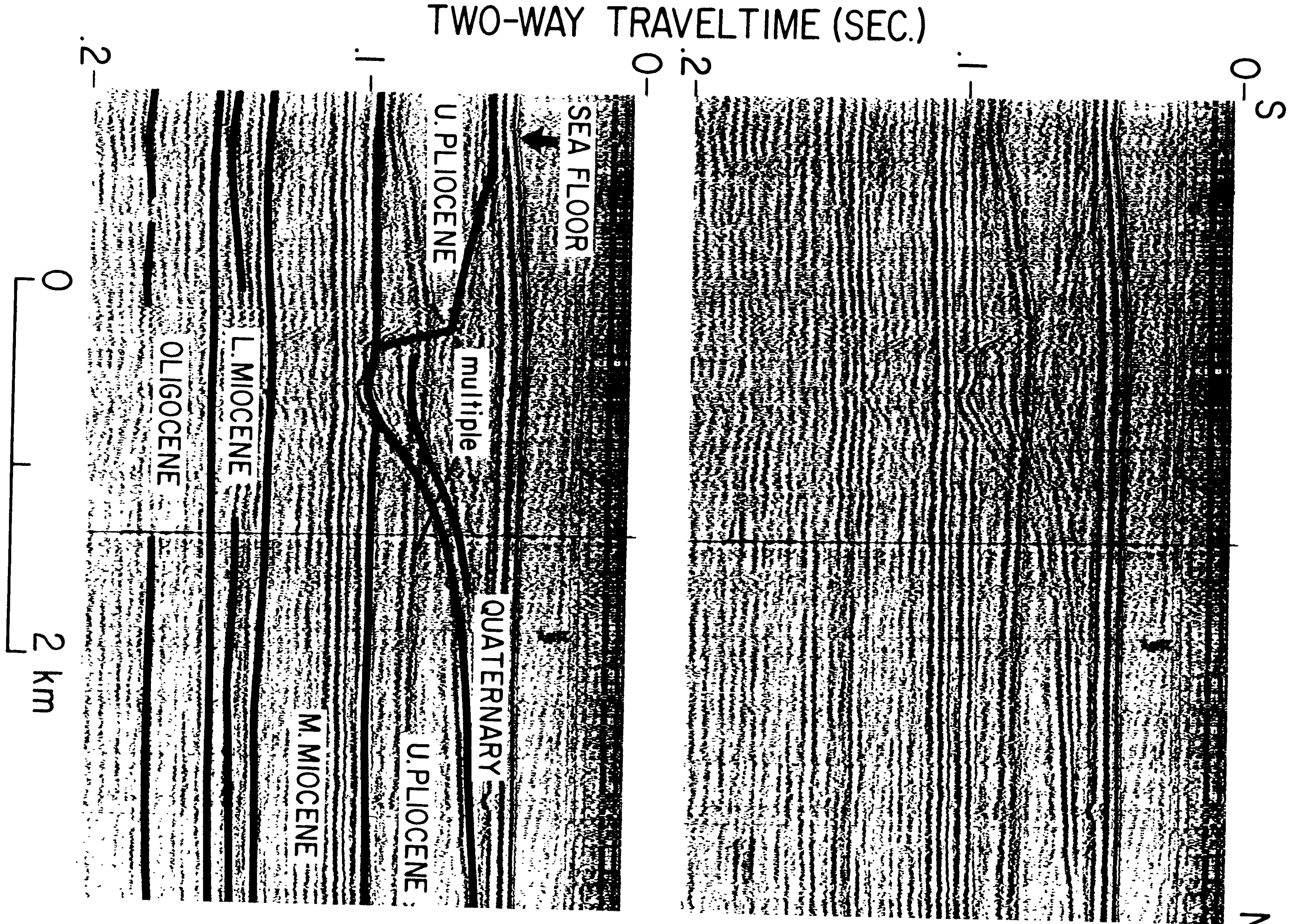

Figure 9. Part of GILLISS line 7 showing a large Quaternary erosional channel of probable fluvial origin on the mid shelf off southern Georgia.

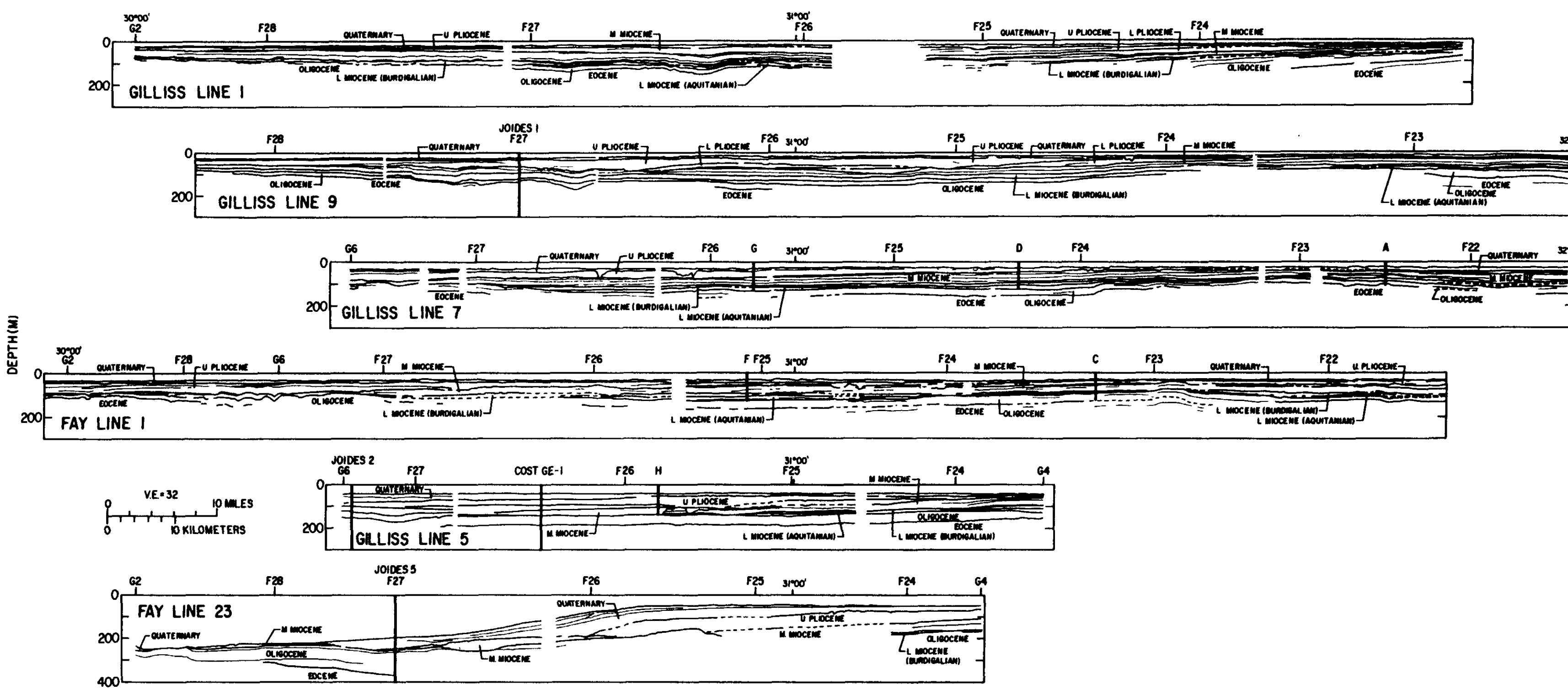

Figure 10. Interpreted scale-adjusted cross sections based on strike-oriented seismic-reflection profiles GILLISS lines 1, 3, 5, 7, and 9, and FAY line 1. Locations shown on Figure 1. The cross sections are aligned on 31°00′ N. latitude. and are viewed from offshore to onshore. Locations of line crossings and proximity to well or TACTS coreholes are shown above each line. Major boundaries of seismic-stratigraphic units are shown by heavy solid lines and minor boundaries by lighter lines. Dashed lines indicate where boundaries are inferred from cross lines.

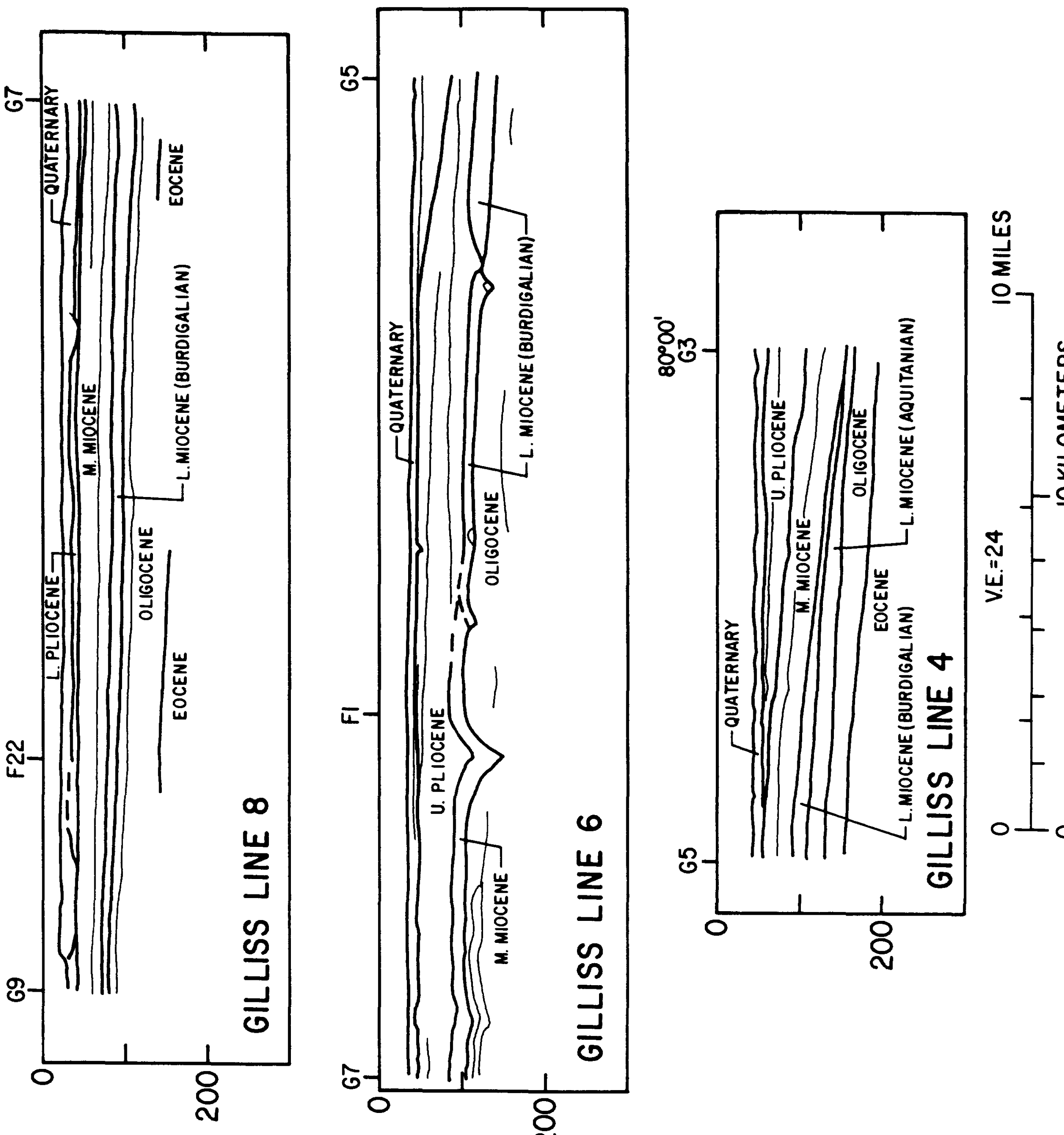

Figure 11. Interpreted scale-adjusted cross sections based on GILLISS lines 4, 6, and 8. Locations shown on Figure 1. Locations of line crossings are shown above each line. Major boundaries of seismic-stratigraphic units are shown by heavy solid lines and minor boundaries by lighter lines. Dashed lines indicate where boundaries are inferred from cross lines.

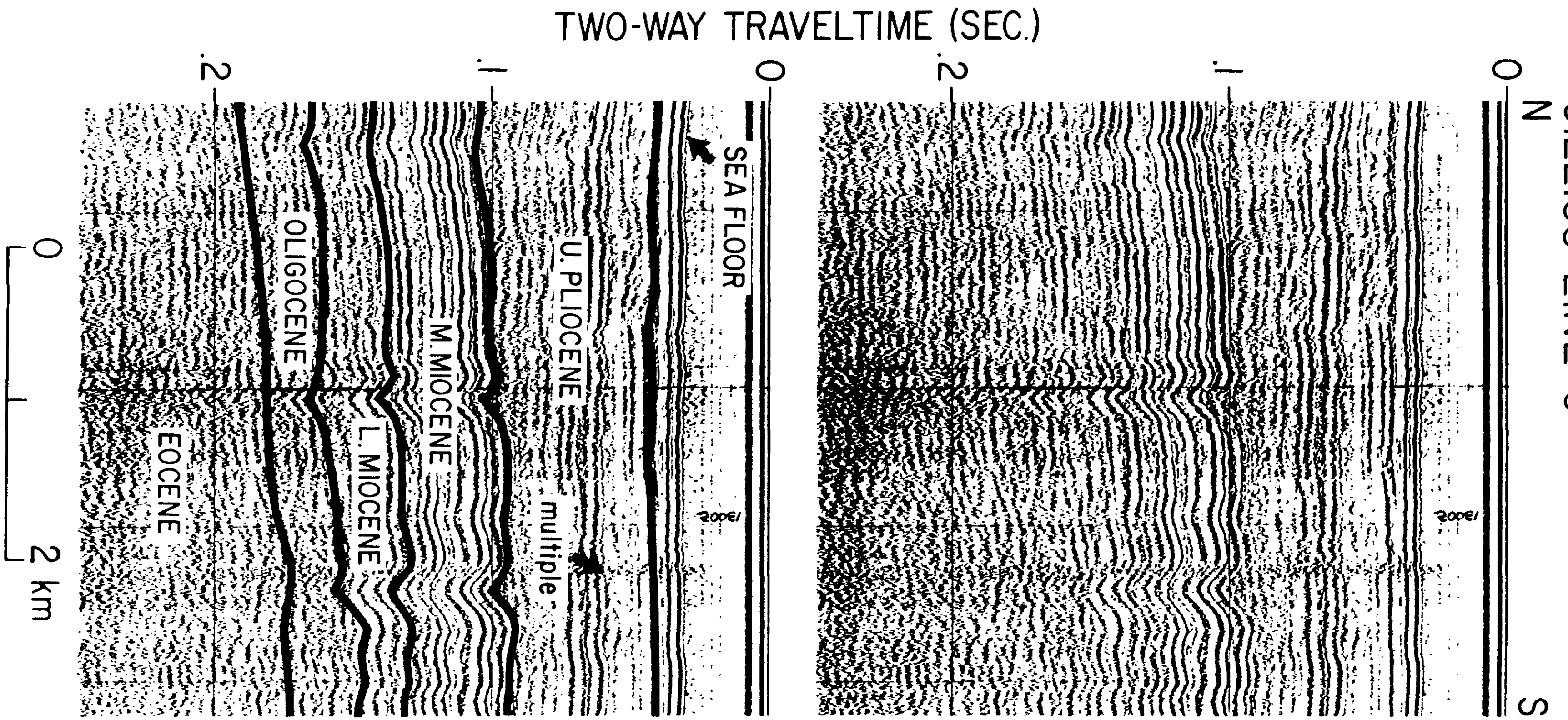

Figure 12. Part of GILLISS line 9 showing apparent folding of Miocene strata caused by karstification of underlying carbonate units. The features do not extend into the overlying upper Pliocene beds indicating that this karstification occurred in the late Miocene or early Pliocene, probably during subaerial exposure of the shelf.

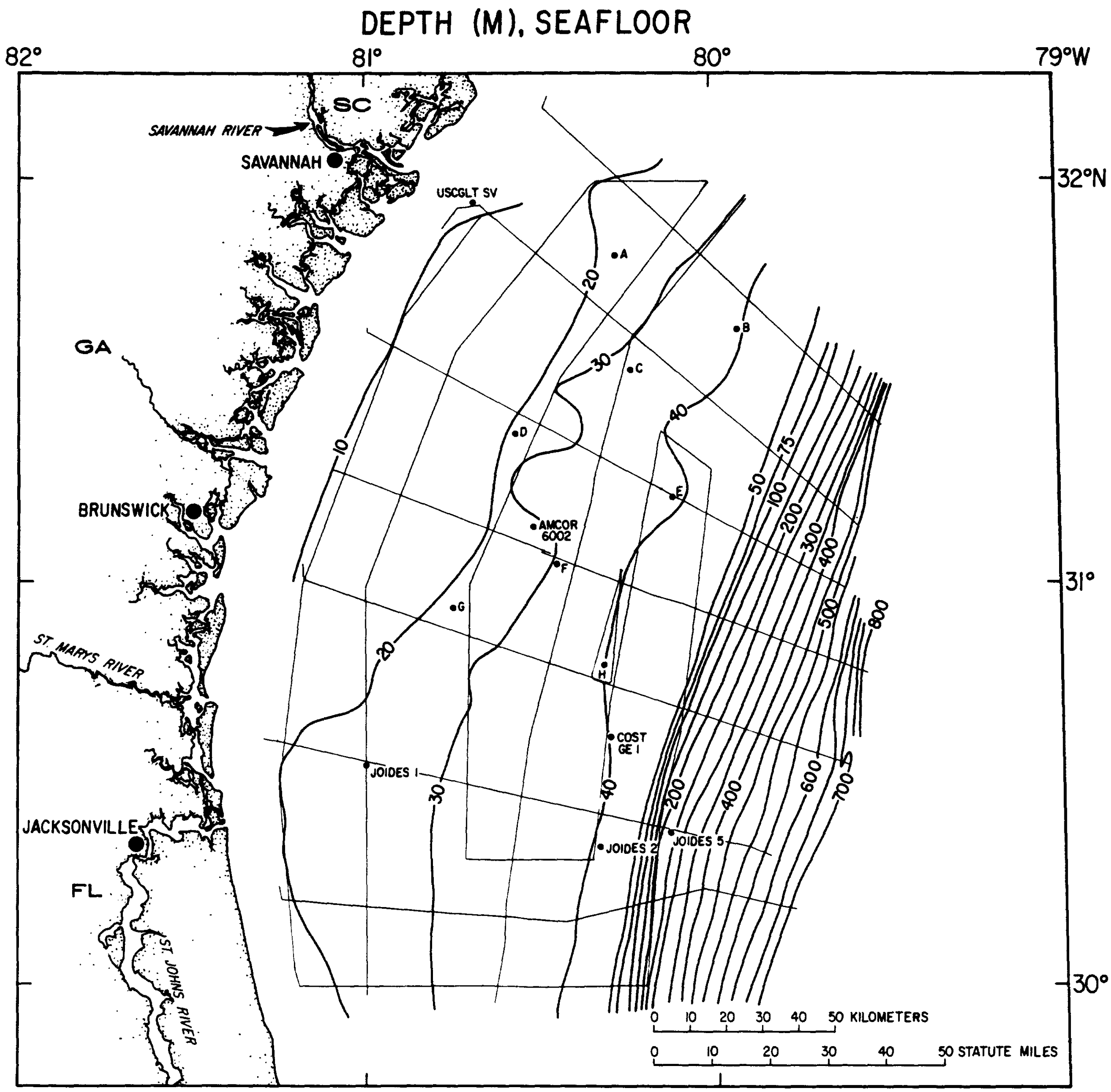

Figure 13. Depth of the sea floor in meters below sea level (BSL) contoured from the seismic-reflection records. Contour interval 10 m on shelf, 100 m on continental slope.

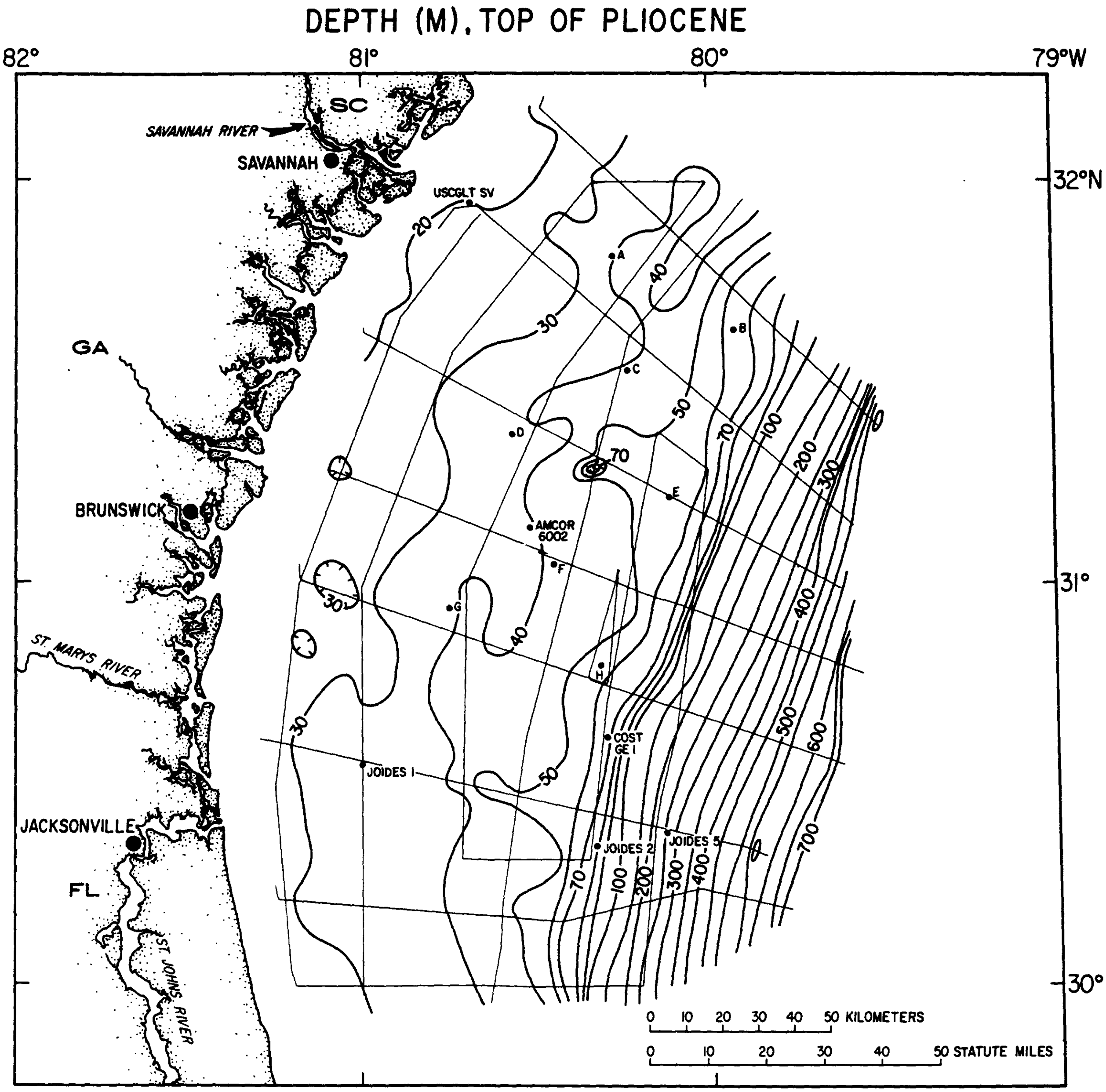

Figure 14. Depth (BSL) to the top of Pliocene strata or the equivalent unconformity. Contour interval 10 m on shelf and 50 m on the continental slope

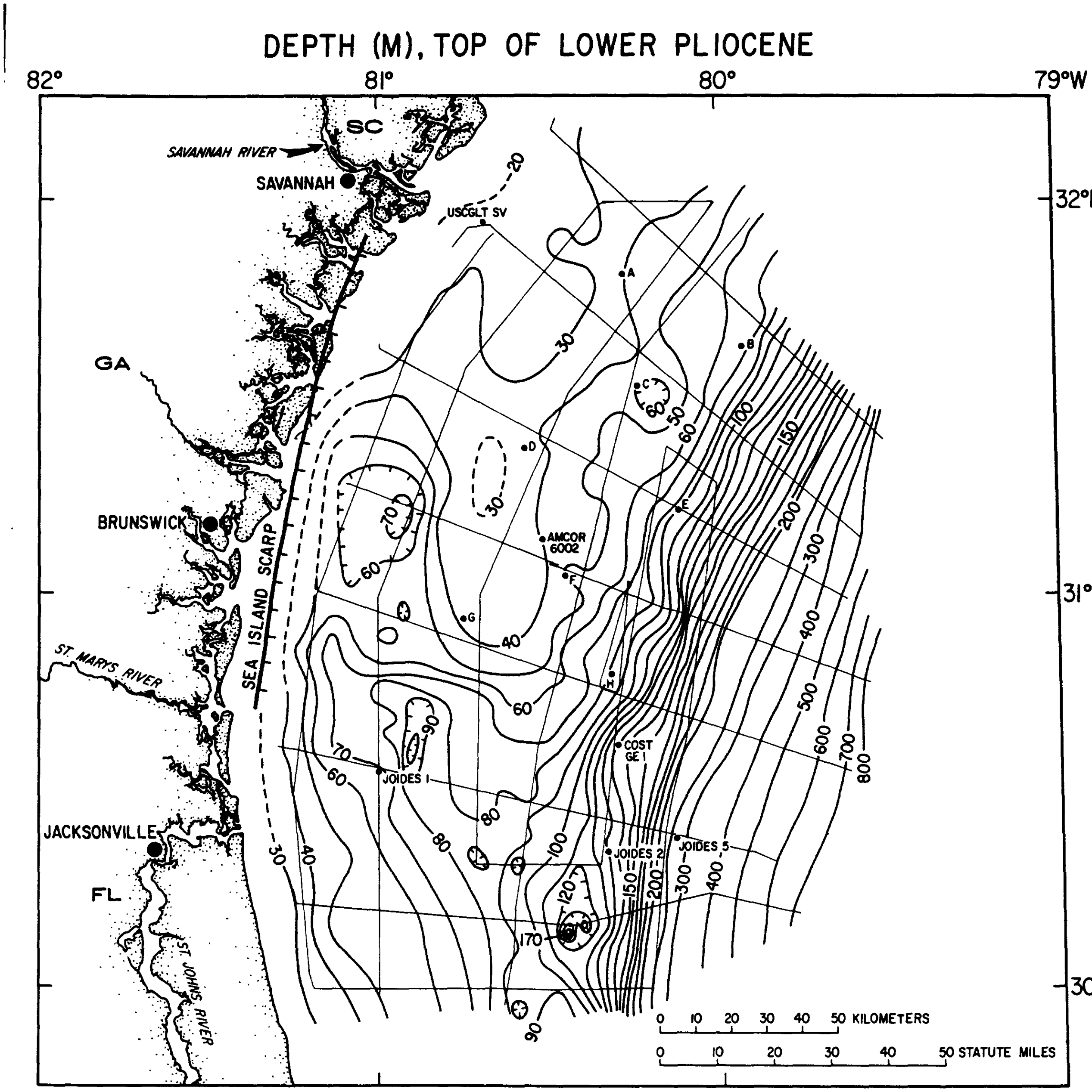

Figure 15. Depth (BSL) of the top of the lower Pliocene strata or equivalent unconformity. Contour interval 10 m on shelf, 50-100 m on slope.

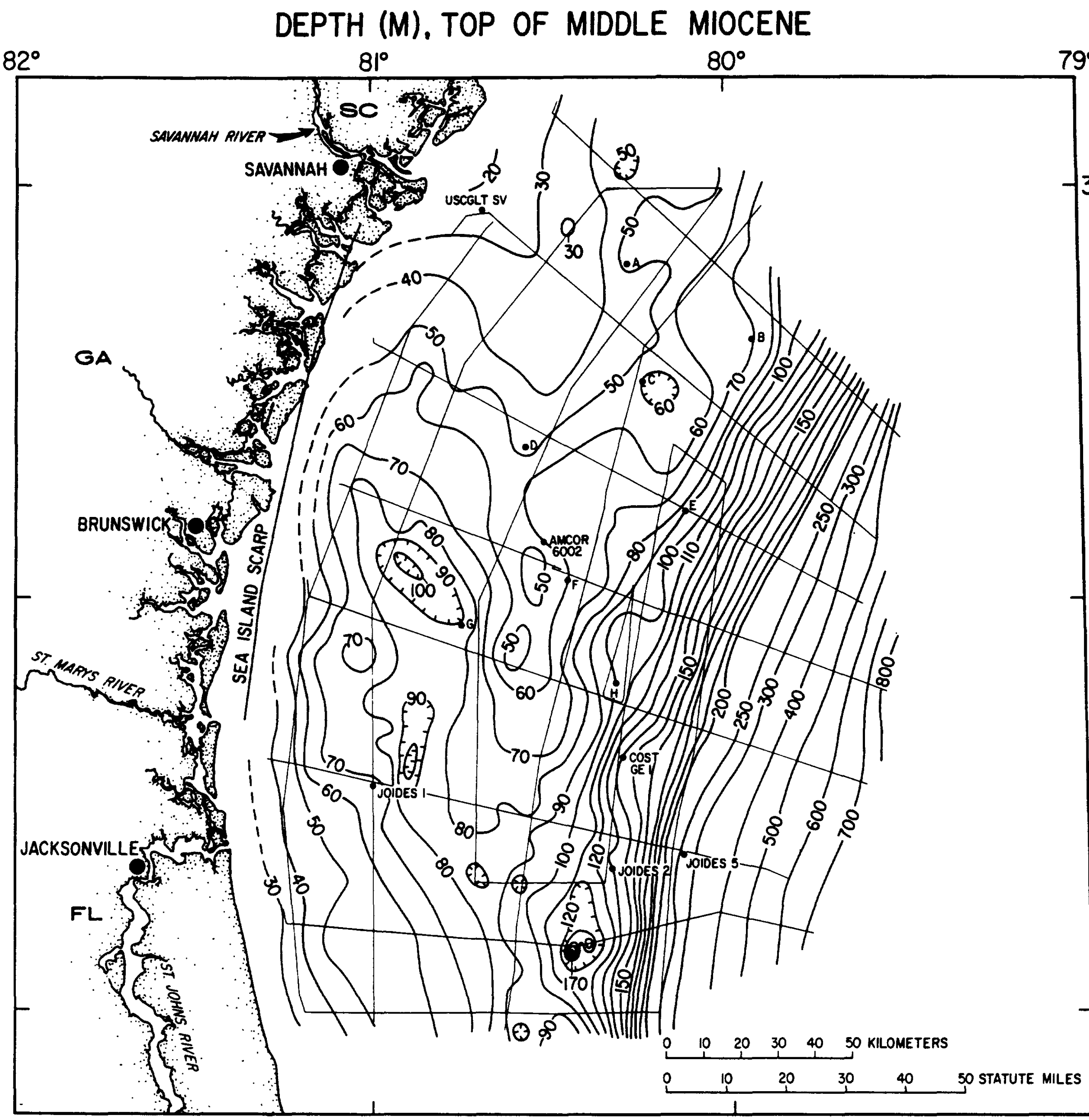

Figure 16. Depth (BSL) to the top of middle Miocene strata or the equivalent unconformity. Contour interval 10 m on shelf, 50-100 m on slope.

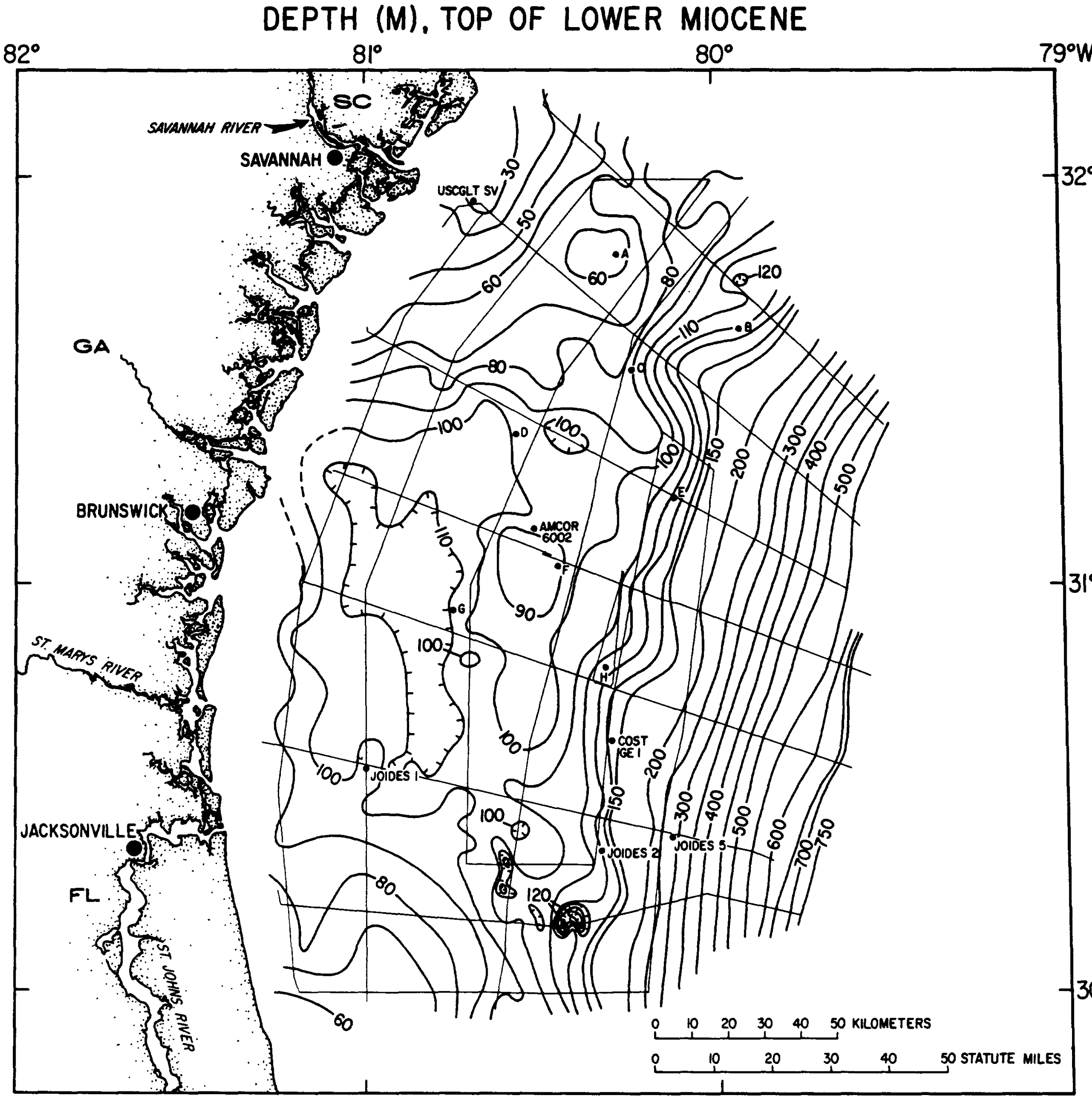

Figure 17. Depth (BSL) to the top of lower Miocene (Burdigalian) strata or the equivalent unconformity. Contour interval 10 m on shelf, 50 m on slope.

DEPTH (M), TOP OF OLIGOCENE

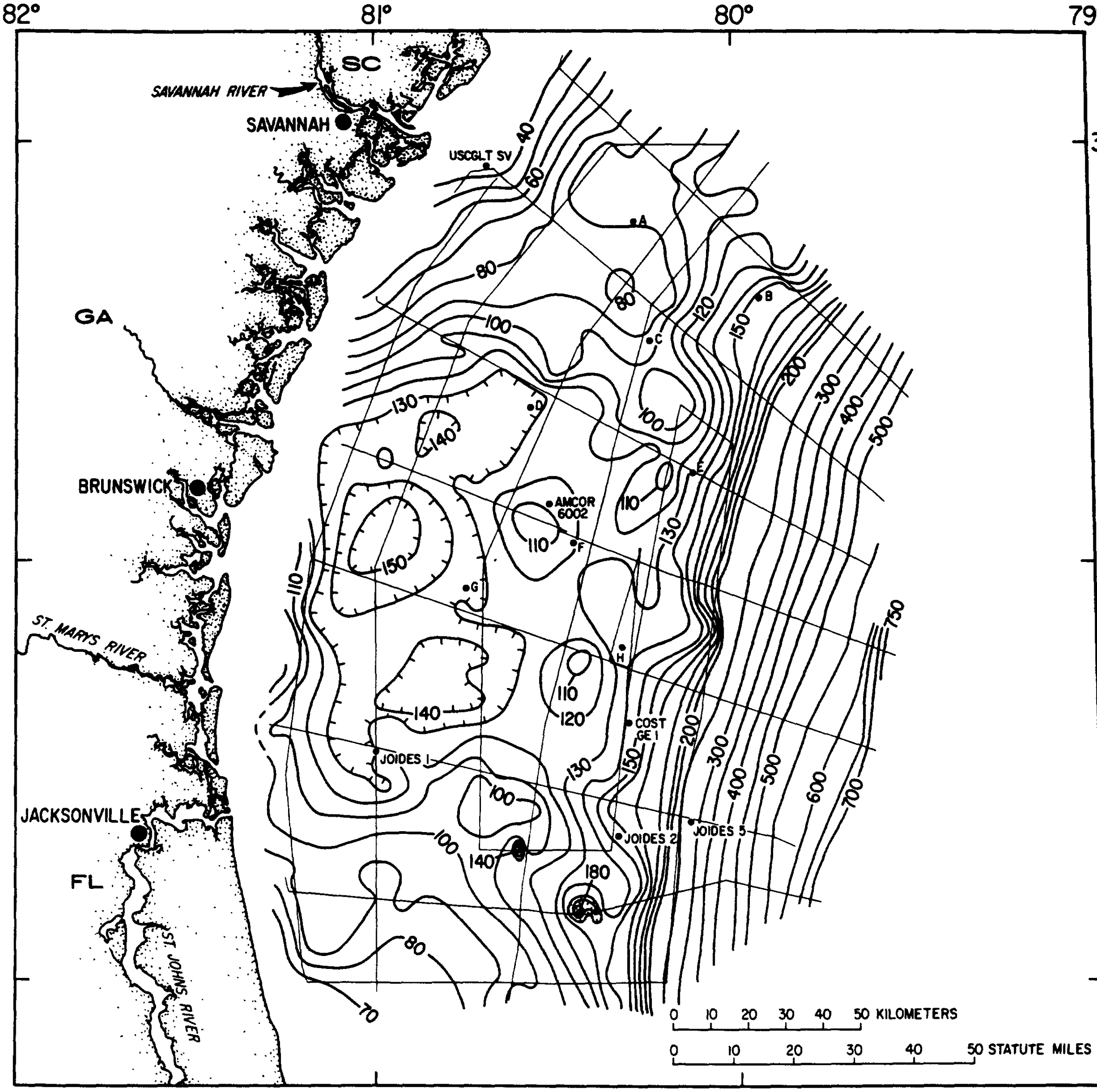

Figure 18. Depth (BSL) to the top of Oligocene strata or equivalent unconformity. Contour interval 10 m on shelf, 50 m on slope.

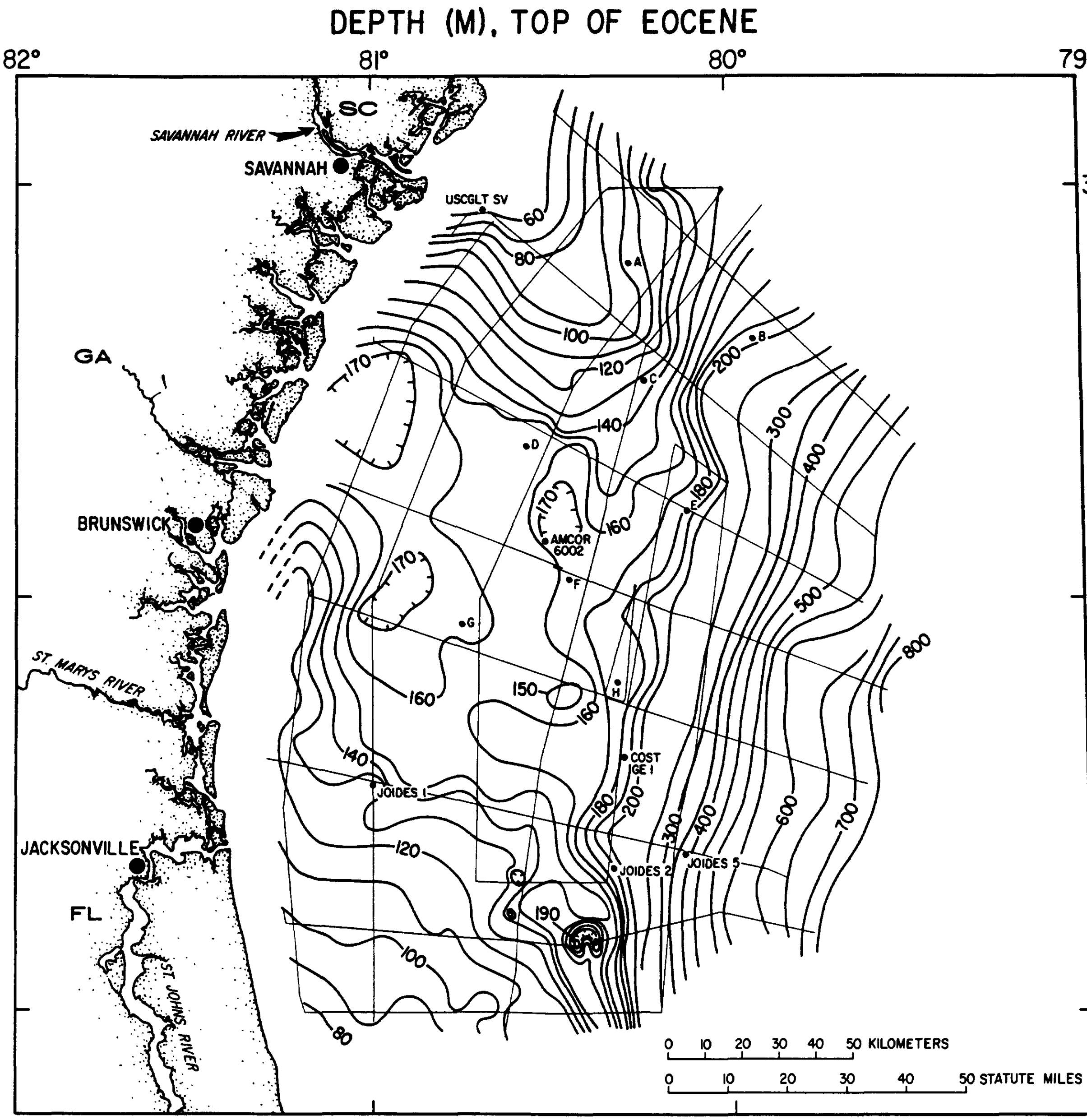

Figure 19. Depth (BSL) to the top of Eocene strata or equivalent unconformity. Contour interval 10 m on shelf, 50 m on slope.

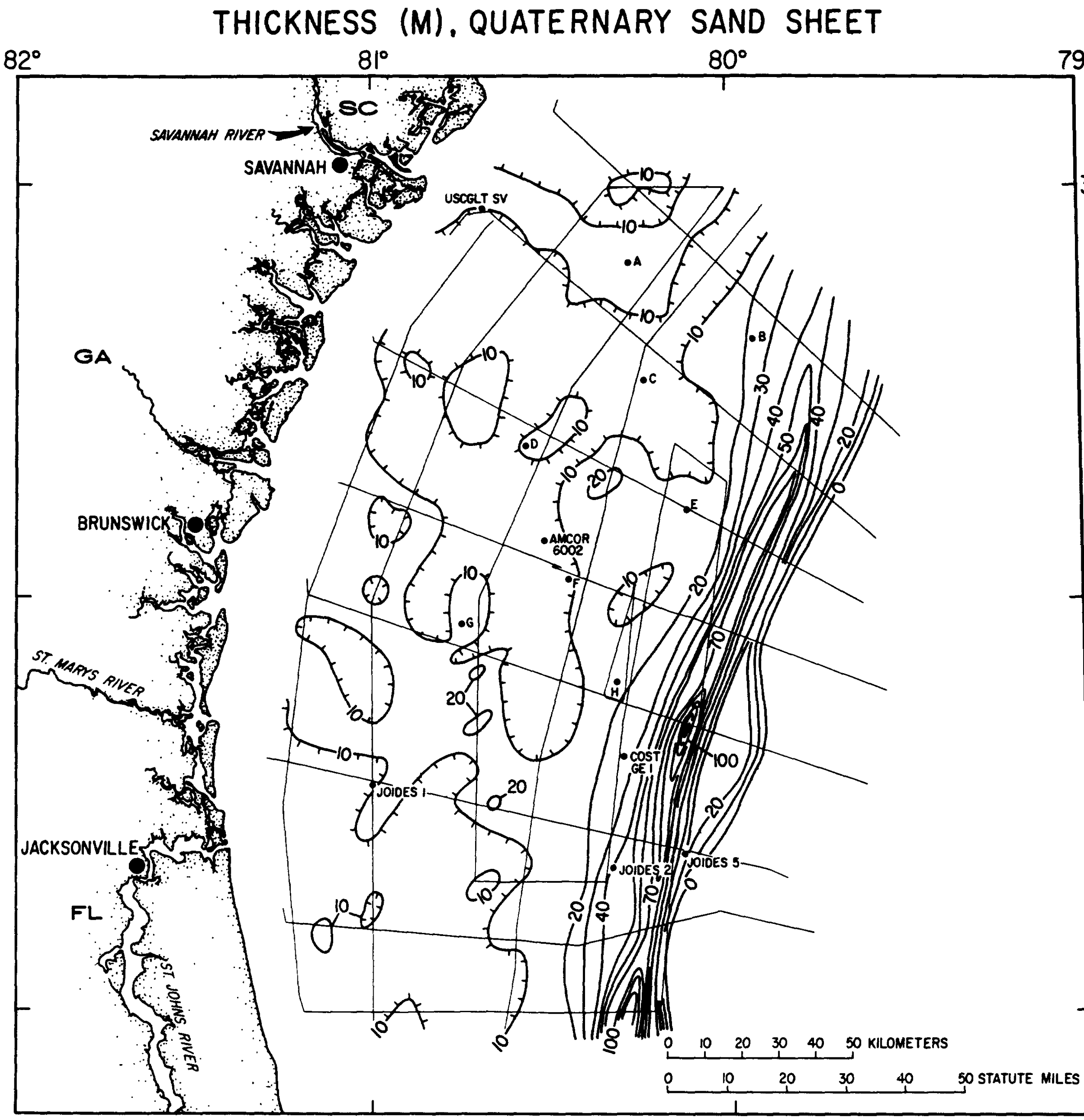

Figure 20. Thickness of Quaternary sediments. Contour interval 10 m.

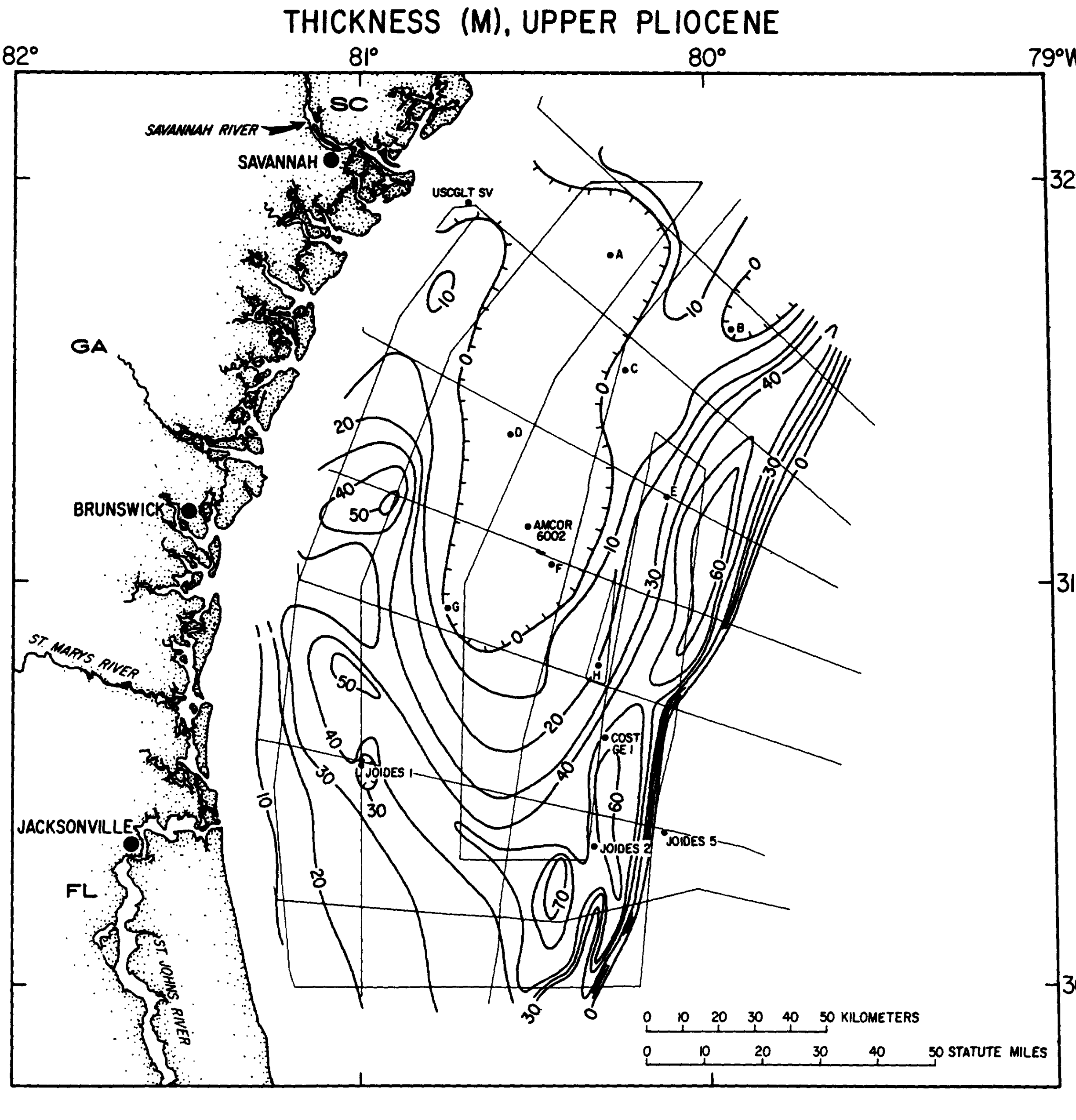

Figure 21. Thickness of upper Pliocene sediments. Contour interval 10 m.

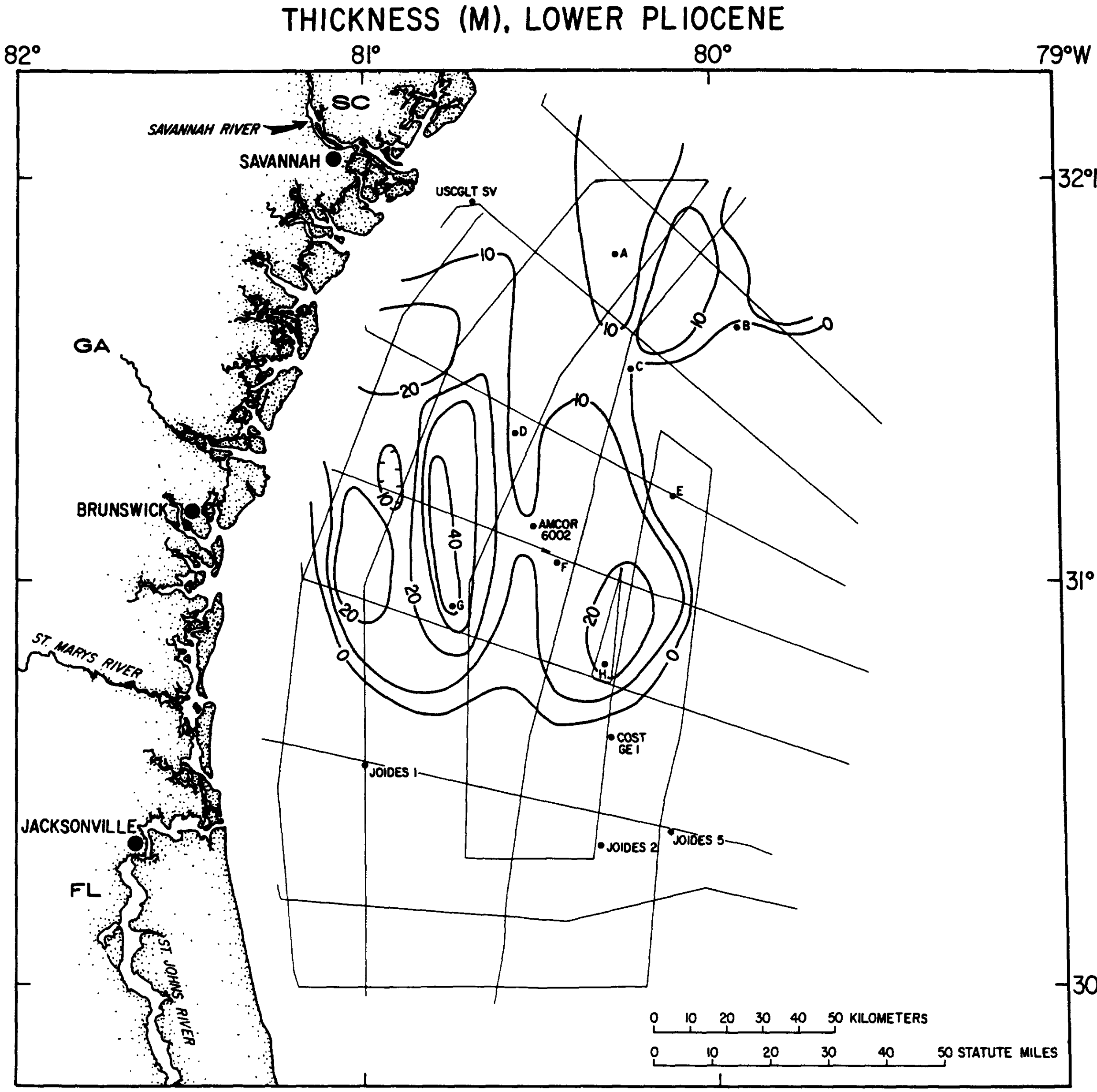

Figure 22. Thickness of lower Pliocene sediments. Contour interval 10 m. Upper Miocene sediments are included with lower Pliocene sediments as they are discontinuous in the subsurface, of similar seismic character to lower Pliocene sediments, and cannot be traced with any degree of certainty as a separate unit.

THICKNESS (M), MIDDLE MIOCENE

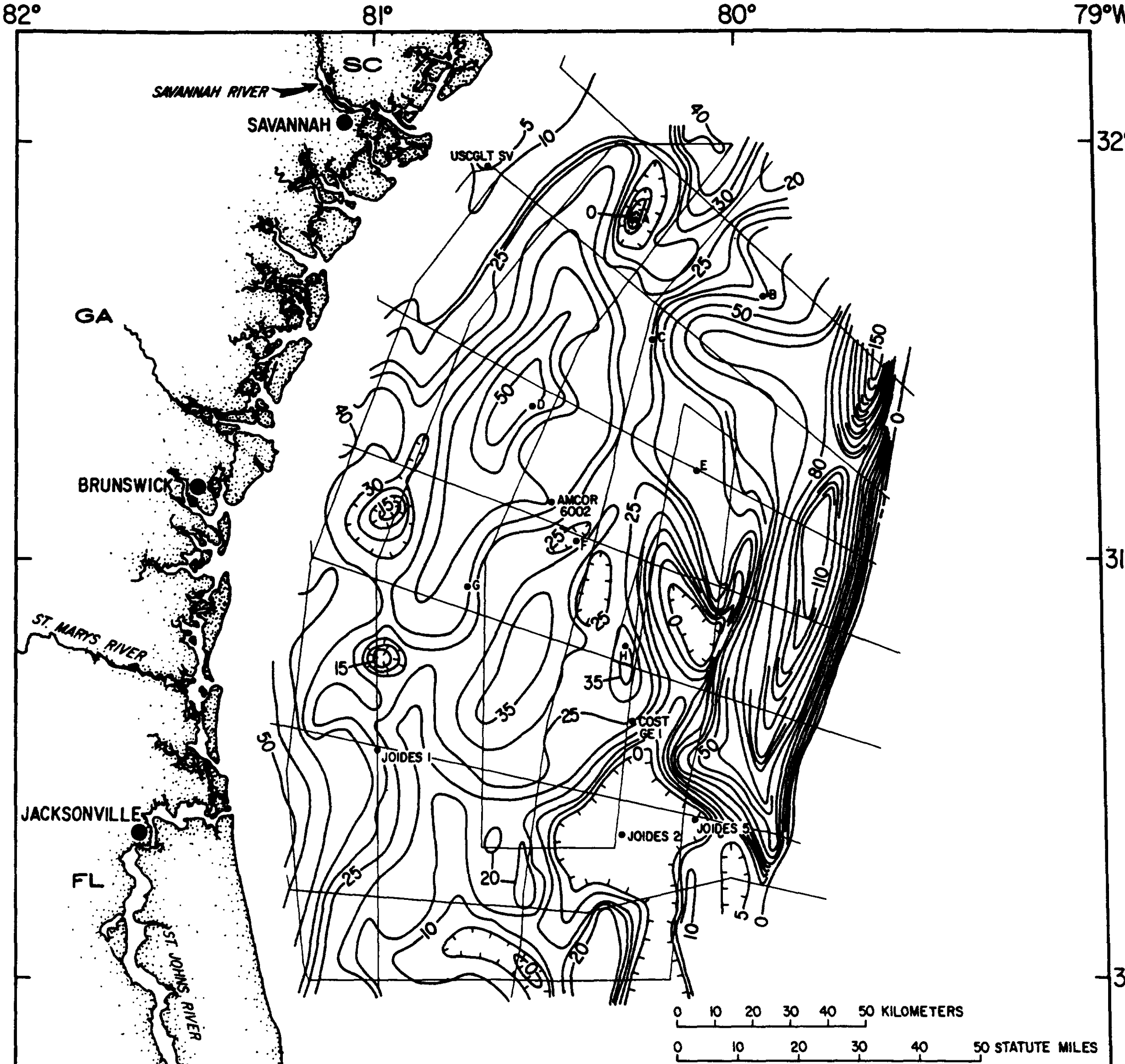

Figure 23. Thickness of middle Miocene sediments. Contour interval 5 and 10 m.

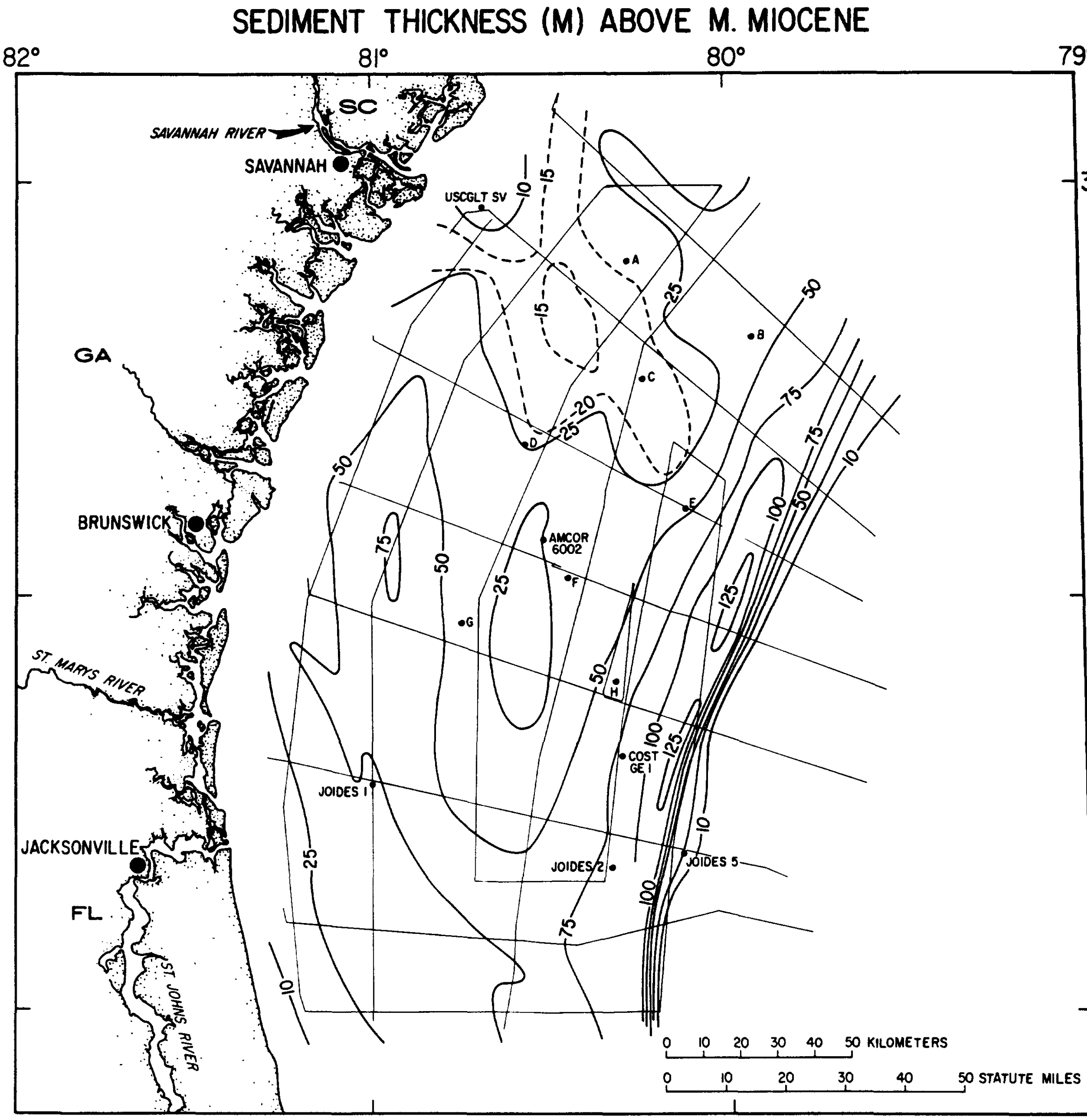

Figure 24. Total thickness of sediments above the middle Miocene strata. Contour interval 5 and 25 m.

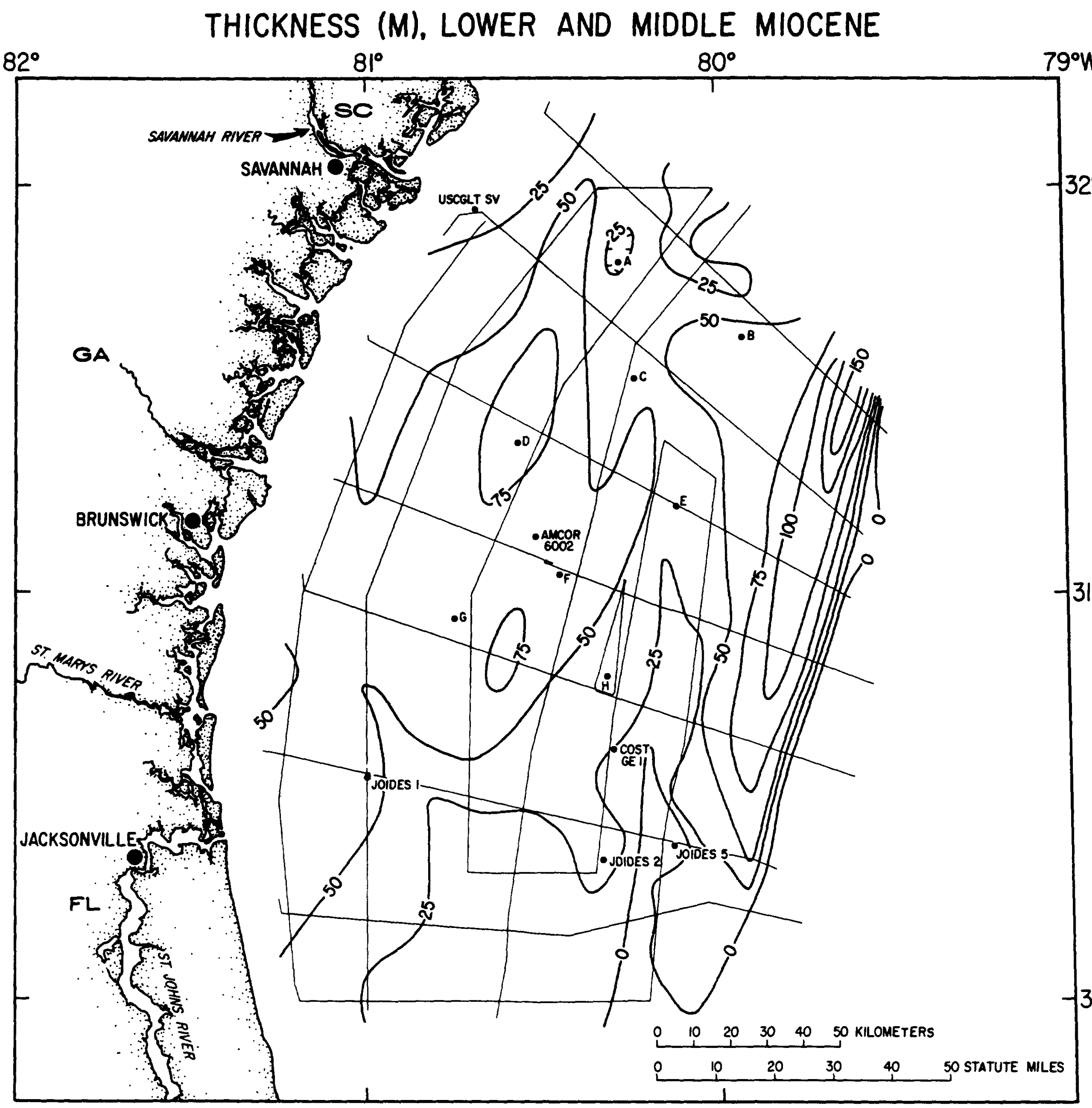

Figure 25. Thickness of lower and middle Miocene sediments. Contour interval 25 m.

THICKNESS (M), OLIGOCENE

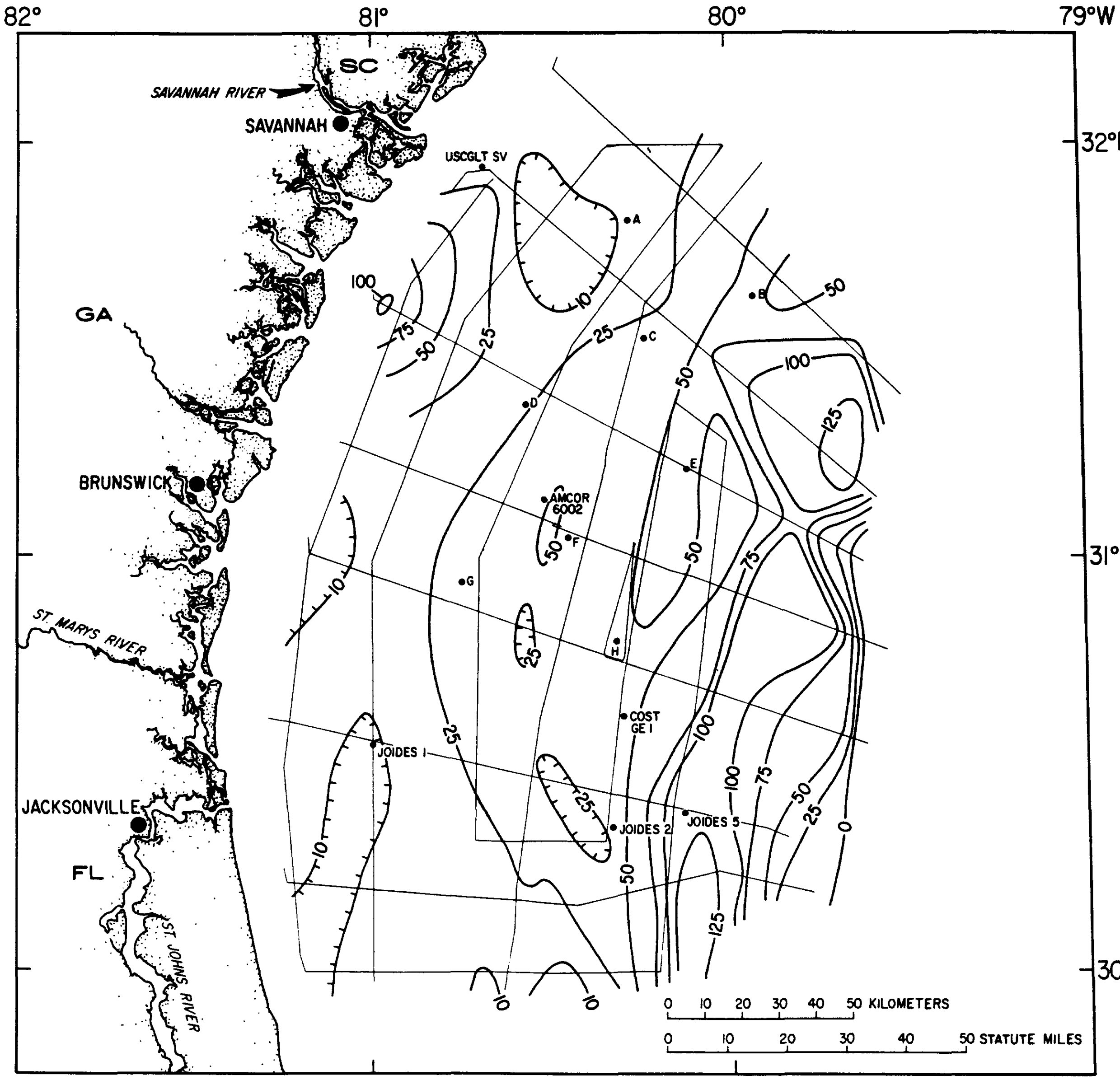

Figure 26. Thickness of Oligocene sediments. Contour interval 10 and 25 m.