UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

POTENTIAL GEOLOGIC HAZARDS AND CONSTRAINTS FOR BLOCKS IN SOUTH ATLANTIC OCS OIL AND GAS LEASE SALE 43

(Sale Held March 28, 1978)

By

John C. McCarthy, Richard S. Clingan, and Joan W. Roberts

Open-File Report 80-866-A

1980

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Errata

1. Abstract: 1st paragraph, 3rd line - OCS should appear as (OCS)
2. Abstract: 1st paragraph, 8th line should read "...sand waves), and water-column plumes."
3. page 4: 1st paragraph, 5th line should read "...north of 31°N. (on pl.1) is..."
4. page 30: 1st full paragraph, 5th sentence should read "Towed underwater television observations have confirmed the existence of outcrops in swales and have documented traction of coarse sediment and algal nodules by bottom currents along the seabed."

POTENTIAL GEOLOGIC HAZARDS AND CONSTRAINTS FOR BLOCKS IN SOUTH ATLANTIC OCS OIL AND GAS LEASE SALE 43

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ABSTRACT

Multispectral high-resolution acoustic surveys were conducted for prelease assessment of hazards and constraints on the Outer Continental Shelf OCS in the area of Lease Sale 43 (offshore Florida, Georgia and South Carolina). The surveys document geologic conditions which have a potential to affect offshore operations. The conditions identified from these data include shallow faults, potentially unstable slopes, anomalous foundation conditions (fill-facies, hardgrounds, sand swells, sand waves, and water-column plumes).

Shallow faults indicate potential planes of weakness subject to reactivation; however, the data examined indicate that detectable displacements are mainly confined to Tertiary strata and do not intersect the sea floor. Because of the low level of seismicity in the region and the lack of evidence for Quaternary displacement, these faults constitute a low risk. One sand-wave field may indicate hazardous operational conditions because of its location on a potentially unstable slope exposed to persistent, strong bottom currents. Because of readily available drilling technology, other identified geologic conditions pose few impediments to oil and gas development.

The most serious drilling problem anticipated in the survey area is cavernous secondary porosity. Our data, however, were not diagnostic of this problem--a problem that would complicate, but not preclude, development.

Operational risks appear to be lower in the Lease Sale 43 area than in other actively developing OCS lease areas of the United States and, as a consequence, operational problems related to oil and gas development should be minimal.

INTRODUCTION

This report summarizes the results of the U. S. Geological Survey's high-resolution geophysical studies conducted for prelease assessment of potential geologic hazards in the South Atlantic OCS Lease Sale 43 area. The area surveyed is located on the outer continental shelf and upper slope east of Florida, Georgia, and South Carolina (fig. 1). The 1:250,000-scale map (pl. 1), showing potential geologic constraints to offshore drilling, supersedes all previous compilations.

Objectives

The principal objectives of this investigation are the detection, identification, and delineation of geologic conditions that have a potential to affect offshore oil and gas operations within tracts considered for leasing by the Department of the Interior. Data from multispectral high-resolution acoustic surveys provide the basis for preliminary evaluation of proposed lease tracts for potential geologic hazards or other conditions which might require specific operational procedures. Information from other sources has been used to aid in making the evaluations.

Geologic conditions identified in U. S. Geological Survey prelease assessments are categorized as hazards or constraints, depending on whether they are high- or low-risk conditions. Hazards are defined as conditions indicative of high risk that cannot be completely eliminated by routine engineering or design. Constraints are conditions categorized as low risk because potentially adverse effects are less consequential or more predictable and can be mitigated by routine operational procedures or existing technology. All geologic conditions observed in this investigation fall into the low-risk category although certain combinations of constraints indicate areas where oil and gas operations are subject to a higher overall risk. Table 2 (p. 37) is a categorical listing of blocks that exhibit constraints.

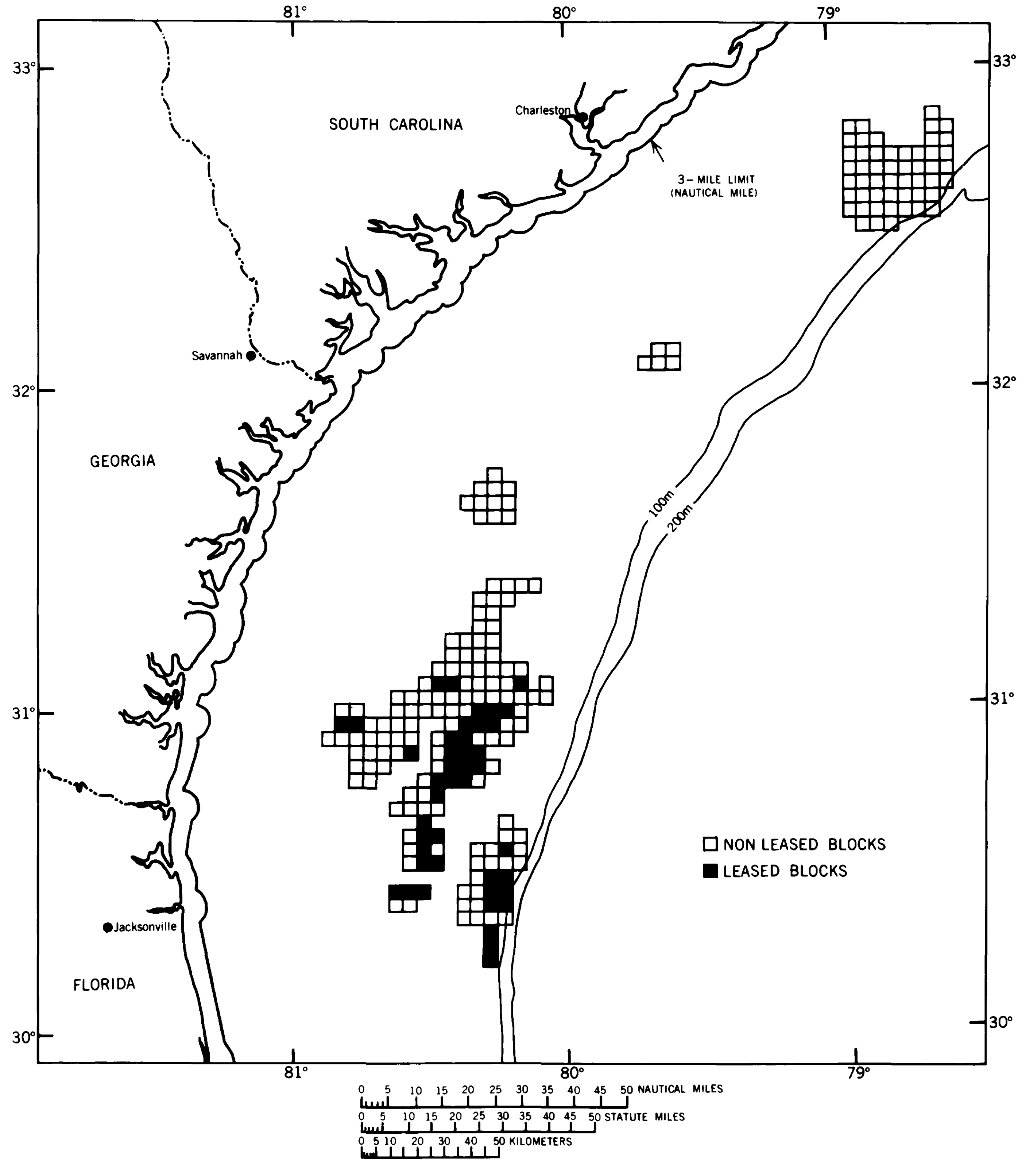

Figure 1.--Index map showing locations of blocks surveyed for OCS Lease Sale 43.

Data Collection and Instrumentation

Geophysical data analyzed for this report were collected by BBN-Geomarine Services Company (Contract 14-08-001-15986) and Digicon Geophysical Corporation (Contract 14-08-001-15995); each contractor surveyed roughly half of the 225 block area (fig. 2). The contractors supplied data-processing and reduction services in addition to preliminary interpretive reports. Data acquisition, processing, and interpretation were monitored by U. S. Geological Survey personnel. Substantive re-evaluation and additional interpretation of the data by U. S. Geological Survey personnel provide the basis for this open-file report.

A total of 9,900 km of high-resolution acoustic profiles was collected during October 1976-February 1977, using echo sounder, shallow subbottom profiler, sparker, and side-scan sonar systems. Profiles are oriented in a rectangular 800-m (dip, roughly normal to regional bathymetry) by 3200-m (strike, subparallel to regional bathymetry) grid. A summary of characteristics of the acoustic systems is given in table 1. Data resolution varied significantly, depending on the sea state, system, and contractor. Side-scan sonographs acquired by both contractors were generally of low resolution. Navigation services were provided by Offshore Navigation, Inc. (ONI), using LORAN C/Accufix, radio-positioning atomic clock, and DR Raydist. ONI states offshore positioning system accuracy to be plus or minus 15 m. Copies of original records used as illustrations in this report include annotations that correspond to post-plot navigation fixes at 400-m intervals.

Archiving

Copies of all contracted deliverables have been archived with the National Geophysical and Solar-Terrestrial Data Center (NOAA/EDIS/NGSDC, Boulder, Colo.) and may be purchased by the public. This data bank (data sets AT15986 and AT15995) consists of microfilm copies of geophysical profiles, a series of navigation and interpretive maps at a scale of 1:48,000, and copies of the contractors' final reports.

Acknowledgments

The authors gratefully acknowledge help received from Kevin Spaner, Keith Good, and Robert Lewis in reducing and compiling the data.

Table 1.--Data acquisition system* used during South Atlantic OCS survey, October 1976-February 1977

Subareas surveyed (pl. 1)	Echo sounder	Side-scan sonar	Shallow subbottom profiler	Deep Subbottom Profiler	
				Source	Recording mode/ processing
CONTRACTOR: BBN-Geomarine Services Company					
A, B, C, $D_{(N)}$	Raytheon RTT-1000 tuned transducer	EG&G-1B 105 kHz 200-m slant range	"Acoustipulse" 1-kj electro-mechanical transducer, 0.4-4.0 kHz, Typical penetration 50m.	10-kj sparker, 40-180 Hz bandpass, typical penetration 400m	Analog monitor of single trace, optical stacking and deconvolution (selected profiles)
CONTRACTOR: Digicon Geophysical Corporation					
$D_{(S)}$, E, F	Simrad model ES	EG&G-1B 105 kHz 200m slant range	ORE Model 1036 tranceiver and model 132 transducer, 3.5 kHz nominal; maximum penetration 20m.	32-kj multi-electrode sparker, 27-248 Hz bandpass, typical penetration in excess of 500m	Analog monitor of near trace, 12-fold CDP digital processing (selected profiles)

*Use of trade names is for descriptive purposes only and does not constitute an endorsement by the U.S. Geological Survey. Note: $D_{(N)}$, northern subarea; $D_{(S)}$, southern subarea.

REGIONAL GEOLOGIC SETTING

Physiography

The blocks surveyed for OCS Lease Sale 43 are located on the submerged southeastern part of the Atlantic Coastal Plain physiographic province. The shelf is bounded on the west by the drowned barrier island coast between Jacksonville, Fla., and Charleston, S.C., and on the east by the Florida-Hatteras Slope (fig. 2). The regional physiography of the Atlantic Continental Shelf and Slope has been described in detail by Uchupi (1968) and additional source material and discussion can be found in Emery and Uchupi (1972).

The most prominent morphologic element within the survey area is the shelf break, which occurs at depths between 50 and 60 m and demarcates the transition between shelf and slope physiographic and sedimentary provinces. The shelf break strikes north to northeast in a broad arc about 120 to 135 km seaward of, and roughly parallel to, the present shoreline.

Shelf gradients are typically less than 6 m/km and dip toward the east-southeast. The steepest slopes are associated with small depressions, escarpments, and the flanks of sand ridges. Local relief is low, attaining a maximum of about 8 m in association with aggradational features such as sand swells and shelf-margin buildups. In contrast to the very low shelf gradients, the upper Florida-Hatteras Slope typically dips to the southeast at a rate of 20 m/km within the surveyed blocks. Locally, gradients as steep as 190 m/km are present in association with the seaward scarps of the shelf-margin ridge system in the southeastern part of the study area (pl. 1 , Area F).

Other shelf and upper slope features, such as sand waves, terraces, low-relief hardgrounds and erosional escarpments, contribute to the general irregularity of the sea floor within the study area. Features indicative of conditions having a potential for affecting development operations are discussed in more detail under Results.

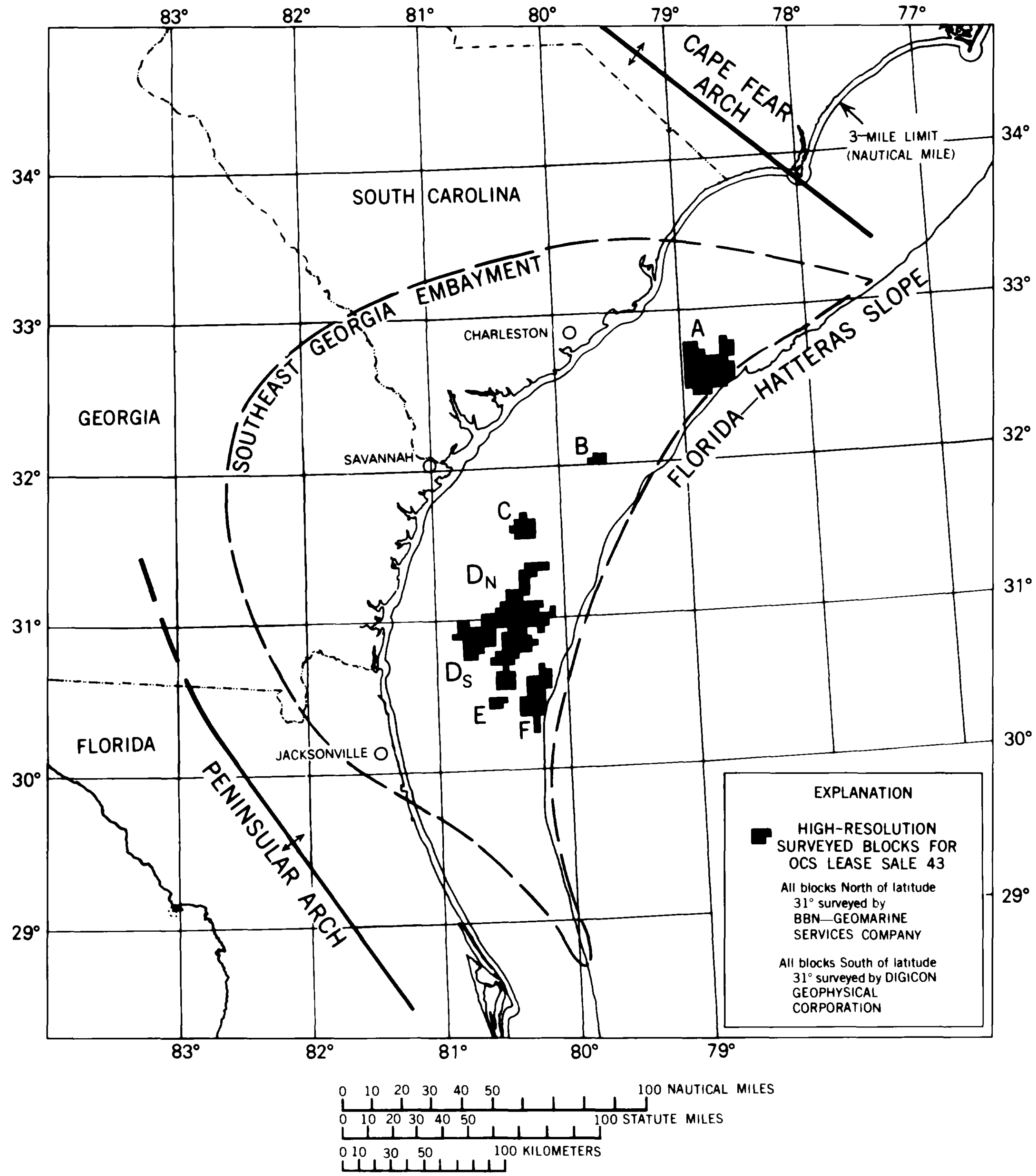

Figure 2.--Major structural elements in the South Atlantic OCS area. Survey Areas A-C, D_N, D_S, E and F contain numbered blocks studied for Lease Sale 43, shown on plate 1.

Surficial Sediments and Hardgrounds

Surficial sediments of the Southeast Georgia Embayment shelf are characterized as well-sorted, unimodal, medium-sized sands consisting mainly of quartz and biogenic calcium carbonate. Although medium sand (0.25 to 0.5 mm) tends to dominate, gravel (greater than 4 mm) is present on the shelf in concentrations as high as 10 percent, and silt accounts for as much as 40 percent of the surficial sediments on the Florida-Hatteras Slope (Dillon and others, 1975). Hollister (1973) noted a seaward increase in grain size on the inner shelf, which Emery and Uchupi (1972) attribute to differences in age and origin between finer, more recent, nearshore sediments and coarser, relict sediments offshore. Dillon and others (1975) stated that the approximate relict-recent boundary occurs at a water depth of 10 m; therefore, all the blocks surveyed lie within the zone dominated by relict sediments.

A significant part of the study area contains exposures of consolidated substrate or hardgrounds. These occur in three major trends known informally as the inner, middle, and outer banks (Hunt, 1974; Bureau of Land Management, 1978). The outer banks are most easily defined, as they include the discontinuous trend of shelf-margin ridges and patch reefs that are characteristic of much of the shelf break south of Cape Hatteras (Avent and others, 1977). Rocks dredged from the outer banks include algal limestone, calcarenite, calcareous quartz sandstone, oolitic material and shell hash (MacIntyre and Milliman, 1970; Henry and Giles, 1980).

Stuctural and Stratigraphic Framework

The stratigraphy and structure of the U. S. South Atlantic Continental Margin is summarized in Dillon and others (1975) and Paull and Dillon (1979). Oil and gas exploration targets for Lease Sale 43 occur within the principal structural feature in the area, the Southeast Georgia Embayment. This negative structural element is characterized as a broad, southeast-plunging basin bounded by the Cape Fear Arch on the northeast and the Peninsular Arch on the southwest (fig. 2). Crustal inhomogeneities, including igneous intrusive bodies, rift valleys, deep-seated basement ridges, and old plate boundaries, have been inferred from gravity and magnetic anomalies within the embayment. Offshore stratigraphic control near the study area is provided by the early JOIDES stratigraphic tests

(Bunce and others, 1965), three tests from the U.S. Geological Survey's Atlantic Margin Coring Project (Hathaway and others, 1976), and the COST GE-1 well (Amato and Bebout, 1978). The locations of these stratigraphic tests are shown on figure 3. Seismic reflection profiles correlated with these tests indicate subsidence was predominant in the middle and Late Cretaceous and continued at lesser rates through most of the Tertiary. The Southeast Georgia Embayment is estimated to contain a 2.8- to 5.5-km thick section of sedimentary rocks of which 0.6-1.1 km are Tertiary in age (Scott and Cole, 1975).

Paull and Dillon (1979) noted two Cenozoic unconformities of regional significance on seismic-reflection profiles from the South Atlantic OCS. These acoustic unconformities bound a major Eocene/Oligocene depositional sequence and are the result of widespread erosion of the shelf during the late Paleocene and Oligocene. Paull and Dillon's isopach map of this depositional sequence defines a small triangular depocenter on the outer shelf which encompasses study areas D_N, D_S, E, and F (fig. 3). They noted that differential subsidence along the seaward margin of this depocenter was more than 500 m, relative to the flanks, during the Cenozoic.

Stratigraphic tests indicate that the late Paleogene depocenter defined by Paull and Dillon (1979) approximates the locale of a gradual transition from predominantly marine carbonates in the south to marginal marine and marine clastics in the north. Marginal marine and marine clastics dominate the Neogene stratigraphic record in the study area. Because of lithologic contrasts between consolidated Paleogene carbonates and unconsolidated Neogene clastics, the most recent of the two regional unconformities (T_o) is a prominent acoustic marker for the Paleogene-Neogene boundary on most reflection profiles from the southern part of the study area.

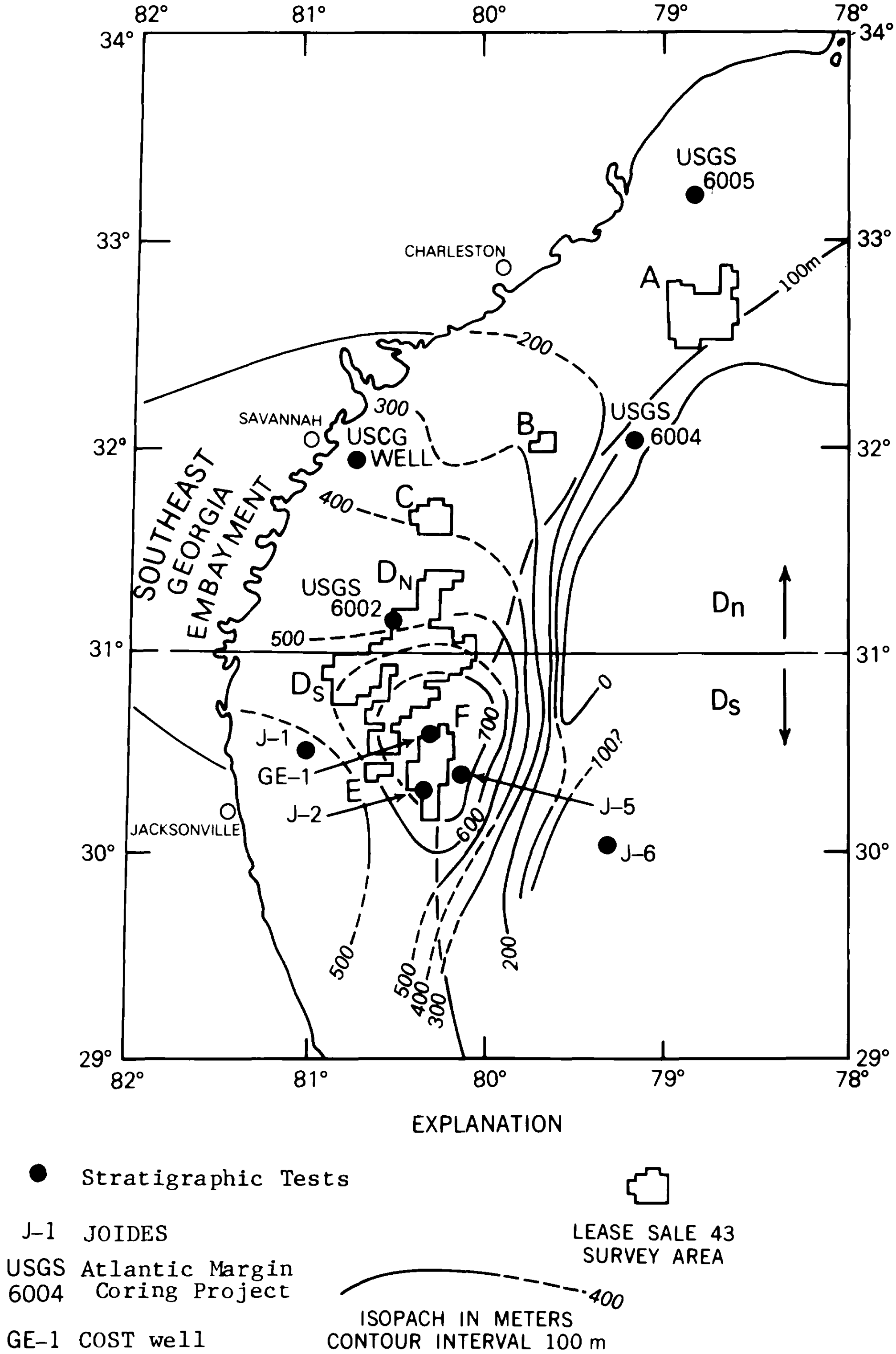

Figure 3.--Isopach map of Eocene/Oligocene sediments and showing locations of stratigraphic tests (From Paull and Dillon, 1979.)

RESULTS

Faulting and Seismicity

Evidence for shallow, small displacement (about 5 msec or less), high-angle faulting is present on many of the processed multichannel sparker profiles. The majority of these faults are inferred from disrupted reflections within Tertiary units in the southern part of the study area. The lower incidence of faulting north of 31°N. on (pl. 1) is solely related to the characteristics of the data base. Less conclusive evidence for possible shallow faulting north of 31°N. is noted on higher frequency Acoustipulse data and on optically-stacked analog sparker data.

Figure 4 illustrates an example of a simple fault having an apparent vertical displacement of about 5 msec (4 m)*. The only major variation encountered in this investigation is illustrated on figure 5 and is interpreted as a distributive fault complex consisting of at least three minor step faults. The total apparent displacement of this distributive fault complex is on the order of 15 msec (11 m) at the acoustic horizon, which approximates the Neogene-Paleogene boundary. Because shallow subbottom profiles and side-scan sonographs show no evidence of surface offsets or lineations, none of the faults are interpreted to be the result of recent events. Only one fault appears to offset reflections within the upper 50 msec (38 m) subbottom and it occurs in blocks NH 17-5-72 and -116 (fig. 4 and pl. 1).

The faults inferred from our data exhibit a few common attributes including small apparent displacement and, with one exception (fig. 4), a general absence of evidence indicating post-Paleogene movement. Although most are assumed to be high-angle normal faults, the apparent angle of the fault plane is too high on most of the profiles to discount the possibility of reverse faulting (for example, fig. 4). All show displacement of the prominent regional acoustic unconformity, T_0 (fig. 5), which approximates the top of the Oligocene/upper Eocene limestone horizons encountered in JOIDES test J-2 (Charm and others, 1969). The downthrown blocks most commonly occur landward of the fault plane, especially for

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* Depths inferred from seismic reflection data assume a sound velocity of 1.5 km/sec, unless stated otherwise.

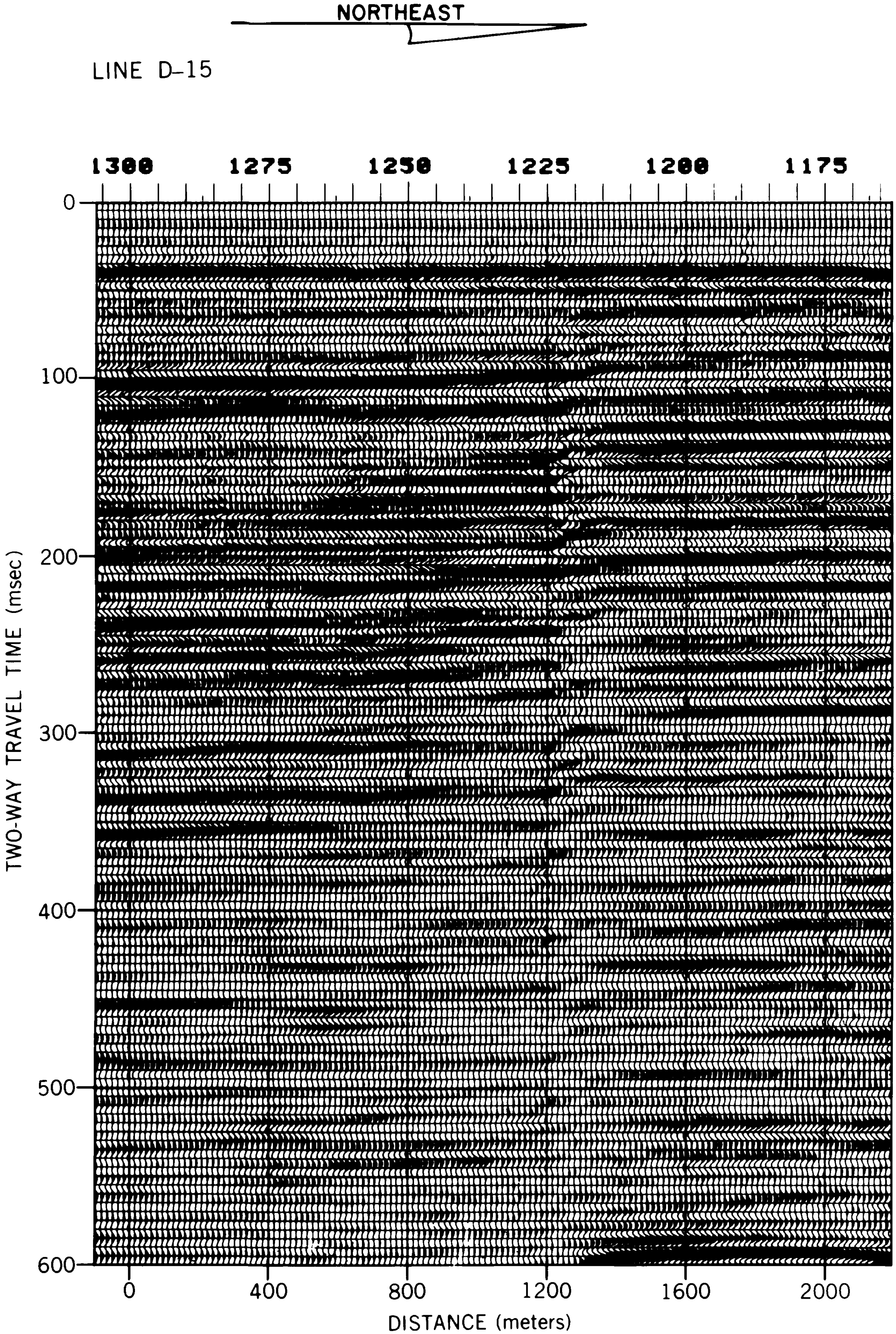

Figure 4.--Sparker profile of a simple fault. Vertical exaggeration X7. (See pl. 1, blocks NH 17-5-72 and NH 17-5-116.)

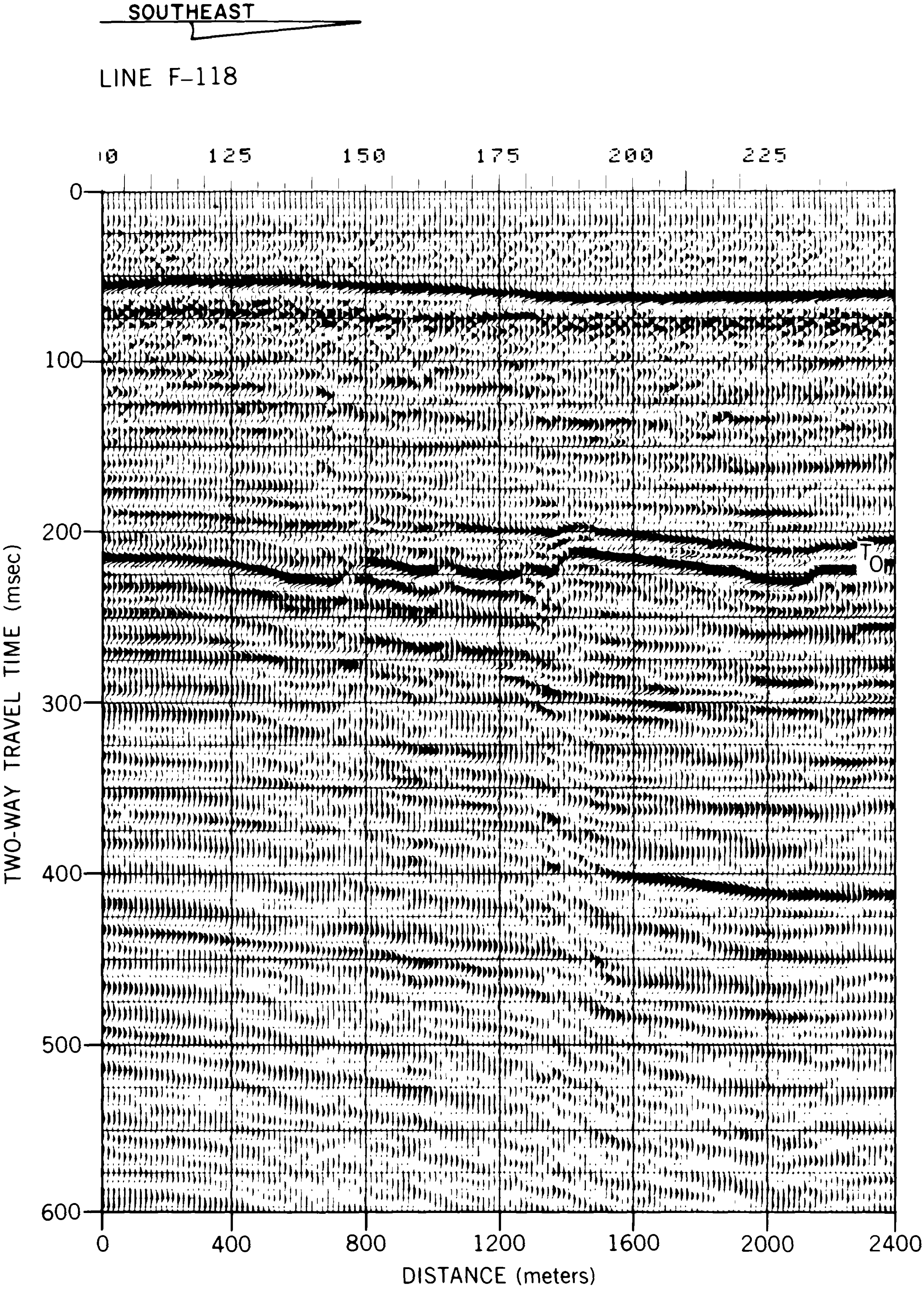

Figure 5.--Sparker profile of a distributive fault complex (zone of step faulting). T_o is interpreted to be the Paleogene/ Neogene unconformity, which separates unconsolidated Neogene sediments from indurated Paleogene limestones. Vertical exaggeration X7. (See pl. 1, block 17-5-696.)

faults near the shelf break. All the faults identified appear to die out at depth, although this may be more a consequence of depth-dependent acoustic phenomena than geologic structure.*

Ball and others (1980) have identified several shallow, small-displacement faults within Miocene and Oligocene strata of the Southeast Georgia Embayment. As a group, the faults they observed show a slightly preferred downthrown block orientation to the southeast. Because Neogene to Holocene sediments are mainly unconsolidated to poorly consolidated, they interpreted these faults to be the consequence of sediment compaction or subsidence. Our most reliable observations of faulting occur within the late Paleocene depocenter defined by Paull and Dillon (1979), which tends to support the fault mechanisms suggested by Ball and others (1980). Nevertheless, existing data does not entirely preclude a tectonic origin because of the decrease in instrumental resolution with depth.*

Evaluation of risk potential for a particular mode of faulting requires consideration of the controlling mechanisms and the age of faulting. Despite the uncertainty about actual fault controls, the lack of evidence of Holocene displacement implies a low-risk condition. These faults do, however, constitute avenues that could permit gas to escape from depth. Although there is no evidence for a tectonic origin for these faults, it is desirable to consider them in the context of regional seismicity as they may indicate potential planes of weakness in the upper crust.

In general, the southeastern Atlantic Coastal Plain is characterized by low levels of seismicity (Bollinger, 1975). Principal earthquake activity adjacent to the South Atlantic OCS is associated with the Carolina-Georgia seismic zone (Tarr, 1977). Definition of this zone is based on Bollinger's (1975) earthquake catalog which indicates a broad band of activity extending southeast from the Appalachian seismic zone across most of South Carolina and northeastern Georgia. Unlike most seismically active areas, the Carolina-Georgia seismic zone is a consi-

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*Instrumental resolution effectively decreases with depth because of (1) relatively higher attenuation coefficients for acoustic energy from the higher frequency part of the output spectrum and (2) the increase in the size of the Fresnel zone as a function of distance from the source.

derable distance from any active plate margins. Preliminary reports of several multidisciplinary studies related to the Charleston-Summerville 1886 earthquake are included in U. S. Geological Survey Professional Paper 1028 (Rankin, 1977).

The recent history of the Carolina-Georgia seismic zone is dominated by the major shocks associated with the 1886 Charleston, S.C., earthquake (maximum Modified Mercalli (MM) intensity of X). The 1886 shocks were preceded by at least a century-long period of lower activity (Bollinger, 1977; Coffman and von Hake, 1973). Following the 1886 events, macroseismic and instrument data indicate a 20- to 30-year period of frequent aftershocks followed by a gradual decline in activity to the present (Bollinger, 1977; 1975). Between 1970 and 1975, the Charleston-Summerville area has experienced a minimum of 15 earthquakes having an MM intensity of V or greater. Tarr (1977) suggested that seismic activity in the area had not declined to pre-1886 levels. Simple offshore projection of Bollinger's (1977) isoseismal trends of the 1886 event suggests that most of the OCS Lease Sale 43 area could be subjected to shocks of MM VI or greater if an earthquake of similar magnitude recurred in the Charleston-Summerville area.

The frequency of events must also be considered when assessing seismic risk. Although the Carolina-Georgia seismic zone has a history of recent earthquakes, Bollinger's (1975; 1977) data indicate that the frequency of events (per unit time, per unit area) is about one-tenth that noted for the west coast of the United States.

On the basis of the evidence cited, shallow faulting, seismicity, and related ground accelerations appear to constitute a low risk to offshore operations within the area surveyed. However, because faults are former planes of weakness subject to possible reactivation and are potential conduits for gas discharge, a higher overall risk to operations in the immediate vicinity of a fault trace is indicated.

Shallow Gas

Acoustically turbid or opaque signatures on seismic-reflection profiles are commonly associated with gaseous sediments (Schubel, 1974; Antoine and others, 1976; Whelan, 1976). These types of anomalies were not observed on our data from the OCS Lease Sale 43 area. Several high-amplitude anomalies were noted on shallow subbottom profiles from Area A. These anomalies are interpreted to be the result of lithologic contrasts, such as a well-indurated zone overlain by unconsolidated sediments. Processed multichannel sparker and debubbled sparker data contain no evidence of classical bright-spot signatures. Amplitude anomalies present on these data are not characterized by phase shifts; consequently, they are attributed to differences in reflectivity associated with lateral facies changes.

Test 6002 of the Atlantic Margin Coring Project (Block NH 17-2-867; Hathaway and others, 1976) observed low concentrations of methane (138-293 ppm) in middle Miocene calcareous sands and silty clays at depths between 69 and 107 m. Traces of hydrogen sulfide were observed above this zone. No acoustic anomalies that might be associated with these gas zones were detected on our reflection profiles. The COST GE-1 well reports (Amato and Bebout, 1978; Scholle, 1979) did not describe any gas shows, and no other well information indicates the presence of gas at depth within the Lease Sale 43 area.

Water-column anomalies observed on high-frequency reflection profiles and side-scan sonographs tend to occur in conjunction with bathymetric prominences and hard-bottom zones along the shelf margin. Their distribution trends, lack of gas-seep morphology (for example, lack of upward-expanding plume), and an absence of associated vent structures, such as mud mounds, craters, or faults, indicate that most of the observed water-column anomalies can be attributed to biologic phenomena such as fish schools. The water-column anomaly shown on figure 6 is one of the few upward-expanding plumes observed, in this investigation. As it does not occur above a turbid or opaque zone, or in association with a vent structure, it is not interpreted to be a seep originating from a high-pressure gas deposit.

After evaluating available acoustic data and the limited drilling history of the area, we conclude that, although shallow sediments contain gas, there is no evidence of high-pressure gas accumulation of the type commonly associated with blowouts. The risks related to shallow gas are therefore considered minimal.

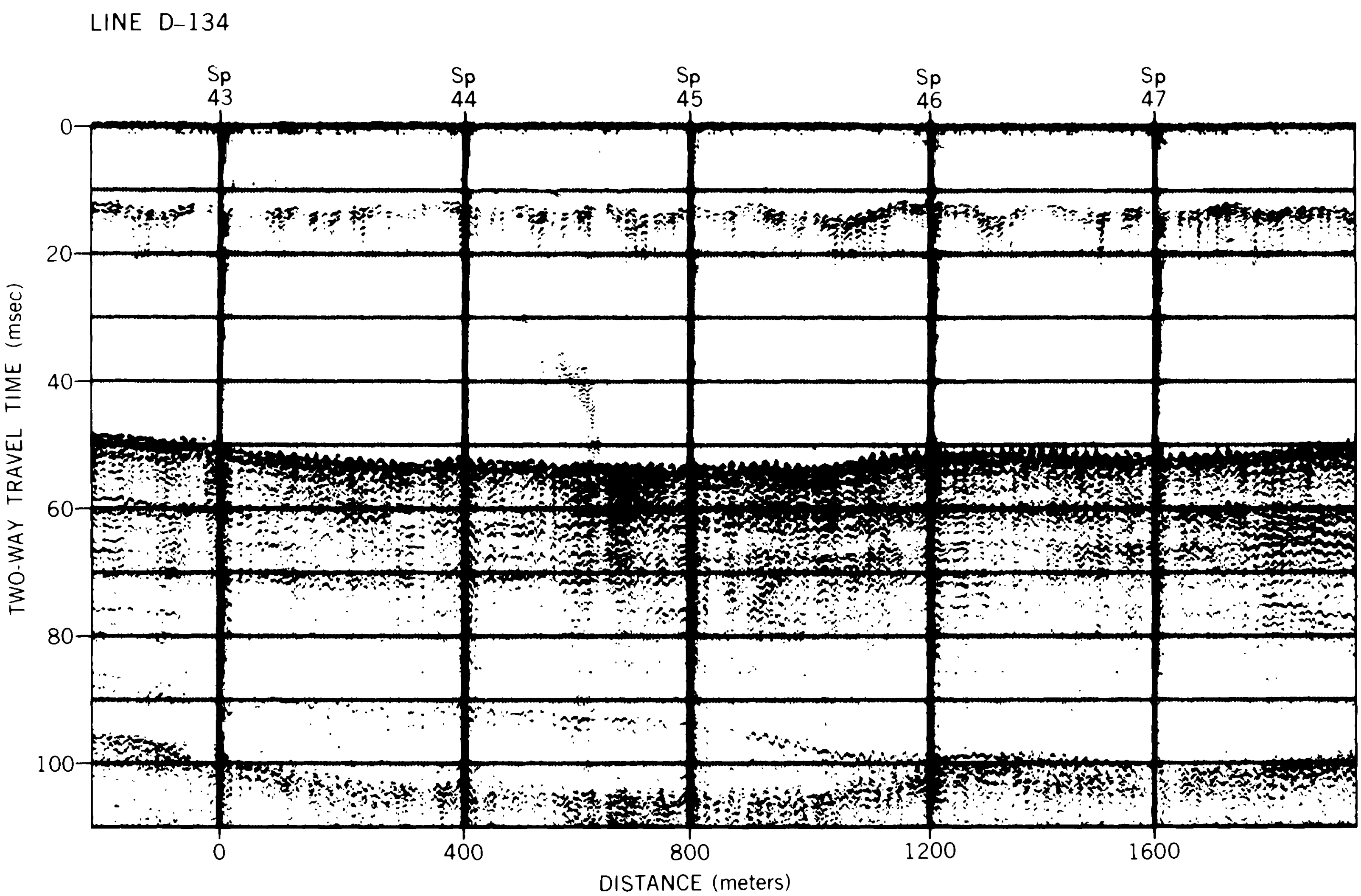


Figure 6.--Shallow subbottom profile (Acoustipulse) of an upward-expanding water-column plume. Sp, Shotpoint. Vertical exaggeration X15. (See pl. 1, block NH 17-2-916.)

Cavernous Limestones

Cavernous secondary porosity in carbonate rocks has been encountered in wells north and south of the Lease Sale 43 area (Dillon and others, 1975). Limestones of the Ocala Group (Eocene) are the principal components of the aquifer in southeastern Georgia and Florida and they are known to be cavernous in much of that area. The offshore equivalents of these limestones have been recognized in JOIDES tests J-1 and J-2 (Charm and others, 1969), and the upper boundary correlates with the prominent acoustic unconformity designated T_0 on sparker profiles from Area F (fig. 5). The probability is high that cavernous Tertiary limestones underlie at least the southern part of the sale area; however, the detection of solution features below 100 m subbottom is nearly impossible prior to drilling because deeper penetrating (lower-frequency) reflection-profiling systems generally lack the requisite resolution, and higher-frequency systems do not penetrate deep enough to characterize the Tertiary limestones that are suspected of being cavernous.

The principal problems associated with cavernous limestones are lost mud circulation or, in the worst case, lost drill string. Abrupt loss of drilling mud can result in hole collapse and (or) loss of down-hole apparatus, both of which could lead to abandonment. On the basis of our present information, cavernous zones may be the most serious potential drilling problem in the Lease Sale 43 area.

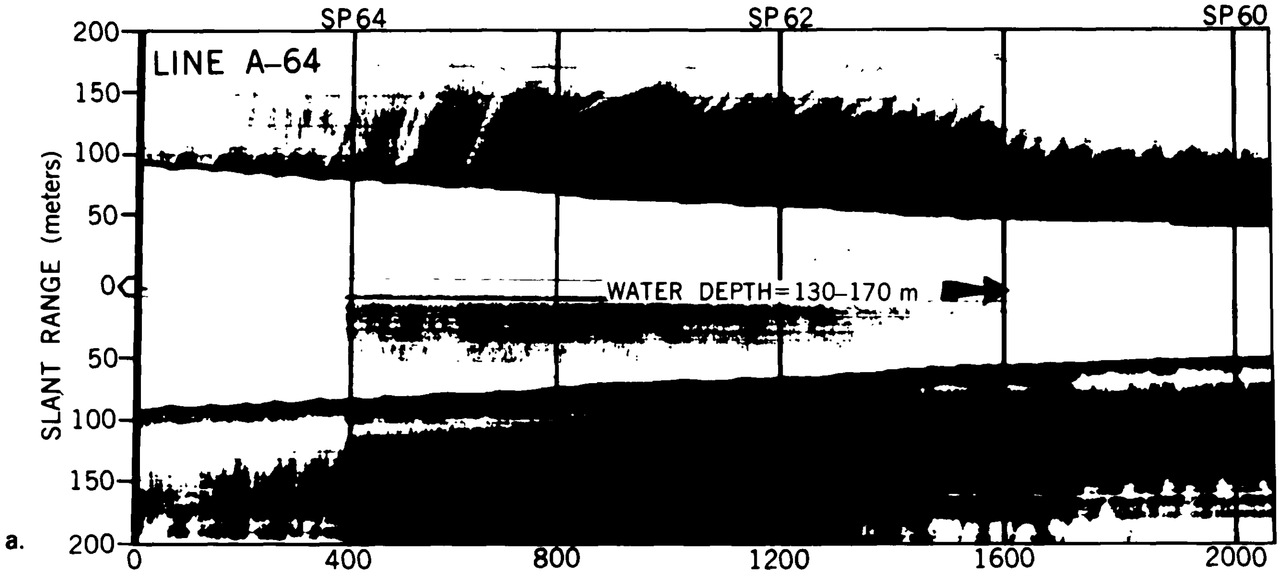
Potentially Unstable Slopes

Potentially unstable slopes are present seaward of the shelf break on the upper Florida-Hatteras Slope. Gradients along unconsolidated slopes in the eastern parts of Areas A and F typically attain values of 20 m/km (greater than 1°). Gradients in excess of 1° have been shown to be sufficient for gravitational mass movement to occur, given the appropriate geotechnical parameters, depositional history, and an effective trigger mechanism (A. H. Bouma, unpublished data, 1978; Lewis, 1971). The upper slope in the South Atlantic OCS area is also subject to strong oceanic currents (Lee, 1978) that are capable of eroding and transporting sand-size material. Such current action could ultimately result in oversteepening of some of the more exposed areas.

No slump, slide, or creep structures are present on any of the acoustic profiles acquired in this investigation. As a result, slope failure due to gravitational processes is not considered to be an operational problem in the Lease Sale 43 area. However, instances of slope failure, due to erosion by the Florida Current, may be present on the upper slope beyond the limits of our geophysical coverage; therefore, because of locally steeper gradients and exposure to strong currents, unconsolidated slopes that lies seaward of the shelf break (and have gradients in excess of 1^{o}) are considered to be potentially unstable. In general, the risk to bottom-mounted structures is considered low because no evidence of dynamic conditions or gravity failure is present. An exception exists on the upper slope in Area A, where evidence of the effects of strong bottom currents is indicated by the sand-wave field identified on acoustic profiles in block NI 17-12-380 (figs. 7a,b). This potentially unstable area is discussed in greater detail under Dynamic Foundation Zone Conditions.

Foundation Conditions

Surface and shallow subsurface conditions need to be considered prior to conducting foundation engineering or other platform-siting operations. From an engineering vantage, these conditions can be categorized as either static or dynamic, depending on whether or not they are being influenced by processes associated with the present hydraulic regime in the area. Static foundation zone conditions, such as facies variations associated with fill facies and hardgrounds, can be routinely mitigated; once identified, the critical geotechnical information can be determined and any necessary modifications to design or procedure can be implemented to ensure operational safety. In contrast,the engineering implications of dynamic conditions, such as scour or sand-wave fields, are more difficult to quantitatively assess without sophisticated long-term monitoring studies. In such cases, engineering solutions must commonly rely on previous experience acquired in analogous environments. In addition, routine monitoring may be necessary during the operational life of the platform to ensure the adequacy of any empirical solutions.



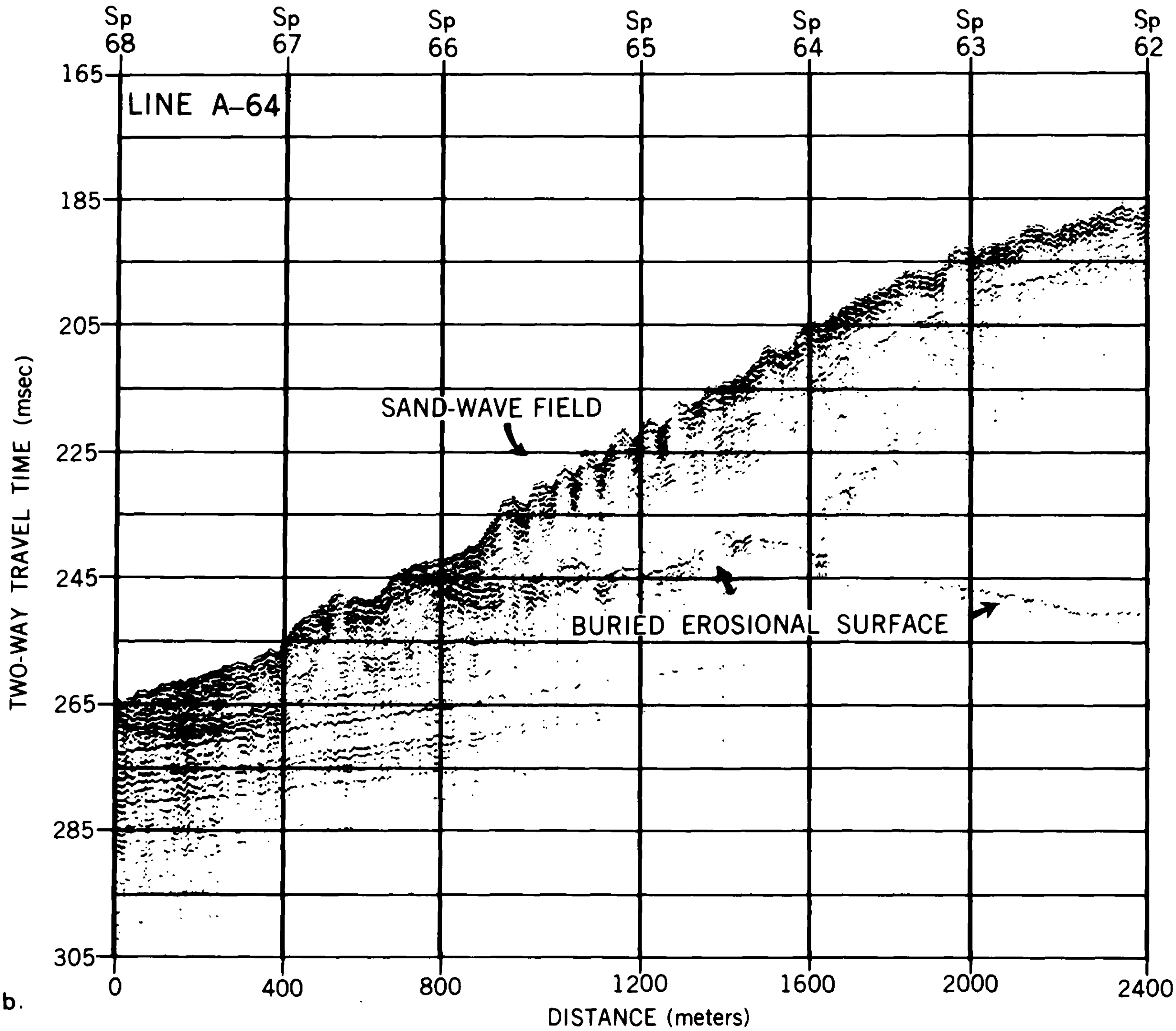


Figure 7.--(a) Side-scan sonograph and (b) shallow subbottom profile (Acoustipulse) across a sand-wave field in Area A. Sp, Shotpoint. Vertical exaggeration (b) X14. (See pl. 1, block NI 17-2-380.)

Static Foundation Zone Conditions

Paleochannel and small paleobasin deposits are recognized on reflection profiles as anomalous sets of reflections referred to collectively as "seismic fill facies" (Mitchum and others, 1977). On the continental shelf, these facies are most often characterized on reflection records by unconformable reflections bounded by an irregular erosional contact incised into underlying strata; they are laterally discontinuous, generally have no bathymetric expression, and often appear to be only locally developed.

Several fill facies trends are recognized on geophysical data from the OCS Lease Sale 43 area. These trends are believed to be the result of former fluvial and submarine processes. No attempt has been made to differentiate, on the basis of origin, fill facies mapped on plate 1 because the geophysical data are insufficient to resolve genetic differences without supplementary geologic information.

The fill facies distribution (pl. 1) is mainly a composite of two large, superimposed channel systems in survey Areas A and D. Maximum accumulations of approximately 150 m of fill occur locally in Area A, where younger cut-and-fill deposits are incised into underlying fill deposits. In contrast, the thinnest fill units mapped are approximately 4 m thick. The distribution of fill facies in Area A shows northeast-southwest lineations associated with a complex, irregular erosional surface (fig. 8). Paull and Dillon (1979) noted that Neogene deposition on the northern part of the shelf has been dominated by the influence of the Florida Current, which migrated repeatedly across the outer shelf and upper slope. Therefore, much of the extensive cut-and-fill in Area A is attributed to submarine rather than fluvial processes.

The other major occurrence of shallow fill facies was observed along the western margin of Area D, landward of the 40-m isobath. This fill trend may be an extension of the shallower of the superimposed trends along the western margin of Area A. The areal distribution and character of these channels suggest development in a nearshore coastal plain environment, possibly a paludal complex analogous to the present coastline between Jacksonville, Fla., and Charleston, S.C.

When comparing the areal distribution of the fill facies between the northern and southern parts of the study area, it should be noted that

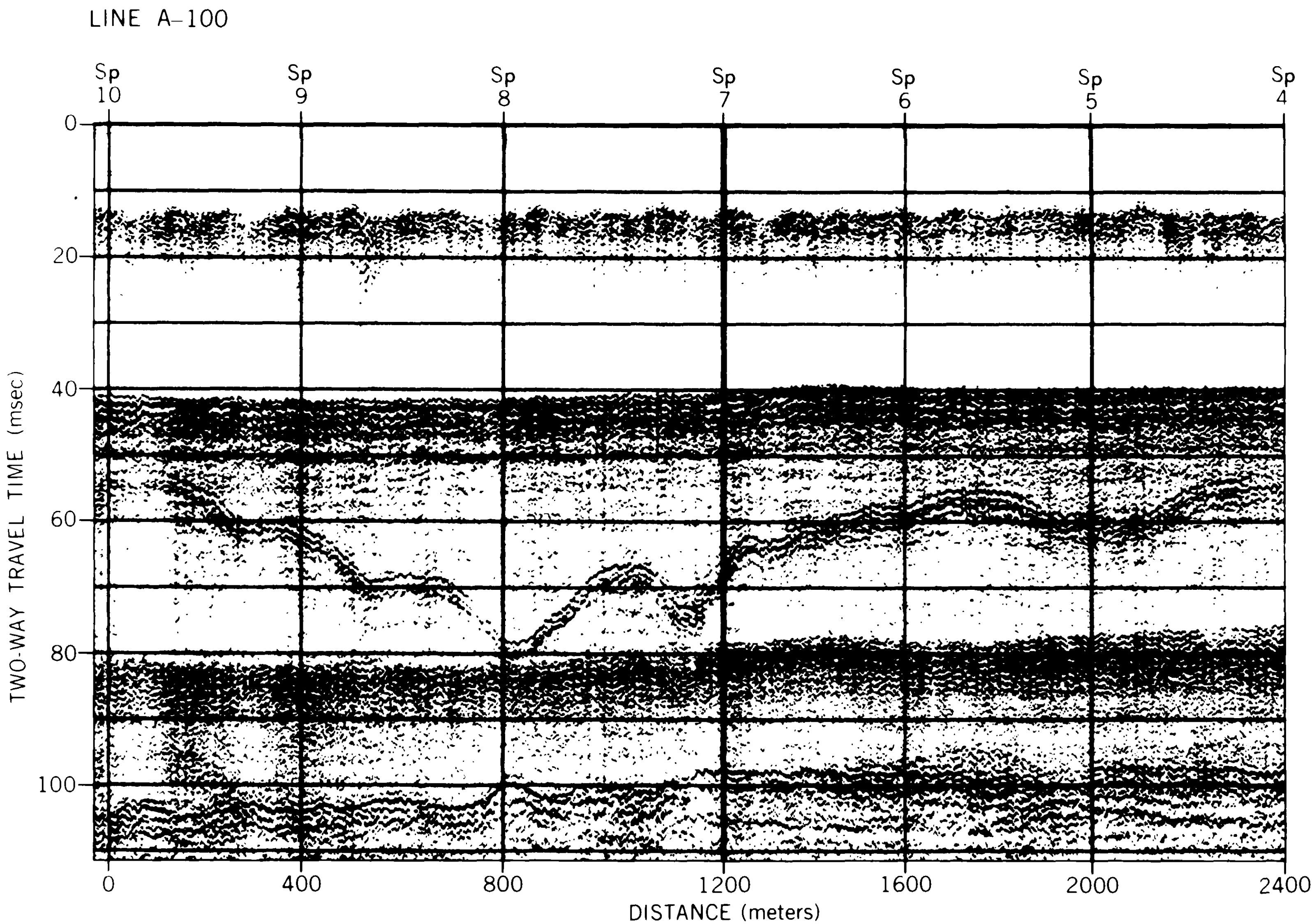


Figure 8.--Shallow subbottom profile (Acoustipulse) showing seismic fill facies (channel fill). Sp, Shotpoint. Vertical exaggeration X18. (See pl. 1, block NI 17-12-153.)

the band-pass of the shallow subbottom profiling systems employed by the two geophysical contractors differed markedly (table 1). Consequently, a larger frequency spectral gap, between complementary reflection profiling systems, occurs in the data base south of 31°N. The difference in spectral coverage results in some resolution and mapping inconsistencies between Study Areas A and D.

Areas in which fill facies occur have foundation-zone characteristics and shallow drilling conditions that may be a potential problem. Geotechnical properties may vary markedly between fill and surrounding materials, and fill deposits often have a heterogeneous character. If fill deposits include units composed mainly of coarse-grained material, high-porosity or "lost circulation" zones may be penetrated, which would impose some constraints during drilling. In general, the tops of more extensively developed fill complexes lie at or just below the base of strata that would be penetrated by the legs of jackup rigs. On the upper slope, in block NI 17-12-423, at least two generations of fill deposits occur within the foundation zone. Elsewhere along the upper slope, fill deposits are commonly absent because of nondeposition beneath the axis of the Florida Current (Paull and Dillon, 1979, fig. 76). In the examples observed, load-bearing capacities of the overlying sandy sediment are expected to be more than adequate; however, differential settlement is not totally precluded. In all cases considered, the risks are low, and prior identification, accurate mapping, and testing can define the steps necessary to avoid any potential design or operational problems. Also, many of these potential constraints can be easily avoided during site selection.

Exposed, or sediment-veneered, zones of lithification (hardgrounds) are a type of static foundation zone condition specific to the Atlantic Continental Shelf south of Cape Hatteras. Most hardgounds within the Lease Sale 43 area occur within the outer banks trend that is indicated on the Bureau of Land Management's Visual 2S (Bureau of Land Management, 1978); the majority being concentrated near the shelf break in Areas A and F.

Linear trends of hardgrounds, having relief in excess of 3 m, are shown on plate 1. Variations in the resolution of side-scan data during the course of the survey prevented consistent regional mapping of low-relief (less than 3 m) hardgrounds. The most obvious trend of hardgrounds (pl. 1) is a curvilinear ridge that defines the shelf break at the 60-m contour in Area F. This continuous trend contrasts with the more discontinuous patch-reef character of high-relief hardgrounds developed along the shelf break in Area A. Profiles across both areas are shown in figures 9 and 10.

The principal operational considerations in areas containing hardgrounds are associated with anchoring, pile penetration, and abrupt lateral contrasts in load-bearing capacity. All of these potential engineering problems can be solved by readily available techniques.

Some shallow subbottom profiles (3.5 kHz) from Areas D and E indicate the presence of irregular surfaces that may be shallow karst. These irregular surfaces occur at the base of the surficial sand sheet, generally beneath sand swells. Alternatively, these anomalous reflectors may merely indicate the presence of a rugged subaerial erosion surface. Shallow karst does not appear to be widespread, if present at all, in the upper 50 m of the sedimentary section within the sale area, and any attendant risks to development are considered minimal.

Dynamic Foundation-Zone Conditions

Side-scan sonographs indicate that bedforms of hydrodynamic origin are widespread on the shelf and upper slope within the study area. These bedforms range from small-scale (wavelengths less than 1 m) to giant-scale (wavelengths greater than 30 m). In general, bedform development becomes more prominent near the shelf margin (that is, in Areas A and F), an expected consequence of the more dynamic hydraulic conditions that occur there.

Of the anomalous areas identified, only one field of large sand waves, in Area A, is interpreted as indicative of a level of active sediment transport that may pose potential foundation-stability problems (fig. 7, pl. 1, block NI 17-12-380). This sand-wave field mantles an offlapping depositional sequence exposed on the northeast slope of the relict cuspate foreland located at the shelf-break (fig. 7). The depth of the sand-wave field ranges from 80 to more than 180 m below sea level. Giant-scale (first-order) bedforms are asymmetrical, attain heights up to 5 m, and strike approximately northeast (locally, the bathymetric trends are northward). The steeper face (lee- or slip-face) dips downslope and

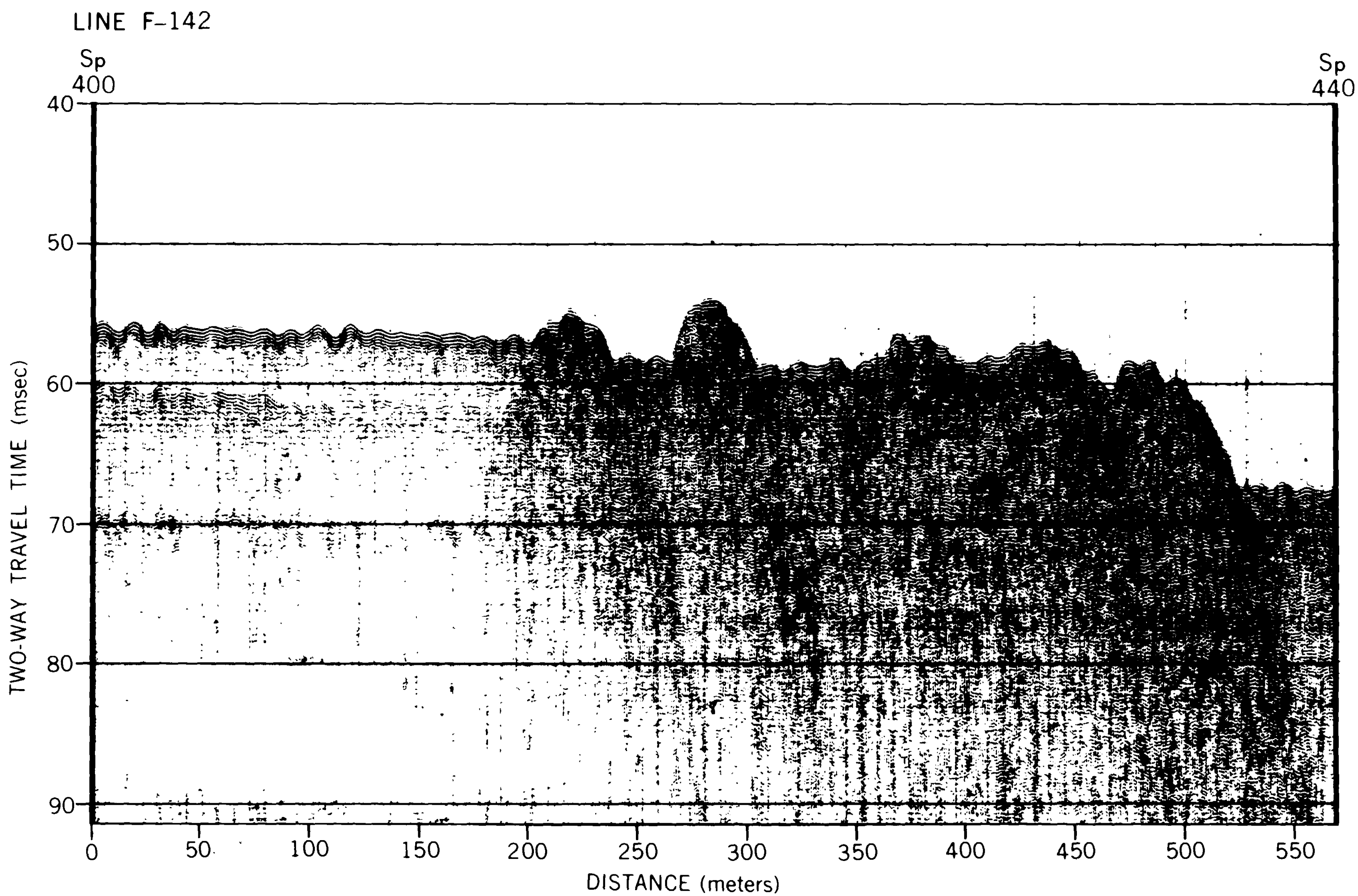


Figure 9.--Shallow subbottom profile (3.5 kHz) of the shelf-margin ridge system (high relief hardgrounds) near survey Area F. Sp, Shotpoint. (See pl. 1, block NH 17-5-828. This block is not within the Lease Sale 43 area but is located adjacent to the southern boundary of lease block NH 17-5-784.) Vertical exaggeration X9.

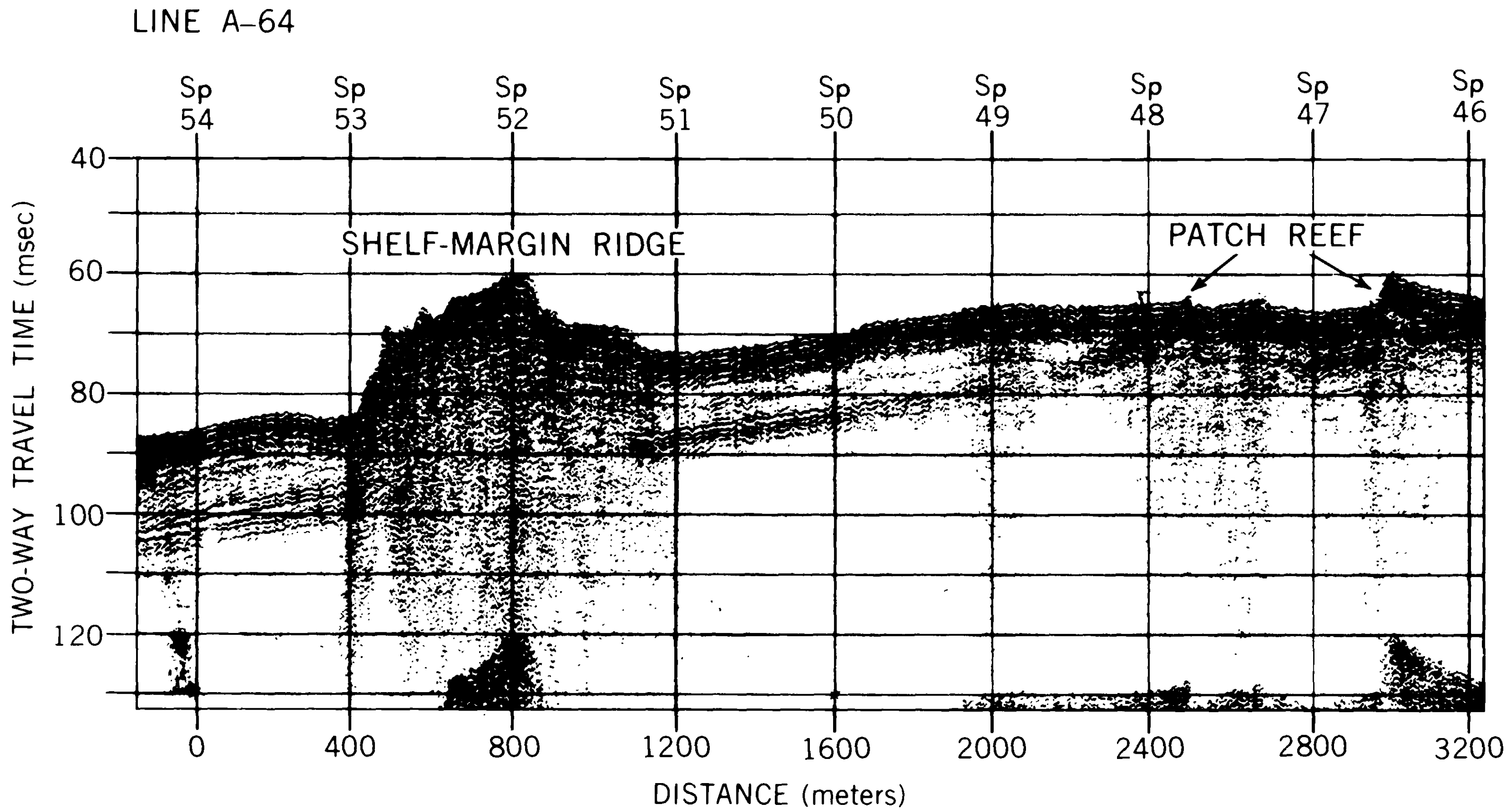


Figure 10.--Shallow subbottom profile (Acoustipulse) of the shelf-margin ridge system and patch reef in Area A. Sp, Shotpoint. Vertical exaggeration X14. (See pl. 1, block NI 17-12-336.)

large-scale ripples (second-order), which strike approximately northwest, are common on the stoss-face (upcurrent-face) of the giant-scale bedforms (fig. 11). The occurrence of two morphotypes (transverse and longitudinal current ripples), which strike normal to each other, suggests that they are the simultaneous products of the same event(s).

Considering the bathymetric setting, bedform orientation, and character of the prevailing current regime, these bedforms may be (1) the result of flow reversals (eddies) caused by the relict cuspate foreland jutting into the northerly flowing Florida Current or (2) they may be the result of seasonal (winter) off-shelf density flows (Dillon and others, 1975). Both are presumed to be active processes and, in conjunction with the relatively steep gradients of the upper slope, make this locality potentially hazardous for long-term emplacement of bottom-supported structures.

Uchupi (1968) described major trends of another type of sand body on the Southeast Georgia Embayment shelf, which he refers to as "sand swells." His map (Uchupi, 1968, p. C18, fig. 14) indicated that these features are widespread on the shelf between Cape Canaveral, Fla., and Cape Romain, S.C. Although Uchupi delineated only a few sand swells within the Lease Sale 43 area, our data indicate that sand swells occur throughout most of the area.

The sand swells observed in the survey area are low-relief (less than 10 m), very broad (as much as 1.5 km), commonly symmetrical sand bodies whose crests can often be traced for distances of 10 km or more (fig. 12). These features are too abundant to include on plate 1, but an interesting example of their mode of occurrence exists in Area F, where an enechelon alinement of northeasterly trending sand swells occur between flanking lithified-ridge complexes. Most swells show no acoustic evidence of internal primary structure, although oblique reflections within one swell near the shelf margin suggest southeasterly progradation. Other sand swells and ridges within the OCS Lease Sale 43 area tend to occur more randomly.

The morphology, areal distribution, and relationship to flanking lithified ridges suggest that sand swells in Area F may be degraded relict remnants of a tidal-current ridge system that developed on a high-energy shallow shelf during the early stages of the Holocene transgression. Their potential mobility under present shelf-margin

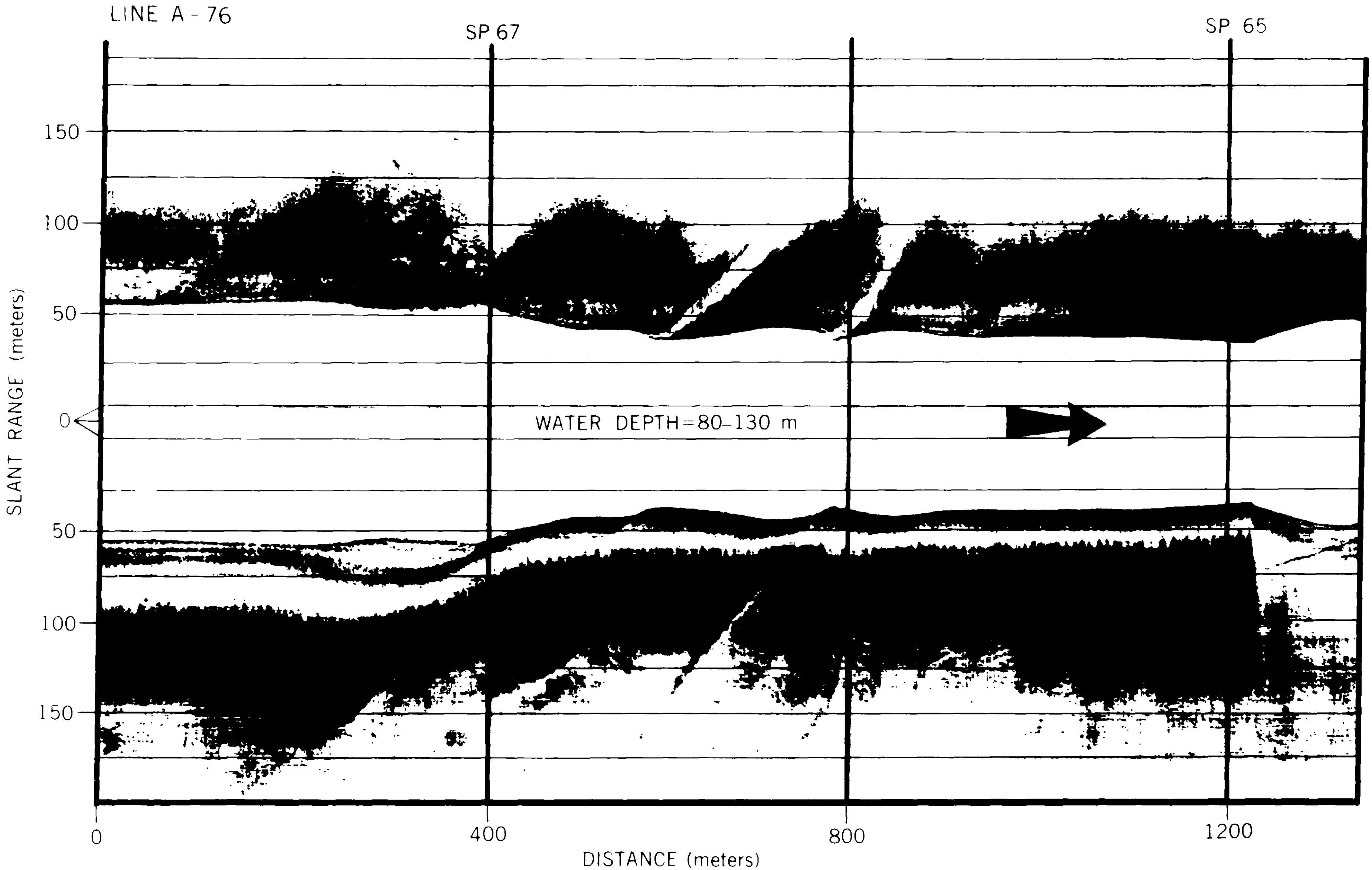


Figure 11.--Side-scan sonograph of sand-wave field in Area A. Note second-order bedforms and patch reef (upper channel) at base of sand-wave field. Sp, Shotpoint. (See pl. 1, block NI 17-12-380.) Arrow shows ships track.

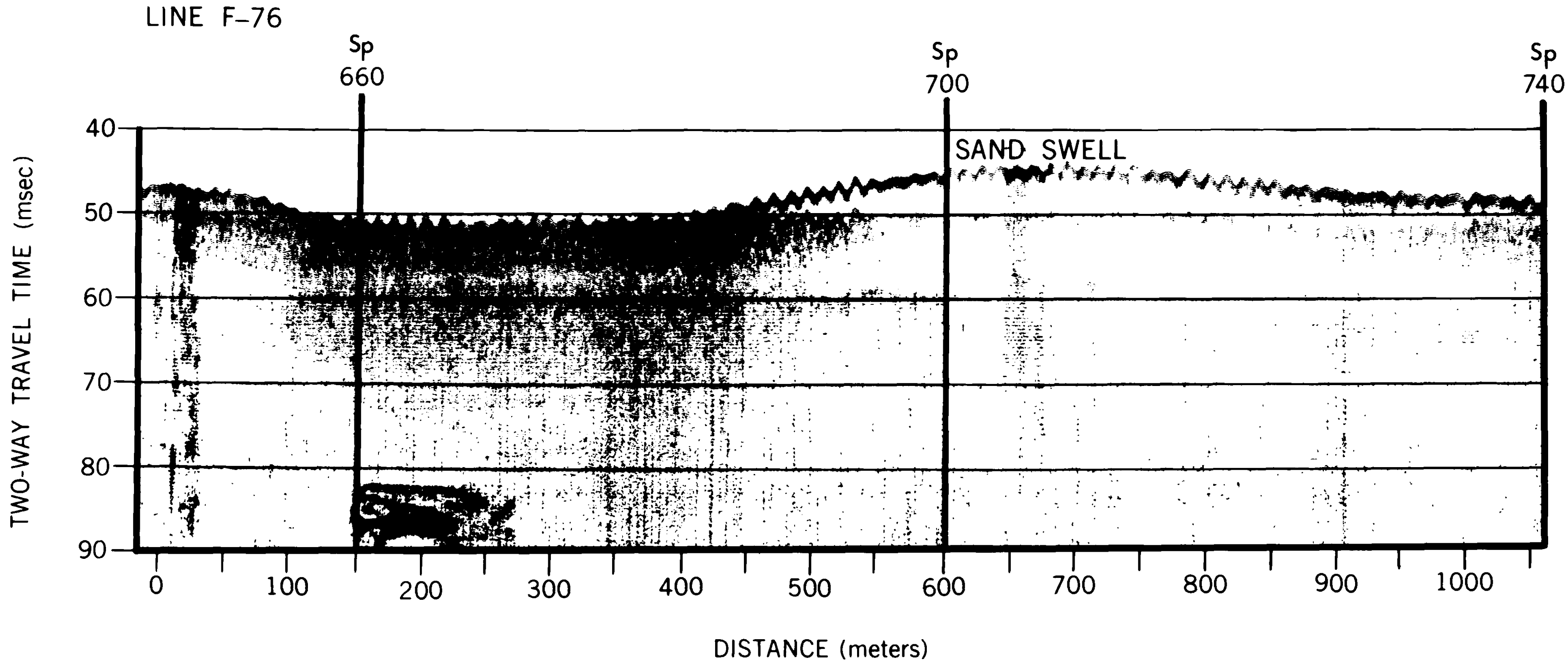


Figure 12.--Shallow subbottom profile (3.5 kHz) of a sand swell. Vertical exaggeration X9. Sp, Shotpoint. (See pl. 1, block NH 17-5-564.)

dynamic conditions is considered to be very low, and they are not expected to pose any constraints on operations within the sale area. However, Hadley (1964) has shown that prolonged gale-force winds can result in wave-induced, deep shelf currents approaching 4 km/hr at a depth of 180 m. Such currents would be sufficiently competent to mobilize sand-size material. Resolution in this survey did not allow detection of more subtle primary structures and precludes any definitive statement regarding the mobility of these sand swells, but our analysis of Hadley's study suggests that a potential for mobility cannot be ignored in foundation design.

An additional operational consideration associated with the sand swells in Area F is potential current scour within swales. The deflationlike erosion of swales as a result of scour is best observed in the southern half of the survey area but is locally apparent throughout. Figure 12 depicts a deflated swale to the left of a prominent swell. The occurrence of submarine outcrops with swales suggests local topographic influence on bottom circulation patterns. Towed underwater television observations have confirmed the existence of outcrops in swales and have documented the seabed. The temporal variability and magnitude of the erosive force of bottom currents in this area are speculative. In the vicinity of the shelf break, bottom-current velocities are generally low, but winter storm tides and incursions of the Florida Current can temporarily raise these velocities to levels approaching 2 knots (Lee, 1978). These conditions would probably result in maximum expectable erosion and scour.

The principal operational considerations associated with scour are sediment mobility and stability of platform foundations. Sediment-bearing currents can scour and abrade pilings and excavate around structural supports and anchors that are in contact with the sea floor. Although these conditions may require special engineering precautions, any adverse effects usually can be controlled by application of readily available technology.

SUMMARY

Geologic conditions that might affect operations in the South Atlantic OCS Lease Sale 43 area include low seismicity, shallow faults, cavernous limestones, and static and dynamic foundation zone conditions.

Seismic risk, by virtue of the unpredictability of events, is difficult to evaluate. Bottom-mounted offshore structures subjected to ground accelerations of the magnitude experienced in the 1886 Charleston earthquake would not be expected to undergo significant damage; however, damage could be expected to be significant for structures emplaced without considering local variations in foundation conditions.

The shallow faults observed do not appear to have a tectonic origin. Available evidence favors a differential compaction and (or) subsidence mechanism. A lack of evidence of Holocene displacement and the relatively low regional seismicity suggest that risks related to seismicity and faulting are low in the Lease Sale 43 area.

Direct evidence of subsurface conditions considered to be constraints to drilling operations, such as high-pressure gas or lost-circulation zones, is lacking on our data. Cavernous limestones may be present in the subsurface, as drilling in adjoining areas with parallel geologic histories has shown. Lost-circulation zones associated with subsurface voids in limestones and high-porosity fill deposits can be expected to be one of the principal drilling problems in the South Atlantic OCS, although such zones merely complicate rather than preclude development.

Bottom-current activity, which is associated with mobile bedforms and scour, may require special engineering precautions in some areas. With the exception of one block, the net effects of bottom-current activity appear to be significantly lower in Lease Sale 43 areas than in other Atlantic OCS areas. Block NI 17-12-380 was ultimately deleted from Lease Sale 43 owing, in part, to the presence of a large sand-wave field that has developed on the relatively steep flank of a relict cuspate foreland. The presence of secondary bedforms and their exposed locations under the direct influence of the Florida Current suggest that their development is a result of modern hydrodynamic conditions in the area.

Slumping is not considered to be an important factor in the study area as few blocks were offered in Lease Sale 43 that include significant acreage on the upper slope. Evidence of slope failure may be present on the upper slope beyond the limits of our geophysical coverage; therefore, the areas seaward of the shelf break, with unconsolidated slopes in excess of 1^{o}, are considered to be potentially unstable even though no direct evidence of gravity failure is present. Other foundation zone conditions such as fill facies, hardgrounds, and sand swells impose some constraints on operations but are not classified as hazards.

In brief, our assessment indicates that geologic features and conditions identified in the Lease Sale 43 area are engineering constraints that constitute a low risk to oil and gas development operations.

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Table 2.--List of blocks exhibiting constraints
[*, withdrawn by Department of the Interior
from OCS Lease Sale 43]

Blocks showing evidence of channel fill				
NI 17-12-115	NI 17-12-330	NH 17-5-30	NH 17-2-611	NH 17-2-911
153	331	34	651	912
159	332	35	652	913
197	333	69	653	914
198	334	70	695	918
199	336	71	696	954
203	373	73	739	955
204	374	76	740	956
241	375	117	781	957
242	376	159	782	958
243	377	294	783	961
244	378	295	784	962
245	379	339	825	963
246	380*	390	826	994
247	417	432	827	997
285	418	434	868	998
286	419	470	869	999
287	420	475	870	1000
288	421	521	871	1001
289	422	565	872	1002
290	423	607	873	1003
291	462	609	874	1005
292	463	784		1006
329	464			

Table 2.--List of blocks exhibiting constraints--Continued
[*, withdrawn by Department of the Interior from
OCS Lease Sale 43]

Blocks showing evidence of faulting			
NH 17-2-653	NH 17-5-30	NH 17-5-209	NH 17-5-521
994	33	211	557
1000	37	251	562
1001	38	295	563
1002	68	384	601
	69	427	606
	72	428	607
	116	433	651
	164	475	652
	166	476	696
	203	519	740
		520	784

Blocks showing unconsolidated slopes gradients in excess of 1°		
NI 17-12-292	NH 17-5-434	NH 17-2-256
336	478	
380*	609	
421	653	
422		
423		
463		
464		

Table 3.--Index to block maps for blocks surveyed in Lease Sale 43
[*, withdrawn by Department of the Interior from
OCS Lease Sale 43]

Block No. NI 17-12	Page	Block No. NI 17-12	Page	Block No. NI 17-12	Page	Block No. NH 17-2	Page
115	43-01	289	43-22	418	43-43	300	43-59
153	43-02	290	43-23	419	43-44	301	43-60
154	43-03	291	43-24	420	43-45	342	43-61
159	43-04	292	43-25	421	43-46	343	43-62
160	43-05	329	43-26	422	43-47	344	43-63
197	43-06	330	43-27	423	43-48	345	43-64
198	43-07	331	43-28	462	43-49	387	43-65
199	43-08	332	43-29	463	43-50	388	43-66
203	43-09	333	43-30	464	43-51	389	43-67
204	43-10	334	43-31	843	43-52	608	43-68
241	43-11	335	43-32	844	43-53	609	43-69
242	43-12	336	43-33	886	43-54	610	43-70
243	43-13	373	43-34	887	43-55	611	43-71
244	43-14	374	43-35	888	43-56	651	43-72
245	43-15	375	43-36			652	43-73
246	43-16	376	43-37			653	43-74
247	43-17	377	43-38	Block No.	Page	695	43-75
285	43-18	378	43-39	NH 17-2		696	43-76
286	43-19	379	43-40			739	43-77
287	43-20	*380	43-41	256	43-57	740	43-78
288	43-21	417	43-42	299	43-58	781	43-79

Table 3.--Index to block maps for blocks surveyed in Lease Sale 43--Continued

[*, withdrawn by Department of the Interior from OCS Lease Sale 43]

Block No. NH 17-2	Page	Block No. NH 17-2	Page	Block No. NH 17-5	Page	Block No. NH 17-5	Page
782	43-80	959	43-108	29	43-131	158	43-159
783	43-81	960	43-109	30	43-132	159	43-160
784	43-82	961	43-110	33	43-133	160	43-161
825	43-83	962	43-111	34	43-134	164	43-162
826	43-84	963	43-112	35	43-135	165	43-163
827	43-85	964	43-113	36	43-136	166	43-164
868	43-86	993	43-114	37	43-137	167	43-165
869	43-87	994	43-115	38	43-138	168	43-166
870	43-88	997	43-116	68	43-139	202	43-167
871	43-89	998	43-117	69	43-140	203	43-168
872	43-90	999	43-118	70	43-141	207	43-169
873	43-91	1000	43-119	71	43-142	208	43-170
874	43-92	1001	43-120	72	43-143	209	43-171
911	43-93	1002	43-121	73	43-144	210	43-172
912	43-94	1003	43-122	74	43-145	211	43-173
913	43-95	1004	43-123	76	43-146	250	43-174
914	43-96	1005	43-124	77	43-147	251	43-175
915	43-97	1006	43-125	78	43-148	252	43-176
916	43-98	1007	43-126	81	43-149	253	43-177
917	43-99			114	43-150	293	43-178
918	43-100			115	43-151	294	43-179
920	43-101	Block No.	Page	116	43-152	295	43-180
953	43-102	NH 17-5		117	43-153	296	43-181
954	43-103			118	43-154	339	43-182
955	43-104	25	43-127	120	43-155	345	43-183
956	43-105	26	43-128	121	43-156	382	43-184
957	43-106	27	43-129	122	43-157	283	43-185
958	43-107	28	43-130	123	43-158	384	43-186

Table 3.--Index to block maps for blocks surveyed in Lease Sale 43--Continued

[*, withdrawn by Department of the Interior from OCS Lease Sale 43]