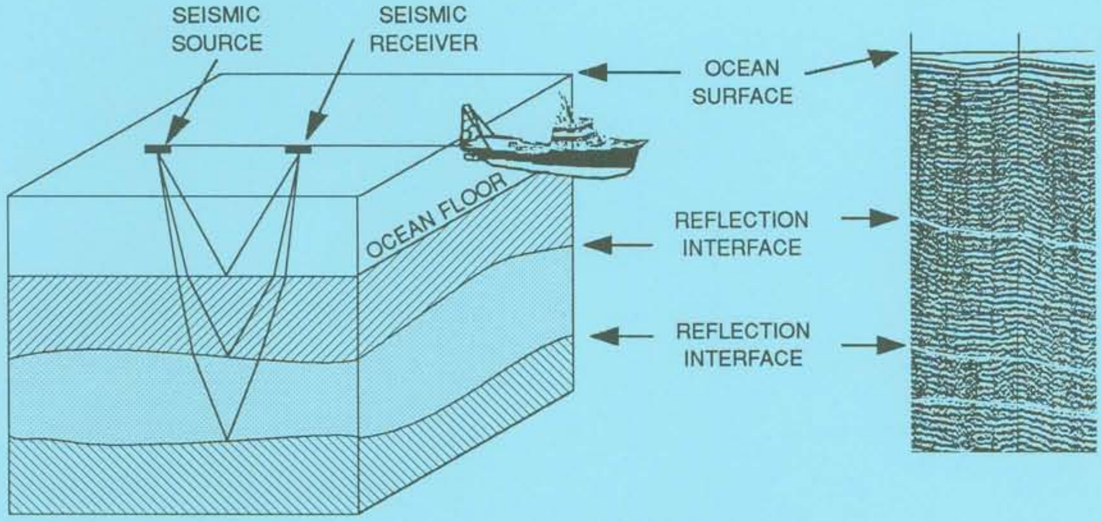
New Jersey Geological Survey
Geological Survey Report GSR 26

A Marine Seismic Survey to Delineate Tertiary and Quaternary Stratigraphy of Coastal Plain Sediments Offshore of Atlantic City, New Jersey



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Cover illustration: Marine seismic profiling. Seismic energy from a source towed by the boat is reflected from the ocean floor and from contacts between geologic layers. The length of time between the energy release and the arrivals of its echoes at the receiver allows geophysicists to infer sea-floor topography and depths to contacts.

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A Marine Seismic Survey to Delineate Tertiary and Quaternary Stratigraphy of Coastal Plain Sediments Offshore of Atlantic City, New Jersey

by
Jeffrey S. Waldner and David W. Hall

New Jersey Department of Environmental Protection
Geological Survey
CN-029
Trenton, NJ 08625

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For readers who prefer to use metric units, conversion factors for terms used in this report are listed below:

Multiply	by	To obtain
feet	0.3048	meters
feet per second	0.3048	meters per second
mile	1.6093	kilometers

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A Marine Seismic Survey to Delineate Tertiary and Quaternary Stratigraphy of Coastal Plain Sediments Offshore of Atlantic City, New Jersey

ABSTRACT

A high-resolution marine seismic survey covering 19 square miles offshore of Atlantic City, New Jersey, identified four geologic horizons along with bottom and subbottom features in the upper 1000 feet of Tertiary and Quaternary sediments. Two sets of data were collected on a survey grid consisting of 100 to 120 line-miles of sparker and boomer profiles. The data were used in conjunction with offshore drilling, onshore borehole, and onshore geophysical data to determine the seaward characteristics and extent of units of the Kirkwood Formation and contiguous units. The boomer profiles also revealed a shallowly buried channel and two sand ridges. The geophysical interpretations were used to position two offshore monitoring wells in the 800-foot sand aquifer of the Kirkwood Formation.

INTRODUCTION

The New Jersey (N. J.) Geological Survey, with technical assistance provided by the New Jersey District of the U. S. Geological Survey, Water Resources Division, and the U. S. Geological Survey, Branch of Atlantic Marine Geology, conducted a marine seismic investigation off the coast of Atlantic City, New Jersey, in 1985. The purposes of the seismic survey were to: 1) locate potential shallow geologic hazards such as gas pockets, 2) delineate the offshore regional hydrostratigraphy, and 3) position two offshore ground-water monitoring wells.

Acknowledgments

We acknowledge the assistance of Philip B. Duran and Gary J. Barton, both formerly of the New Jersey District of the U. S. Geological Survey, in obtaining seismic equipment, aiding in data collection, and collecting check-shot data at the two offshore wells. The U. S. Geological Survey, Branch of Atlantic Marine Geology, supplied the marine seismic equipment and operations technicians, Kenneth F. Parolski and John West. We also thank William Eisele, William E. Suoninen, Captain Lewis Eggert, and Alan Johnson of the NJ. Geological Survey for lending their expertise and for the use of the Richard J. Sullivan research vessel.

Location

The seismic survey grid extended from 0.5 to 5.7 miles off the coast of Atlantic City, N. J. (fig. 1). Four northwest-trending survey lines, spaced at one-mile intervals, were approximately parallel to the southeastward regional dip. Northeast-trending traverses were roughly parallel to the regional strike and shoreline, ranging from half-mile intervals nearshore to one mile intervals farther offshore.

Figure 1. Map of New Jersey showing locations of Atlantic City and the seismic survey area

MARINE SEISMIC REFLECTION

Marine seismic reflection enables the geophysicist to determine geologic structure beneath the water surface by measuring the behavior of acoustic waves transmitted from a seismic source at the water surface and reflected from bottom and subbottom features. The reflected response is detected by pressure-sensitive transducers, called hydrophones, located near the ocean surface. The method depends upon the transmission of pressure waves and their reflection from earth layers of different acoustic properties (fig. 2a). A reflection may be caused by a difference in water content, sediment density, or small differences in lithology, but it

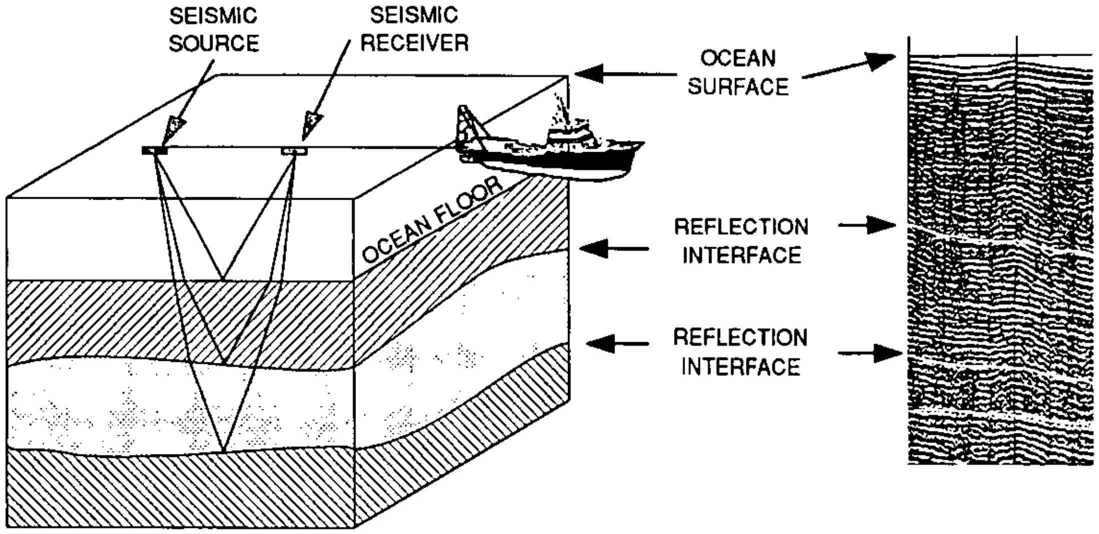

Figure 2a. Single-channel, continuous-reflection, marine profiling operation and corresponding survey record (analog). The analog record (at right) shows as shades of gray which correspond to reflected signal amplitudes (not recognizable at this size). Interpreted reflected interfaces have been highlighted in white.

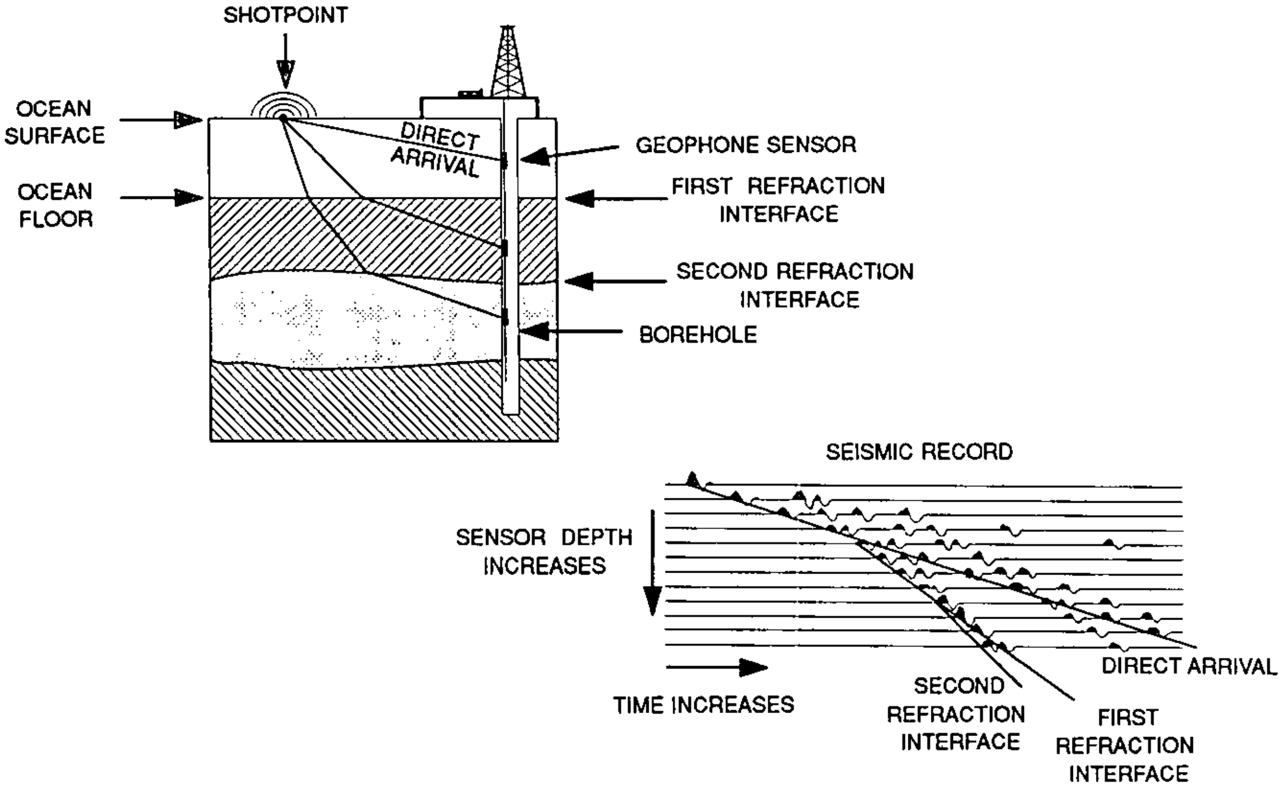

Figure 2 b. Borehole seismic check-shot survey array showing the geometry of a three-layer case and the corresponding seismic record. From these data, interval velocities can be calculated from the arrival times of the initial events.

usually results from gross changes in sediment type (Elliott and Wiley, 1975).

In seismic profiles, the depths to reflecting surfaces are represented as a function of time. Depth information can be obtained by converting the two-way traveltime values into depth, using velocities calculated from seismic reflection or refraction data, borehole sonic logs, or seismic velocity borehole check-shot surveys. Velocity information for this survey is based on onshore seismic-reflection data, subsequently rechecked with borehole check-shot surveys from offshore monitor wells.

Seismic velocity borehole check-shot survey

A check-shot survey is a method of determining the velocity of strata as a function of depth by lowering a geophone into a borehole and recording the energy arrivals from a shot point at the surface (fig. 2b). Seismic data are recorded at set depths, from which interval velocities are calculated. The interval velocities can then be used to convert two-way travel times (from the seismic profiles) to depth.

INSTRUMENTATION

Continuous seismic reflection profiling

Marine seismic data were collected from 21 to 29 April 1985 aboard the N. J. Geological Survey research vessel Richard J. Sullivan. High-resolution profiles of the shallow sediments were needed to assess possible geologic hazards encountered in drilling offshore wells. A second set of profiles was collected using a higher-energy, lower-frequency system in order to obtain deeper peneteration. Accordingly, each trackline was run separately with the two systems.

A boomer system (Ferranti O.R.E. Geopulse) was used for high-resolution profiles of the upper 300 feet of sediments. The transducer was powered by an EG&G Seismic Energy Source (234) generator at 200 joules. Seismic data to depths of 1800 feet were collected with an 800-joule sparker array and a Teledyne Exploration sparker energy source.

An array of hydrophones (Del Norte), connected in series-parallel, detected the reflected acoustic signals. A Geopulse Receiver (ORE 5210A) with time-variant gain was used for the high-resolution shallow data. An Innerspace Preamplifier/Filter Model 202 with a TSS Model 307B amplifier and time-variant gain were used with the sparker system. Analog filters were variably set at bandpasses of 150-1000, 500-1000 and 500-1500 hertz for the boomer profiles and 100-400 to 100-500 hertz for the sparker profiles. Resolution was about 3-5 feet for the boomer profiles and about 10-15 feet for the sparker profiles.

The unfiltered analog data were recorded by an eight-track Hewlett-Packard 3968A Instrumentation recorder. An event-time recorder (EPC 312 Record Annotator) correlated the data on tape to real time.

Analog profiles were generated using an EPC Graphic Recorder. The sparker array sampled at 1-second intervals with a half-second recording (sweep) time. The transducer array sampled at half-second intervals and was recorded at a quarter-second sweep. Examples of sparker and transducer analog records, together with their stratigraphic interpretation, offshore check-shot velocity histograms, and borehole geophysical logs are shown in figures 3, 4, and 5.

Navigation

Navigational positioning was by loran-C. Measured loran time delays were interfaced with a real-time recorder on digital tape for actual positioning during data acquisition. Fixes were plotted every five seconds.

INTERPRETATION

Time-to-depth correlation

The offshore reflectors were correlated with known stratigraphic horizons by: 1) extrapolating the depths offshore using the regional dip, and 2) calculating interval velocities and corresponding reflection coefficients. Interval velocities were by Miller and Dill (1973) from a borehole 3 miles offshore of Little Egg Inlet, from onshore seismic reflection velocity tests collected by the N. J. Geological Survey, and from check-shot surveys at the two offshore monitoring wells. The onshore seismic reflection survey was 1 mile inland from the study area. High-resolution reflection velocity and depth information were obtained for depths less than 1000 feet using methods detailed in Hoffman and Waldner (1986) and Hunter and others (1984). Interval velocities from onshore data were calculated using the formula of Dix (1955):

Onshore stratigraphic depths were obtained from three nearby wells (well nos. 3, 4, and 5) (table 2, figs. 6-9). The observed time values for the seismic profiles were converted to depth by using the onshore interval velocities and offshore velocity data (check-shot surveys from wells no. 1 and no. 2). Each reflector was correlated along and between profiles.

Sparker data

The N. J. Coastal Plain consists of unconsolidated, semiconsolidated, and less common consolidated deposits of sand, silt, and clay ranging in age from Cretaceous to

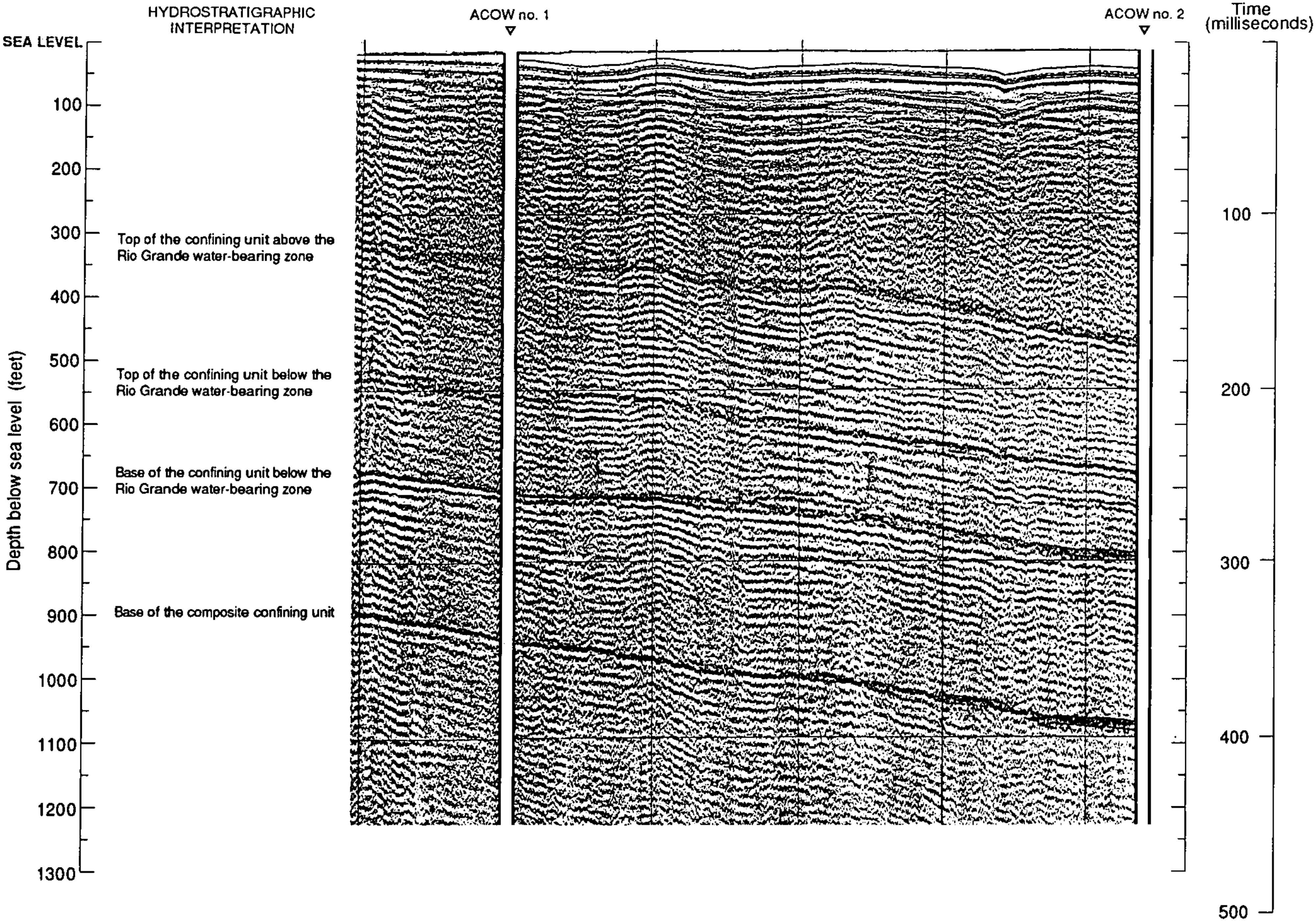

Figure 3. Representative analog profile along sparker section (line D) approximately parallel to dip. Interpreted reflection interfaces highlighted by shading. Locations of offshore wells ACOW no. 1 and ACOW no. 2 projected to section. Depth scale approximate, based on the average velocity to the fourth (deepest) reflector. Horizontal scale 1:50000.

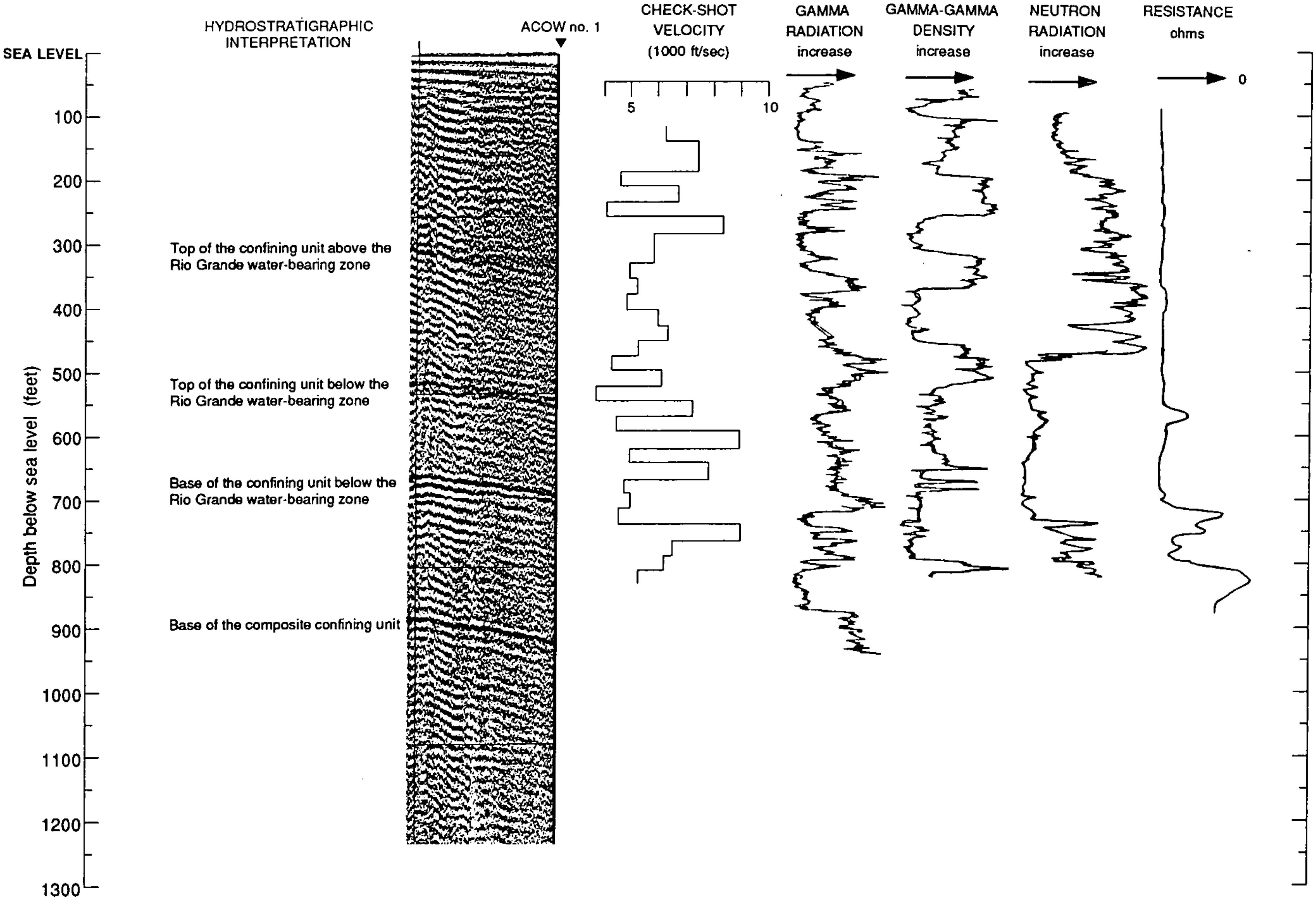

Figure 4. Sample of sparker section (line D) with check-shot velocity histogram and borehole logs for well ACOW no. 1. Exact correlations between the check-shot velocity histogram and borehole logs show apparent shifts which are caused by the greater comparative sampling interval and interval velocity calculations for the velocity data.

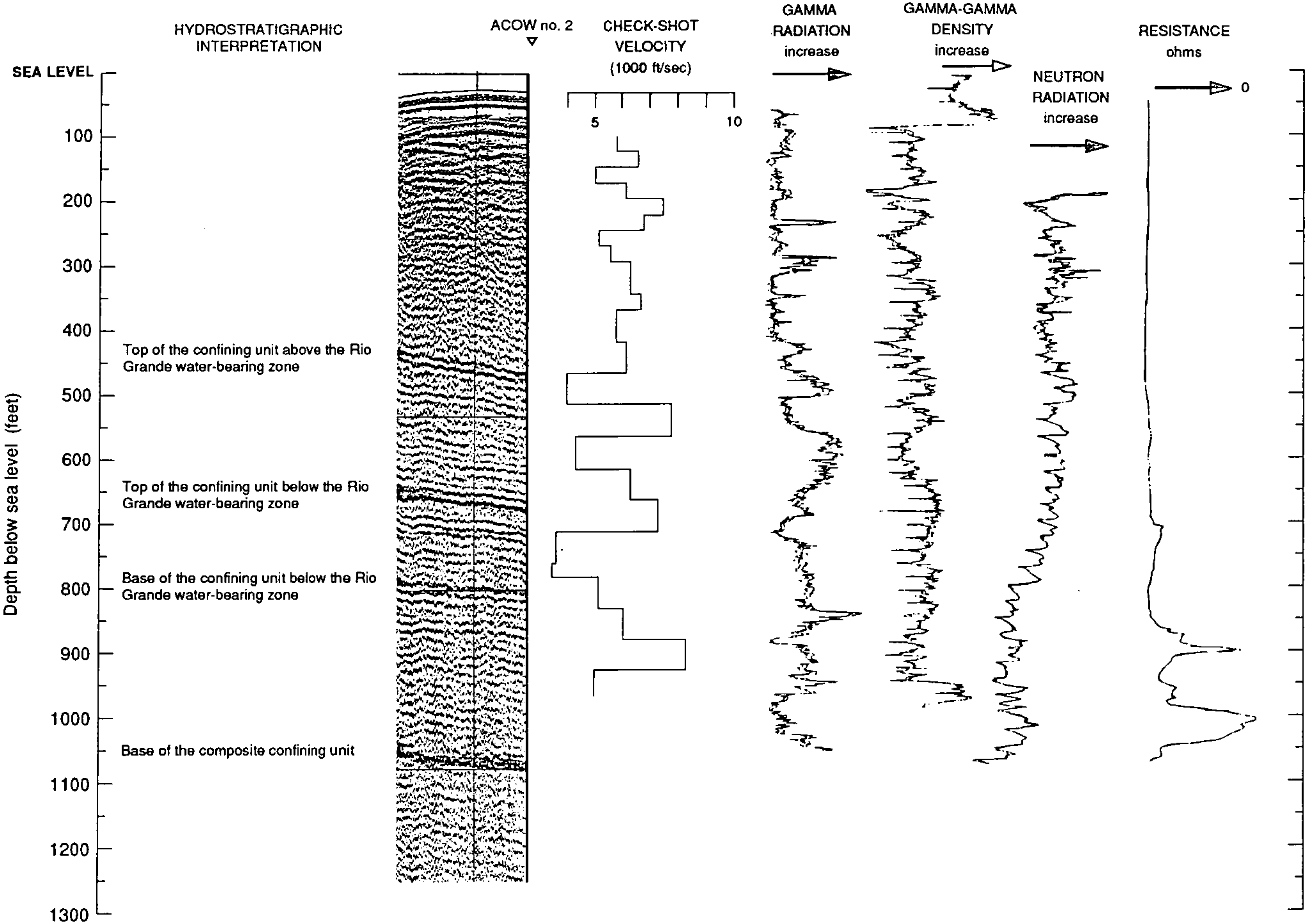

Figure 5. Sample of sparker section (line D) with check-shot velocity histogram and borehole logs for well ACOW no. 2. Exact correlations between the check-shot velocity histogram and borehole logs show apparent shifts which are caused by the greater comparative sampling interval and interval velocity calculations for the velocity data.

Quaternary (table 1). Figure 3 shows four prominent reflectors corresponding to boundaries of some of the hydrogeologic units in the Kirkwood Formation. Borehole gamma-gamma (density) logs from offshore and onshore wells suggest that most of the Coastal Plain sediments have similar densities. As a result, most of the reflectors are due to velocity contrasts (which correlate directly with the changes in calculated interval velocities), indicative of lithologic change or physical water-bearing characteristics.

Geophysical methods have been used to map areas of the Coastal Plain based on changes in the physical characteristics of hydrogeologic units (Sandberg and others, Geophysical investigation of the Potomac-Raritan-Magothy aquifer system in the northern Coastal Plain of New Jersey; Mullikin and others, Hydrostratigraphy of the Kirkwood Formation, manuscripts on file at the N.J. Geological Survey).

Table 1. Geologic and hydrogeologic units investigated in the Atlantic City marine seismic survey (table modified from New Jersey Geological Survey, 1990).

SYSTEM	SERIES	GEOLOGIC UNIT OR UNITS	LITHOLOGY	AQUIFER NAME OR HYDROGEOLOGIC CHARACTERISTICS
Quaternary	Holocene	alluvial, coastal, marsh and eolian deposits	sand, gravel, silt, mud, and peat	Under water-table conditions at most locations
	Pleistocene	Wisconsinan alluvium, Cape May Formation, colluvium	sand, gravel, silt, clay	
Tertiary	Miocene	Pensauken Formation	sand, clayey silt	
		Bridgeton Formation.		
		Beacon Hill Gravel	gravel, light-colored, quartz, sandy	
		Cohansey Sand	sand, medium to coarse, light-colored, quartz, pebbly; local clay beds	Kirkwood-Cohansey aquifer system
		Kirkwood Formation	sand, very fine to medium, gray and tan, quartz, micaceous; dark-colored diatomaceous clay.	confining unit
				Rio Grande water-bearing zone
				confining unit
				Atlantic City 800-foot sand
Tertiary - Cretaceous	Miocene - Upper Cretaceous	ACGS Beta Unit through Navesink Formation	clayey silt, sand, glauconite sand	composite confining unit (includes Piney Point aquifer)

Table 2. Records of wells used in the Atlantic City marine seismic survey (modified from Mullikin, 1990).

Well number	Permit number	Latitude/ longitude	Owner or name	Elevation (ft)[1]	Depth drilled (ft)[2]	Type of log[3]	Remarks
1	36-5615	N391955 W742507	U.S. Geol. Survey	-32	931	L,G	ACOW no. 1 marine observation well - inshore.
2	36-5972	N391726 W742221	U.S. Geol. Survey	-43	1,025	L,G	ACOW no. 2 marine observation well - offshore.
3	56-70	N392108 W742600	Youngs Ocean Pier	20	2,306	L	
4	36-1084	N392124 W742604	Bally's Park Place, Inc.	7	884	L,G	
5	36-964	N392133 W742522	Resorts International	8	887	L	

[1] **Elevation:** feet above or below sea level as estiamted from U.S.G.S. 7.5-minute quadrangle map (contour interval 10 feet)

[2] **Depth drilled:** feet below land surface or, for wells 1 and 2, below sea floor

[3] **Type of log:** L - Lithologic, G - Borehole geophysical

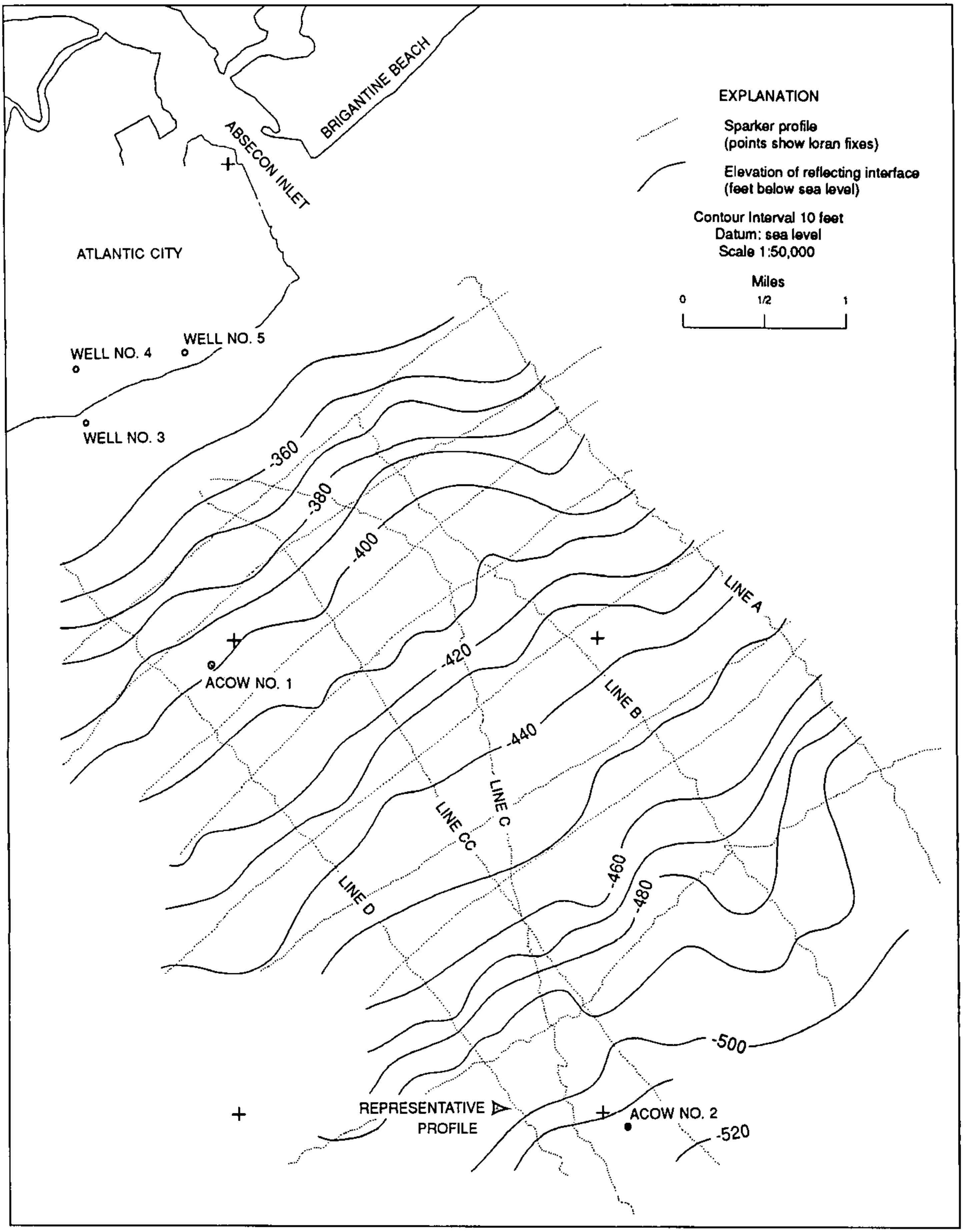

Figure 6. Location of tracklines and elevation of the top of the confining unit above the Rio Grande water-bearing zone in the Kirkwood Formation, based on interpretation of sparker profiles.

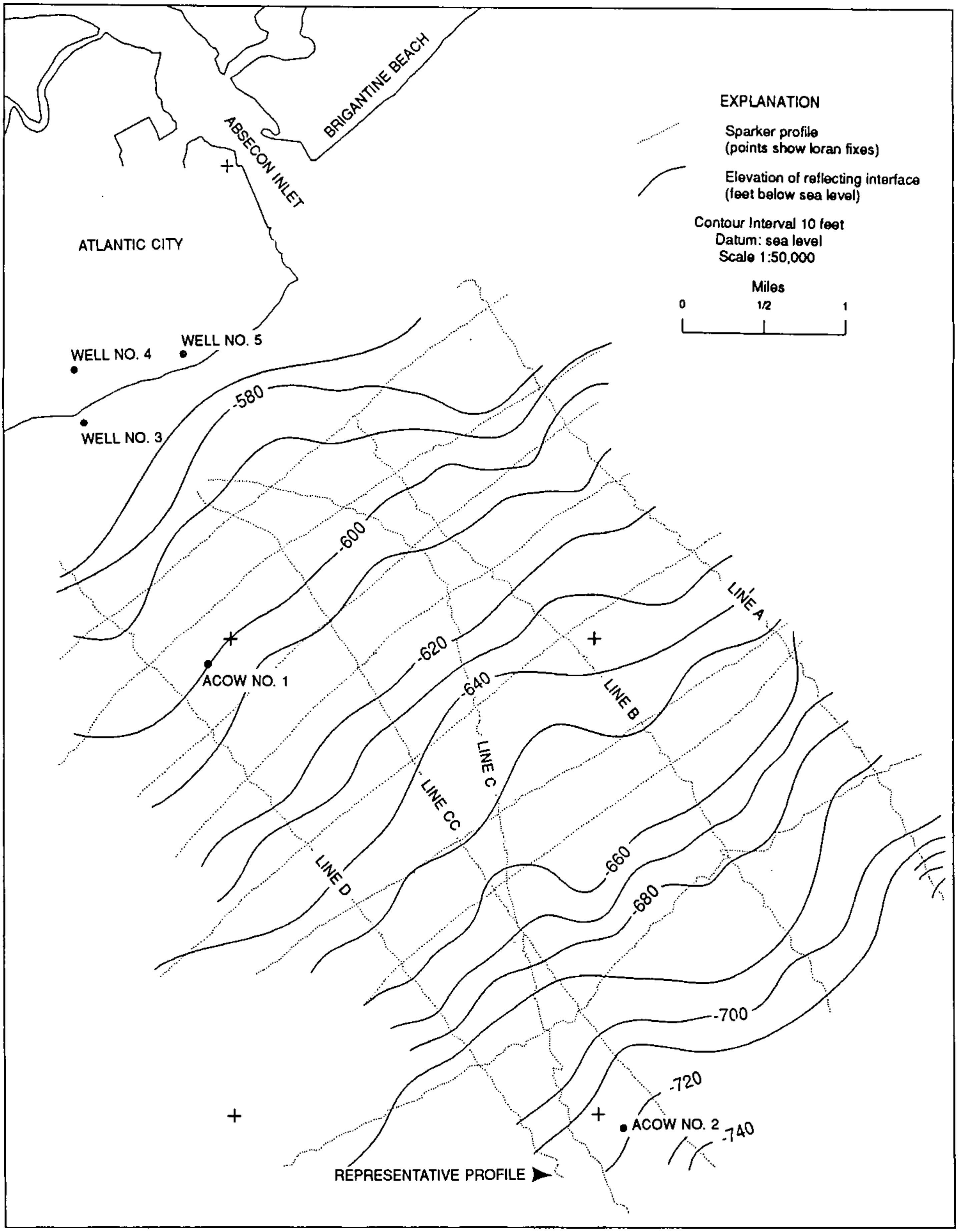

Figure 7. Location of tracklines and elevation of the top of the confining unit below the Rio Grande water-bearing zone in the Kirkwood Formation, based on interpretation of sparker profiles.

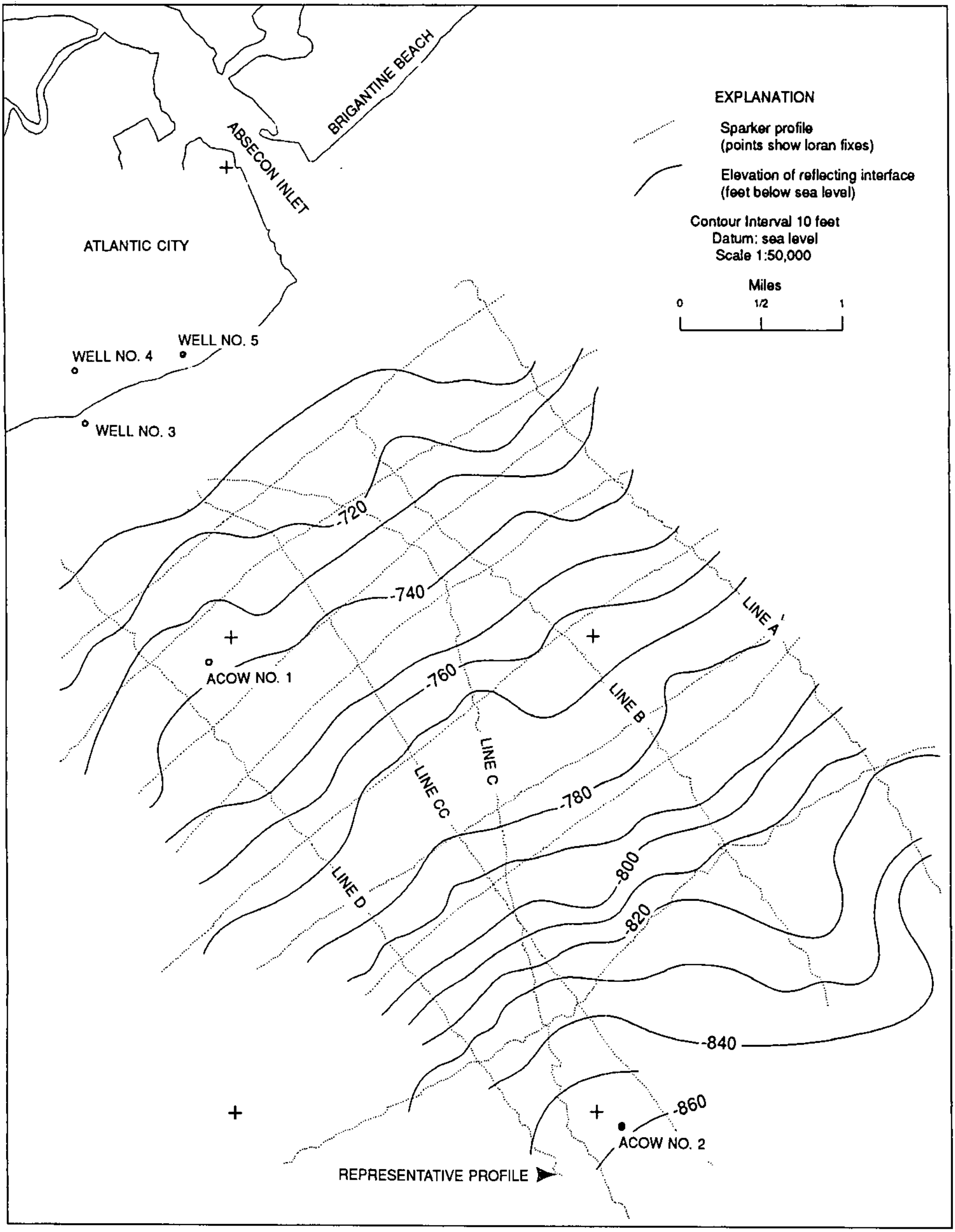

Figure 8. Location of tracklines and elevation of the base of the confining unit below the Rio Grande water-bearing zone in the Kirkwood Formation. based on interpretation of sparker profiles.

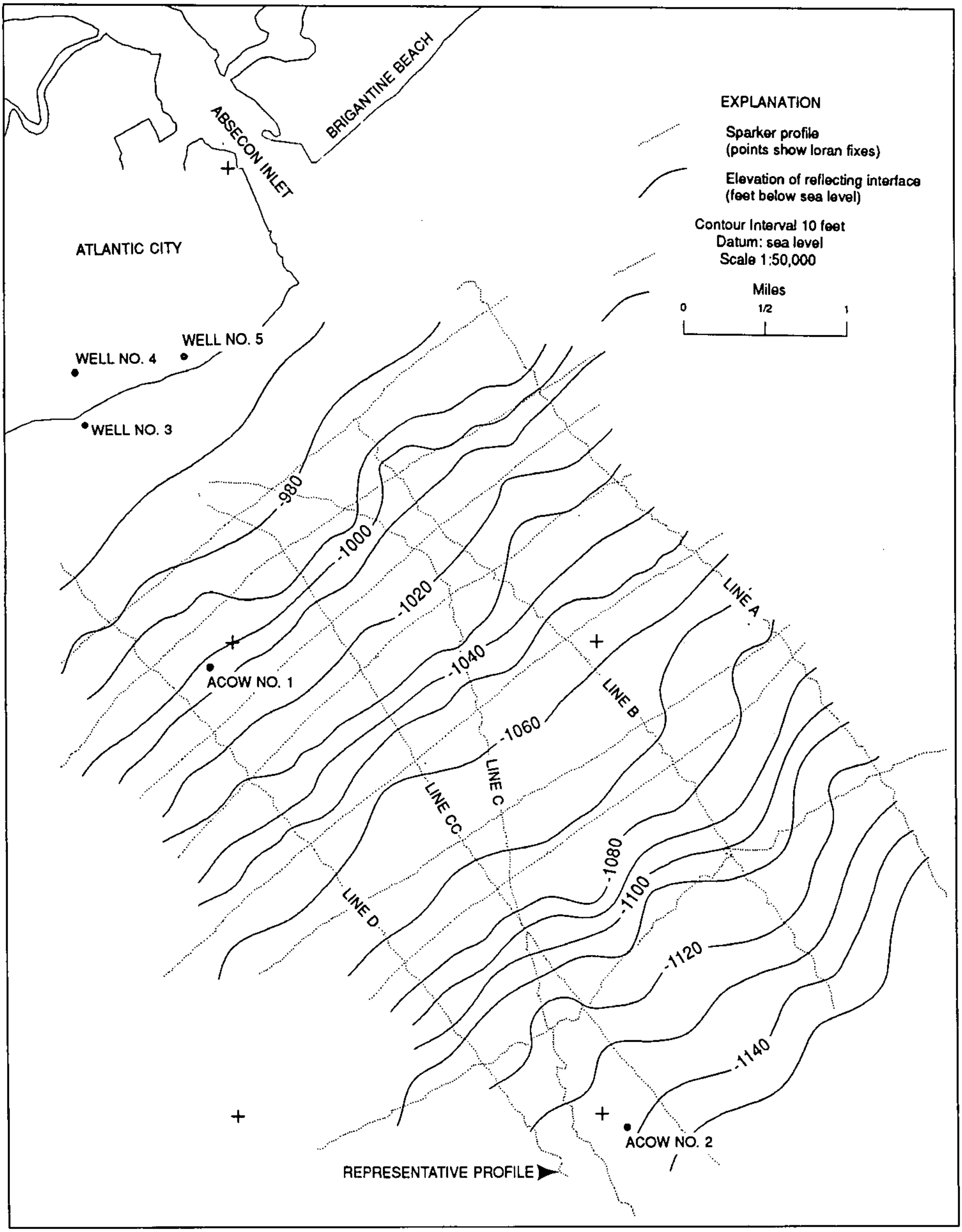

Figure 9. Location of tracklines and elevation of the base of the composite confining unit, based on interpretation of sparker profiles.

The two monitoring wells, ACOW no. 1 (1 mile offshore) and ACOW no. 2 (5 miles offshore), were drilled in July 1985 off the coast of Atlantic City (table 2), and are located within the geophysical survey grid (figs. 6-9). The N. J. District office of the U. S. Geological Survey, Water Resources Division, collected several different geophysical borehole measurements in these offshore wells, including check-shot velocity data. The check-shot measurements were reduced and interval velocity histograms were projected to the nearest seismic profile, line D (figs. 4 and 5). For this representative profile (figs. 3-5), the time values from the seismic profile have been converted to an approximate depth scale based on the average velocity to the deepest (fourth) reflector.

Depth to the fourth reflecting interface was calculated using data from onshore wells and from inland reflection velocity surveys. Well no. 3 was the only well to penetrate a tightly-packed glauconitic sand below the fourth reflecting interface at the top of basal clay unit. The two offshore wells did not extend to the depth of the fourth reflector, and so an exact offshore interval velocity could not be determined.

Four hydrogeologic interfaces are identified by the four reflectors. As shown by sparker profile D (fig. 3), these are, from the top down: 1) the top of the confining unit above the Rio Grande water-bearing zone of the Kirkwood Formation, 2) the top of the confining unit below the Rio Grande water-bearing zone of the Kirkwood Formation, 3) the base of the confining unit below the Rio Grande water-bearing zone of the Kirkwood Formation, and 4) the base of the composite confining unit (table 1).

Calculated depths from average velocities were used to construct contour maps of the four reflecting interfaces (figs. 6-9). The maps show that the Kirkwood units continue the southeastward regional dip of about 30 feet per mile, and generally thicken seaward. The correlation of these offshore hydrogeologic units with the land-based stratigraphy is incorporated into "Hydrostratigraphy of the Kirkwood Formation" (Mullikin and others, manuscript on file at the N. J. Geological Survey).

Each of the four reflecting interfaces is stratigraphically continuous throughout the survey area. Several zones along the reflection profiles, however, show discontinuous data indicating areas of attenuated seismic energy. These attenuation zones may be attributed to near-surface, locally thick, organic-rich sediments. Elliott and Wiley (1975) interpreted attenuation zones (bright spots) as zones of possible gas-saturated sediments of organic or other origin. The subbottom erosional features shown on the shallow profiles are inferred to be buried channels which may contain organic-rich strata.

Boomer data

The boomer data indicated two prominent geologic features: 1) sand ridges and 2) subbottom, lens-shaped features (fig. 10) interpreted to be erosional surfaces of shallow channels (fig. 11).

Sand ridges

The ridges are sea-floor features similar to others along the Atlantic inner continental shelf. A continuous, northeast-trending sand ridge extends across the area of the survey grid, somewhat parallel to the present-day shoreline (fig. 11). A smaller, bifurcating ridge lies in the southeastern corner of the area. The deposition of offshore sand ridges has been studied for offshore Delaware (Moody, 1964; Sheridan and others, 1974); for offshore New Jersey (Stubblefield and others, 1983; Swift and others, 1984; Charlesworth, 1968; Miller and Dill, 1973; Stahl and others, 1974) and regionally along the northeastern U. S. coast (Schlee, 1973; Swift and others, 1973).

Subbottom erosional surface

The transducer profiles show buried channels (fig. 11). Vibracores from comparable channels, 15 miles north of the study area, consist of organic-matter-rich sand and clay overlying gravelly sand (Miller and Dill, 1973). Similar channels were also studied in Delaware Bay (Knebel and Circe, 1988) and offshore Delaware (Sheridan and others, 1974).

CONCLUSIONS

A grid of seismic data was collected off the coast of Atlantic City, N. J. Sparker records profiling to depths of 1,800 feet confirmed that major lithologic units within the Kirkwood Formation are continuous offshore and that they thicken and maintain the regional dip. The shallow boomer records show lens-shaped features, interpreted to be buried channels, and two sand ridges.

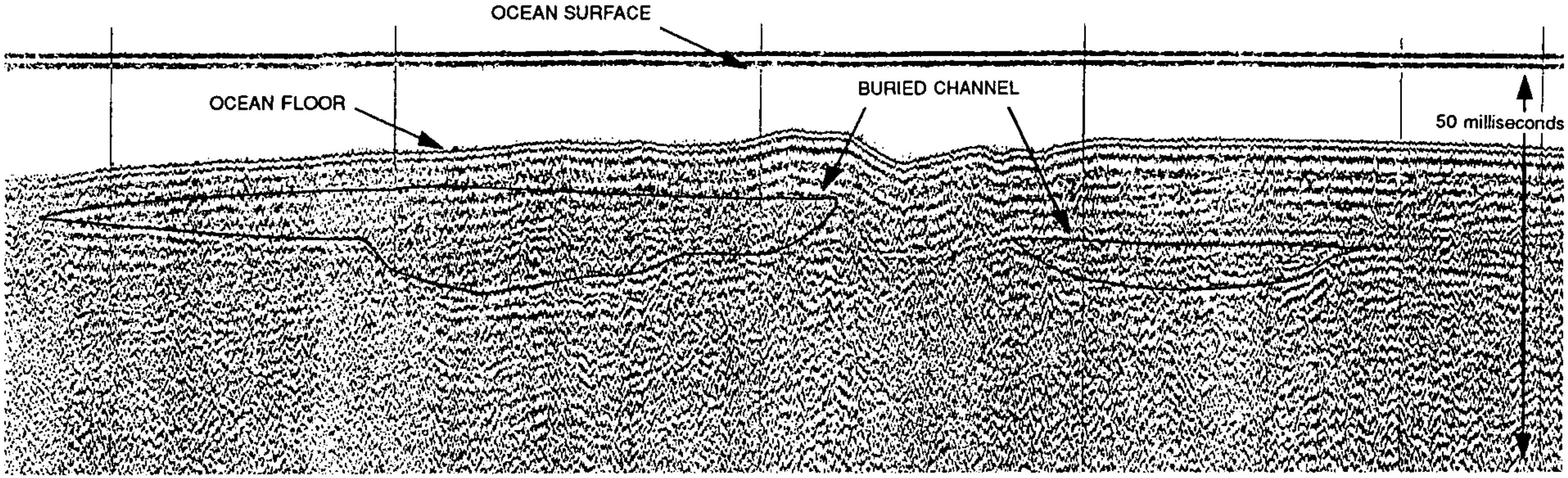

Figure 10. Representative shallow-penetration (boomer energy source) section approximately on-strike showing analog profile data with geophysical interpretation of buried channel features. Horizontal scale 1:25000.

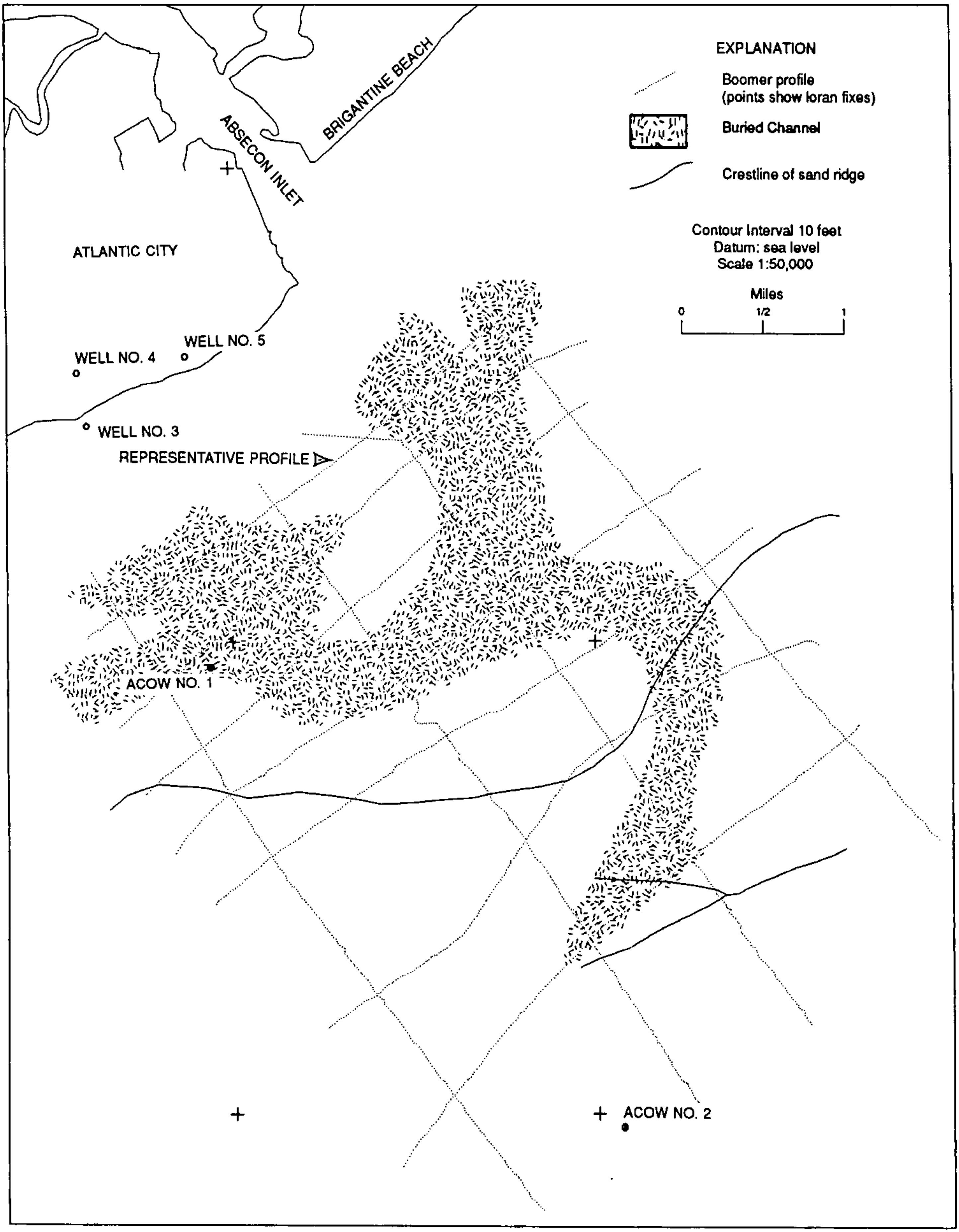

Figure 11. Boomer subbottom interpretation showing location of buried channel and axes of sand ridges.

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GLOSSARY

Boomer: A marine seismic energy source in which capacitors are charged to high voltage and then discharged through a transducer in the water. The transducer consists of a flat coil with a spring-loaded aluminum plate (or plates). Currents force the plates to separate sharply, producing a low pressure region between plates into which the water rushes, generating a pressure wave by implosion.

Dip: The angle at which a structural surface is inclined from the horizontal. The dip is at a right angle to the strike.

Gain: The change in the ratio of output voltage to input, using an amplifier to compensate for variations in input-signal strength.

Gamma-gamma (density) log: A well log which records the formation density. The logging tool consists of a gamma-ray source and a detector so shielded that it records backscattered gamma rays from the formation.

Gamma ray log: A well log which records the natural radioactivity.

Geopulse, see Boomer

High-resolution recording: The recording of seismic frequencies above the normal exploration range with the objective of improving resolution, especially of shallow events. Modifications to data-acquisition parameters must be considered in order to enhance the high-resolution data quality.

Hydrophone: An electroacoustic transducer that responds to sound transmitted through water.

Hydrostratigraphic: Referring to stratigraphic phenomena defined on hydrogeologic characteristics.

Interval velocity: Seismic-wave velocity measured over a depth interval. Commonly refers to compressional velocity and generally implies measurement perpendicular to the bedding. It also may be used for velocity calculated by an equation developed by Dix (1955) which relates interval velocities to root-mean-square velocities.

Loran (long-range navigation): One of several government-maintained, long-range, pulse-type electronic positioning systems. Hyperbolic lines of position are determined by measuring the difference in the time of reception of synchronized pulse signals from fixed transmitters at known geographic positions. A mobile receiver times the differences between the arrivals of these pulses to give a hyperbolic line of position.

Profile: A drawing showing a vertical section of the earth along a line.

Profiler: A marine seismic reflection system usually involving a seismic energy source, such as the sparker, and one or two hydrophone groups. Sometimes the only record is produced by a single-channel plotter on electrosensitive paper. The data may also be recorded in reproducible form (generally on magnetic tape) so that subsequently they can be processed.

Real time: Processing of data at the same rate at which it is recorded.

Reflection coefficient: The ratio of the amplitude of the displacement of a reflected wave to that of the incident wave.

Reflector: The energy or wave from a shot or other seismic source which has been reflected from an acoustic-impedance contrast (reflector), or series of contrasts, within the earth.

Sand ridge: Any low ridge of sand formed at some distance from the shore, and that is either submerged or emergent.

Seismic trace: A record of one seismic channel.

Sparker: A seismic source in which an electrical discharge in water is the energy source.

Strike: The bearing of the outcrop of an inclined bed or structure on a level surface; the direction or bearing of a horizontal line in the plane of an inclined stratum, joint, fault, cleavage plane, or other structural plane. It is perpendicular to the direction of dip.

Subbottom: Term used to indicate the limited depth-penetration capabilities of a unit of geophysical equipment; for example, a boomer is often referred to as a subbottom profiler due to its limiting source-energy potential.

Time-variant: An operation in which the parameters vary with record time, as in "time-variant gain."

Variable-density: A method of displaying the seismic recording in which the photographic density is proportional to the signal amplitude.

Vibracore: A method of coring soft sediment by driving a coring pipe into it by pneumatic action. The Vibracore has a penetrating capability of 20-40 feet for most cores and a 50-foot capability for selected regional cores.

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