CONTINUOUS SEISMIC REFLECTION PROFILING OF HYDROGEOLOGIC FEATURES BENEATH NEW RIVER, CAMP LEJEUNE, NORTH CAROLINA

By Alex P. Cardinell, Douglas A. Harned, and Steven A. Berg

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 89-4195

Prepared in cooperation with the

DEPARTMENT OF THE NAVY, U.S. MARINE CORPS

Raleigh, North Carolina

1990

DEPARTMENT OF THE INTERIOR

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U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS

The following factors may be used to convert the U.S. customary units published in this report to the International System of Units (SI).

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Velocity	
foot per second (ft/s)	.3048	meter per second (m/s)
mile per hour (mi/hr)	1.6093	kilometer per hour (km/hr)
	Energy	
British thermal unit, International Table (BTU_{IT})	1,055.1	joule (J)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

Continuous seismic reflection profiling of the New River within the Camp Lejeune Marine Corps Base was conducted to collect data for use in describing the structural and depositional setting of the surficial and Castle Hayne aquifers and other hydrogeologic units underlying the New River. The Castle Hayne aquifer serves as the prinicipal water supply for the Base.

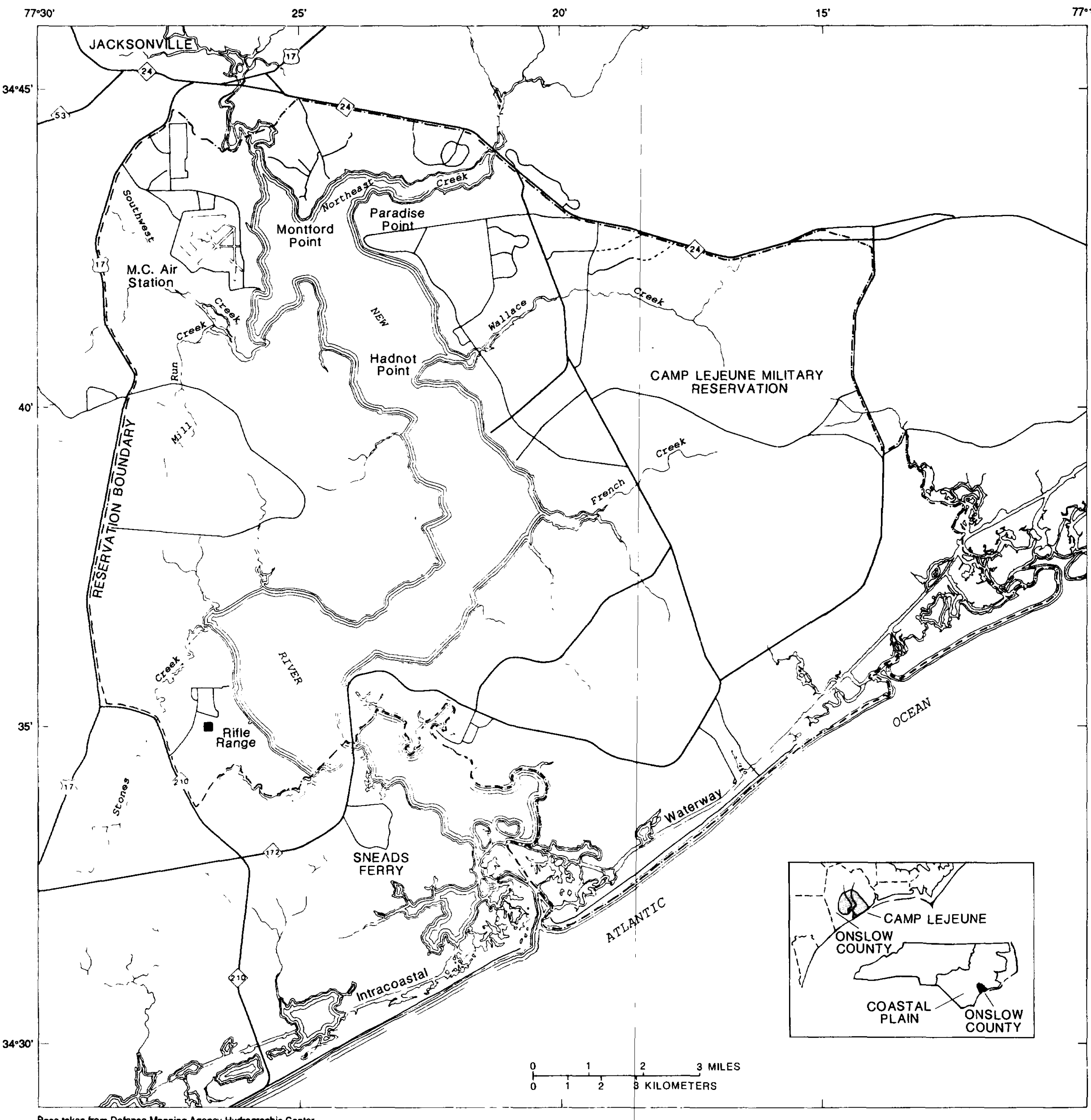
A medium-power, wide-frequency seismic system was used to collect more than 100 miles of continuous single-channel, shallow-water seismic reflection records in the study area over a 4-day period in December 1987. Positioning of the seismic boat was controlled by an onboard integrated navigation system throughout the survey. LORAN C and Global Positioning Systems were integrated to plot position during the profiling.

The Castle Hayne aquifer and deeper aquifers show continuous reflectors throughout the study reach and gently dip to the southeast. There is no evidence of faulting across the New River. The younger, shallower reflectors generally are undifferentiated and lack the lateral continuity of the underlying older reflectors.

Paleochannels of Quaternary and Tertiary age were found at several locations and depths in the New River. If paleochannels filled with permeable material exist beneath the present land surface, these features could act as conduits for ground-water flow or movement of contaminants between the surficial and Castle Hayne aquifers.

INTRODUCTION

Camp Lejeune Marine Corps Base is located in Onslow County, in the Coastal Plain of North Carolina (fig. 1). The Base presently (1988) covers



Base taken from Defense Mapping Agency Hydrographic Center, Camp Lejeune Special Map, 1 50,000

Figure 1.--Camp Lejeune Marine Corps Base and the New River study area.

an area of 164 square miles (mi^2), including 30 mi^2 of the New River estuary, which bisects the Base. The total military and civilian population of the Base is about 68,000 people.

Since Camp Lejeune was first opened in the late 1930's, freshwater has been supplied from wells that tap sands and limestone between about 50 and 300 feet (ft) below land surface. Over the years, as the Base's functions and population have grown, more than 100 wells have been drilled and operated to satisfy increasing demands for water. In 1986, ground-water withdrawals ranked among the largest in the State and were estimated at 7.5 million gallons per day (Mgal/d) (Harned and Lloyd, 1988).

An increase in the amount of waste generated by Base operations has accompanied the growth of the Base (Putnam, 1983). As a result, significant amounts of wastes containing hazardous compounds have been disposed of or spilled on the Base. Most of the disposal and spill sites are underlain by sand and lack barriers to prevent downward movement of waste to the water table and into the ground-water system. Consequently, some wastes have contaminated the ground water locally, and hazardous compounds have been detected in several supply wells causing them to be abandoned.

In addition to the threat of contamination from waste-disposal sites, saltwater that occurs in the tidal reaches of the New River, its tributaries, and in the deeper parts of the ground-water system also poses a threat to freshwater parts of the supply aquifer. Lowered hydraulic heads around wells located near the saltwater may induce saltwater flow toward the wells.

The U.S. Geological Survey, in cooperation with the U.S. Marine Corps, began a 4-year study in May 1986 to describe the ground-water resources of the Marine Corps Base at Camp Lejeune, North Carolina, and to construct a ground-water flow model that can be used to evaluate alternative ground-water management practices. An important step in connection with the flow model is the description and mapping of the sediments that make up the aquifers and confining units in the ground-water system. A description of the hydrogeologic framework of the aquifers will provide a physical basis for estimating the parameters of the ground-water flow model.

Hydrogeologic data are not available for nearly 20 percent of the Base area represented by the New River. In order to obtain data defining the continuity of sediments and structures that lie below the New River, a seismic reflection profile of the river was planned and executed.

Purpose and Scope

This report presents the methodology and results of seismic reflection profiling of the New River area. More than 100 miles of seismic reflection profiles were collected in the New River and parts of the Intracoastal Waterway. A review of methodology and equipment used is followed by data interpretation, which consists primarily of presentation of selected examples of subsurface features and their hydrologic implications. Five seismic profile segments are used to show examples of the new information on the continuity and structure of the Castle Hayne aquifer and the other sediments that underlie the New River. The seismic data obtained will be useful for the construction and interpretation of the hydrogeologic framework of the Camp Lejeune area.

Hydrogeologic Setting

The sedimentary Coastal Plain aquifers and attendant confining units consist of interbedded sands, clays, calcareous clays, shell beds, sandstone, and limestone (LeGrand, 1959; Winner and Coble, 1989). They are layered, interfingering beds and lenses that locally gently dip and thicken to the southeast. In North Carolina, they thicken from zero at the western boundary of the Coastal Plain province to more than 10,000 ft (Winner and Coble, 1989). In the Camp Lejeune area, the sedimentary sequence is about 1,500 ft thick and overlays igneous or metamorphic basement rocks. These sediments were deposited in marine or near shore environments. The Castle Hayne aquifer and the surficial aquifer are the principal aquifers for the water supply of Camp Lejeune. Locally, the strike of these beds in the Camp Lejeune area is N 79° E, and the dip is 17 feet per mile (ft/mi) to the southeast.

The surficial aquifer is composed of a series of sediments, primarily sands and thin, discontinuous clays, that overlie the Castle Hayne. These deposits are post-Miocene in age and range from 50 to 100 ft thick. The surficial aquifer is not used directly for water supply and is reported to have areas contaminated by waste disposal, particularly in the northern and north-central parts of the Base (Putnam, 1983).

The Castle Hayne aquifer is composed of a series of sand, limestone, and clay beds that are in the Oligocene River Bend Formation and the middle Eocene Castle Hayne Formation. Supply wells tap the upper part of this aquifer between a depth of 50 and 300 ft. The Castle Hayne aquifer ranges in thickness from about 250 ft in the northern part of the Base to about 400 ft in the southeastern part. This aquifer is the most productive in North Carolina (Coble and others, 1985) and is a critical water-supply source for the southern coast and east-central Coastal Plain. Onslow County and Camp Lejeune lie within the area where this aquifer contains freshwater suitable for water supply; however, the proximity of saltwater in the New River estuary and in the aquifers that lie below the Castle Hayne is of concern in managing local withdrawals from the aquifer.

The Beaufort aquifer lies below the Castle Hayne aquifer and consists of a sequence of sediments that are primarily sands and thin clays. These sediments are in the Paleocene Beaufort Formation and range in thickness from a few feet in the southwestern part of the Base to as much as 100 ft in the easternmost part. This aquifer may contain saltwater in the southern and eastern parts of the area. The descending sequence of Peedee, Black Creek, and upper and lower Cape Fear aquifers, which lie below the Beaufort aquifer, are composed of sediments in the Cretaceous Peedee, Black Creek, and Cape Fear Formations. The aquifers in rocks of Cretaceous age are the most widely used for water supply in the Coastal Plain; however, in the Camp Lejeune area, they contain saltwater.

New River Setting

The New River estuary is approximately 30 mi^2 in area or about 20 percent of the total Base area and splits the Base into two parts. The river is shallow, with depths ranging from 2 to 5 ft in most areas to a maximum of about 15 ft. The central channel of the river has been dredged to allow navigation by boats. Tidal currents deposit soft sediments and organic mud in the deeper parts of the estuary and at the mouths of several tributaries. Because the sediment layers of interest are at relatively shallow depths and the New River is shallow and a relatively sheltered basin from most ocean storms, the area is well suited for a shallow seismic reflection profile.

Acknowledgments

Robert Alexander of Staff Facilities at Camp Lejeune served as the principal liaison between staff on the Marine Base and the U.S. Geological Survey.

John West of the U.S. Geological Survey, Geologic Division, Denver, Colorado, provided technical assistance in setting up and operating the seismic reflection profiling equipment.

Ned Lassiter of Navigation Management, Inc.[1], provided and captained a boat built specifically for use in making shallow seismic profiles. The boat was equipped with a state-of-the-art navigation system.

Gunnery Sergeant L.E. Hawse, Boson's Mate Second Class Robert Hamil, and Chief Boson's Mate V.R. Caudill of Range Control at Camp Lejeune helped to coordinate our survey efforts.

SEISMIC REFLECTION PROFILING

Continuous marine seismic reflection profiling provides a means for studying the structure of rocks and sediments beneath the floor of water-covered areas and is limited to water bodies. The continuous single-channel, seismic reflection profiling system used for this study provided virtually continuous record of reflected seismic echoes in the upper 300 ft of sediment. Poorer quality data was obtained to depths of about 600 ft.

Principles of Seismic Reflection Profiling

The hydrogeologic system beneath Camp Lejeune is a multi-layered medium with nearly horizontal layering. Because individual layers with different

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[1] Use of brand/firm/trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

lithologies have different velocity and density contrasts, part of the seismic wave front generated by an acoustic source will be reflected back from each layer interface. The number of interfaces reflecting energy to the surface and the strength of the returned echo depend on the power and frequency spectrum of the source, the velocity-density contrast at the interfaces, and scattering, spreading, and absorption losses within the medium itself. Horizontal resolution is determined by firing rate, vertical resolution by the returned frequency, and depth by source type and strength.

The reflection produced by a layered boundary is a function of the acoustic impedance. Both unconsolidated and consolidated units within the section have different densities (d) and sound wave propagation speeds (v). Each medium is characterized by its acoustic impedance (z), which is the product of density of the medium multiplied by the velocity of the sound wave through it:

$$z = dv. \tag{1}$$

The amount of energy reflected depends on the contrast in acoustic impedance on both sides of an interface and is defined by the reflection coefficient (R):

$$R = \frac{d_2 \, v_2 - d_1 \, v_1}{d_2 \, v_2 + d_1 \, v_1} \,, \tag{2}$$

where:

d_1 and d_2 and v_1 and v_2 are densities and propagation speeds (acoustic velocities), respectively, of adjacent layers or statigraphic units.

Reflection coefficients of typical geologic boundaries are presented in table 1.

The necessary quality, extent, and resolution of continuous seismic reflection recording depend on the purpose of the study. Degrading factors within the medium are dispersion, selective frequency filtering in sediments and rocks, attenuation, especially by soft and/or gassy sediments, side echoes, multiples, and scattering. Other factors include limitations and nonlinearity of the amplifiers and filters, signal to noise ratio of the cable used, the quality of the acoustic signal, and the response of the hydrophones.

Table 1.--*Reflection coefficients (R) of typical geologic boundaries* (from Sylwester, 1983)

Geologic boundary	R
Water-sand	0.3 -0.4
Water-limestone	.5
Water-clay/silt	.1 - .2
Water-mud	.05- .1
Water-air	-1
Mud-clay/silt	.1
Clay-sand	.1
Sand-limestone	.2
Clay-limestone	.3
Sand-granite	.4

The boat is equipped with either a hull-mounted or towed sound source that pulses at regular intervals as the boat travels along a selected course. A receiver (hydrophone) or groups of receivers (streamer cables) towed behind the boat pick up the reflected echoes. The relation of the acoustic paths (ray paths) to the acoustic source, reflecting surfaces, and hydrophones are shown in figure 2. The depth to a reflector can be computed if the velocity of the wave front is known. The end result is a time section, which represents the two-way travel time of the seismic wave front from the sound source to a reflector and back to the hydrophones placed in the streamer cables. This time section provides continuous representation of the reflectors beneath the vessel. A more detailed discussion of the principles of seismic reflection profiling can be found in Dobrin (1976), Telford and others (1976), and Sylwester (1983).

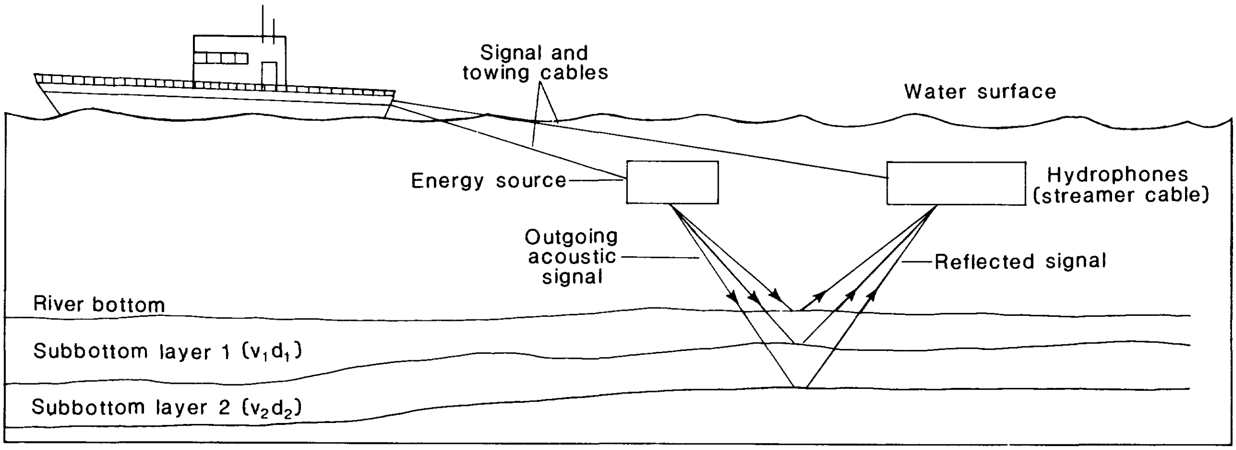


Figure 2.--Ray paths from acoustic source to hydrophones for single-channel seismic profiling.

Selection and Use of Continuous Seismic Reflection Profiling Equipment

Very little was known about the lithologic or acoustical properties of the New River bottom sediments. Tidal currents move up the New River estuary daily depositing fine grained sediments and organic mud. Available U.S. Geological Survey quadrangle maps indicated that parts of the New River channel and Intracoastal Waterway had been dredged and the material was placed in nearby sections of the New River. Consequently, there was the possibility that the combination of shallow water and the unknown acoustic properties of the river bottom might reduce or impede penetration and resolution in some reaches of the river.

In order to determine which of two profiling systems to use, a test profile was run with two different systems: a medium power, wide-frequency system and a low power, low-frequency (400 hertz) system designed for use in areas where sediments are difficult to penetrate. The results indicate that both systems penetrated the river bottom except where soft river bottom sediments occurred. However, greater vertical resolution was obtained with the medium power, wide-frequency system. The system used is the Geopulse System manufactured by Ferranti Ocean Research Equipment (ORE).

Survey Methodology

Continuous seismic profiling requires (1) a rapid-pulse sound source, (2) a hydrophone or groups of hydrophones (streamer cable) to receive reflected signals, (3) a signal processor to amplify and filter the hydrophone output, and (4) a graphic recorder to record and display the reflection profile. A magnetic tape recording of the raw, unfiltered signal is usually made for subsequent analysis. A navagation system should be used for accurate position location. A diagram of a typical seismic profiling system is shown in figure 3.

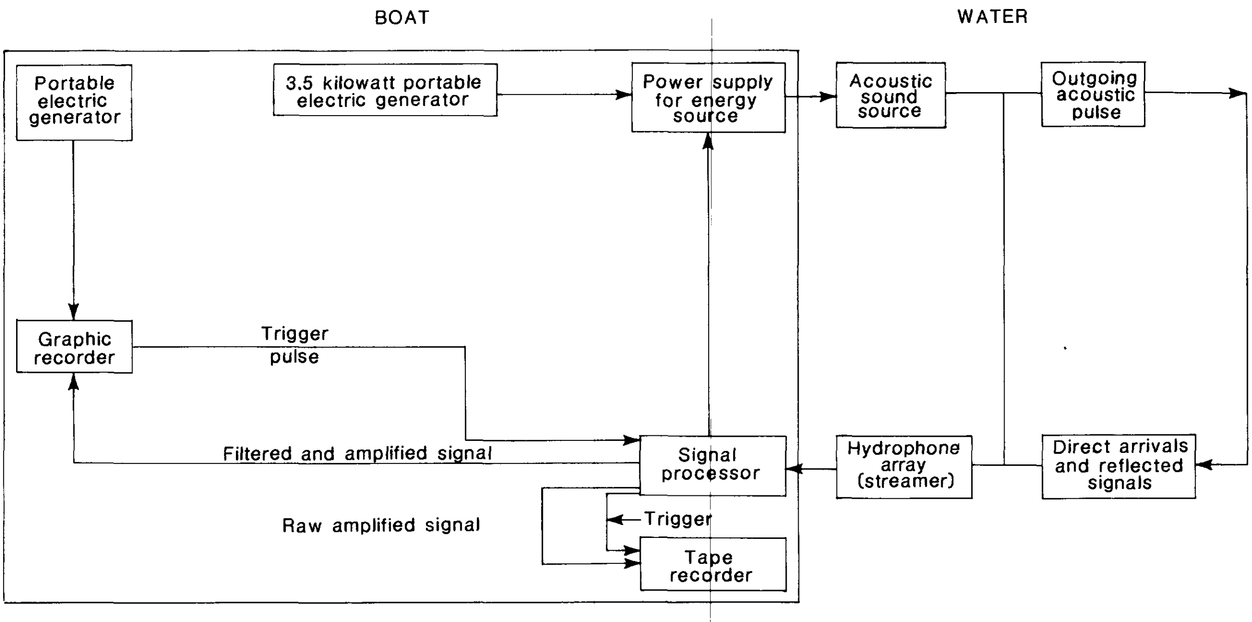


Figure 3.--Main components of high-resolution continuous seismic reflection system.

The survey was conducted along a 25-mile stretch of the New River and Intracoastal Waterway using a 24-foot barge boat equipped with a shipboard navigation system (fig. 4). The acoustic-source catamaran (fig. 5) and the hydrophone array placed within the streamer cable were towed approximately 50 feet behind the boat on opposite sides of the wake, with the catamaran towed even with the midpoint of the hydrophone array. Boat speeds were kept in the 2- to 3-miles per hour range while profiling.

Figure 4.--Barge boat used for seismic profiling.

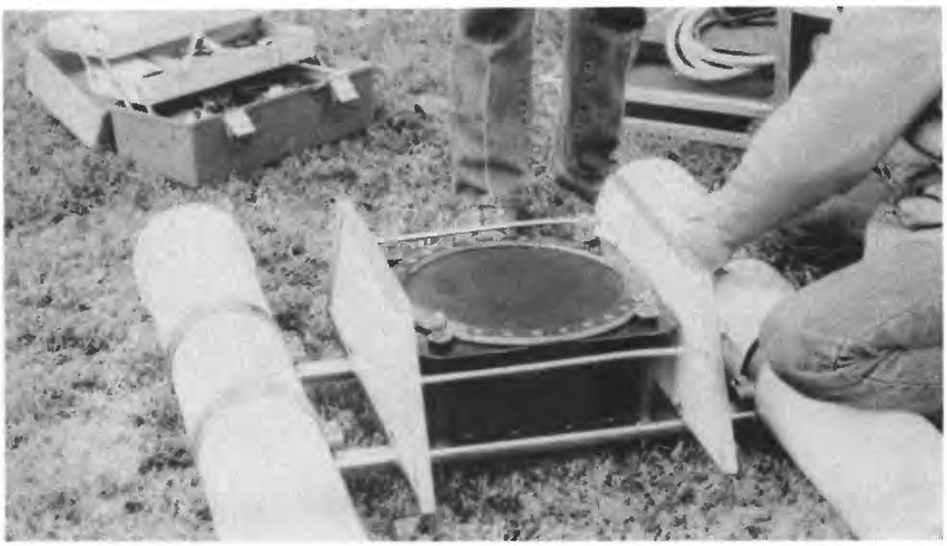


Figure 5.--The acoustic-source catamaran.

The sweep rate (recording time between trigger pulses) was set at 200 milliseconds (ms) and the repetition rate (firing rate) of the sound source at 400 ms at a power setting of 280 joules (J) for most of the survey. In one segment of the Intracoastal Waterway, a 100-ms sweep rate and a 200-ms repetition rate at a power setting of 105 J was used for a shallow penetration survey.

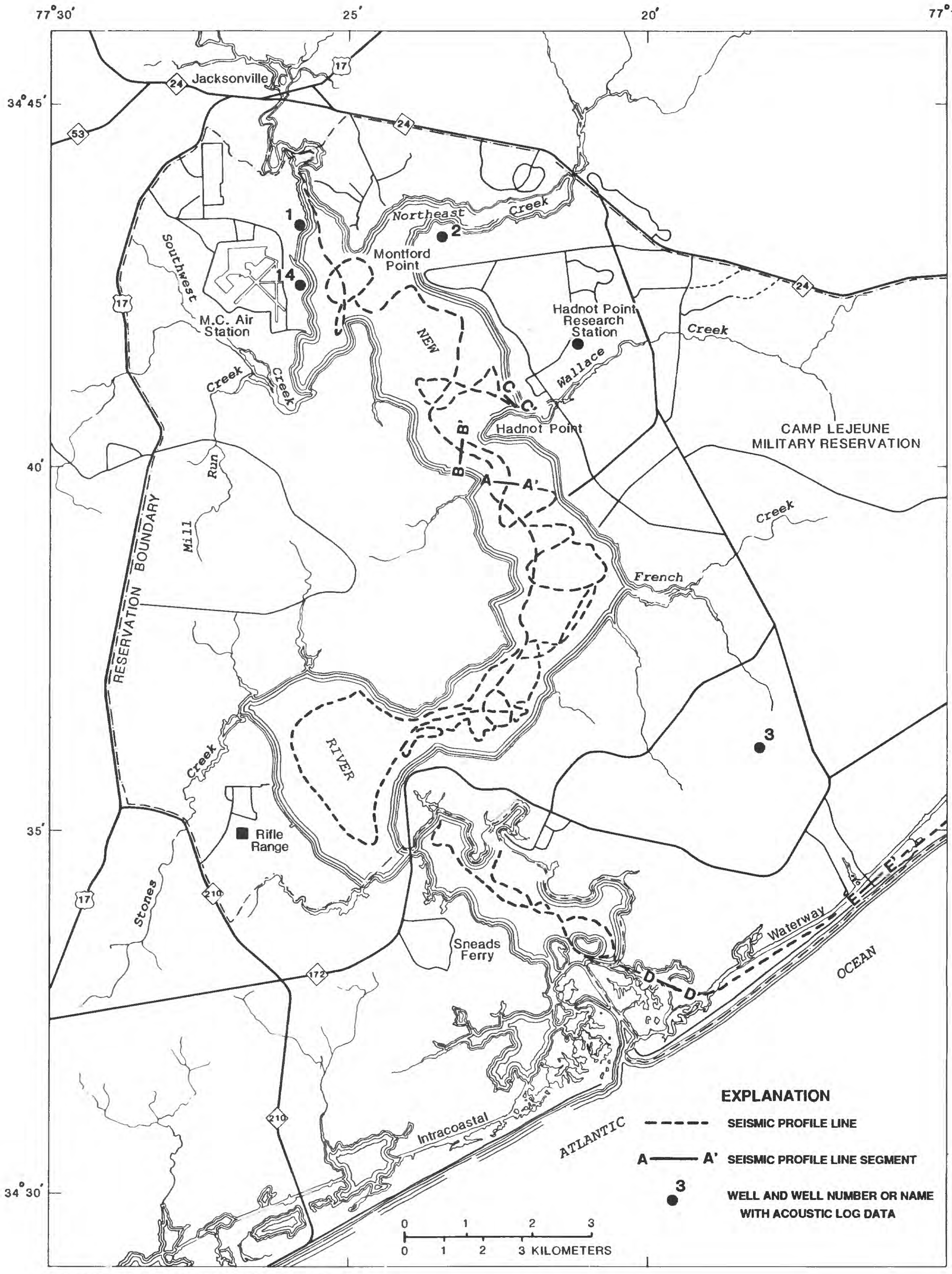
Positioning during the survey was accomplished with an integrated navigation system that uses LORAN C, Global Positioning System, and dead reckoning. Navigation fix marks were automatically placed on the seismic records at set intervals of time, generally every 60 seconds.

More than 100 miles of seismic reflection profile data were collected on the New River and Intracoastal Waterway in a 4-day period. It became apparent after the first day of profiling that the acoustic energy pulse was being heavily attenuated by the soft sediments in the central channel. Attenuation of the seismic signal also occurred in a few sections of Stones Bay due to the effects of tidal sediment deposits. Consequently, the survey was redesigned to collect data at locations mostly away from the central channel. The profile lines, shown in figure 6, therefore follow tortuous paths favoring shallow water areas away from the main channel. Profile lines along key geologic sections, however, were collected across the central channel in hopes that data-enhancement procedures during playback of the recorder tapes would improve data quality across these areas.

Tape recordings of seismic data were played back through the preamplifier to the graphic recorder at various filter settings and gain levels in an attempt to enhance the printed record. Generally, the filter setting of the 400 to 1,200 hertz range on the signal processor gave the best combination of resolution and penetration. However, very little improvement of the record was achieved in the central channel areas or other areas where soft sediment caused signal attenuation.

MAPPED HYDROGEOLOGIC FEATURES

The seismic-reflection records represent acoustic cross sections of the underlying sediments of the New River estuary. The vertical axes are scaled in units of time (milliseconds) and represent one-half of the two-way travel time from the source to a reflector and back to the hydrophone array. The



Base taken from Defense Mapping Agency Hydrographic Center,
Camp Lejeune Special Map, 1:50,000

Figure 6.--Location of seismic profile lines and wells with acoustic velocity logs.

horizontal axes represent the distance covered by the seismic survey in a given amount of time. Slopes of river-bottom reflectors and internal structures are exaggerated due to vertical scale exaggeration.

Comparison to Well Data

One of the more difficult tasks in interpreting continuous seismic profile data is obtaining good depth estimates to correlate with available borehole lithologic and geophysical data. Depth estimates can be obtained from either correlating the seismic wavelet character of the reflection records with available borehole (lithologic and geophysical) data or from estimates of acoustic velocity in sediment. Usually a combination of both methods is used to estimate depth. An example of correlation of the seismic records to borehole data at well site 2 is shown in figure 7. The glauconitic limestone layer at 220 ft on the gamma ray log shows up as a strong group of reflectors on the reflection record.

Seismic velocities in sediments are needed to convert two-way travel times to depths of reflectors in the seismic record. Typically, a velocity of 5,000 feet per second (ft/s) is used for shallow-marine unconsolidated sediments. The well-log correlations (Harned and Lloyd, 1988) show mid-Tertiary-age sediments in the Camp Lejeune area being unconformably overlain by younger sediments. The problem in this case is to separate the average seismic velocities of near-surface sediments from the higher velocities of the underlying, older, and more consolidated sediments.

An average sediment velocity estimate of 6,150 ft/s (fig. 8) was made from the first 500 ft of an acoustic velocity log collected at the Hadnot Point Research Station (fig. 6). This well is one of five wells where acoustic velocity logs were collected on the Base. However, the Hadnot Point Research Station well was selected as the key well because it had the most complete lithologic and acoustic velocity log data for the entire sedimentary section of the Base. This key well had complete lithologic and acoustic velocity log data from about 100 ft to 1,520 ft below land surface. The other four wells had some combination of lithologic and acoustic velocity log data below cased depths (50 to 240 ft below land surface), but these wells were much shallower (175 to 240 ft below land surface). The acoustic velocity of sediments in the cased part of all wells (up to 100 ft below land surface in the Hadnot Point Research Station well) were estimated from Dobrin (1976, p. 50).

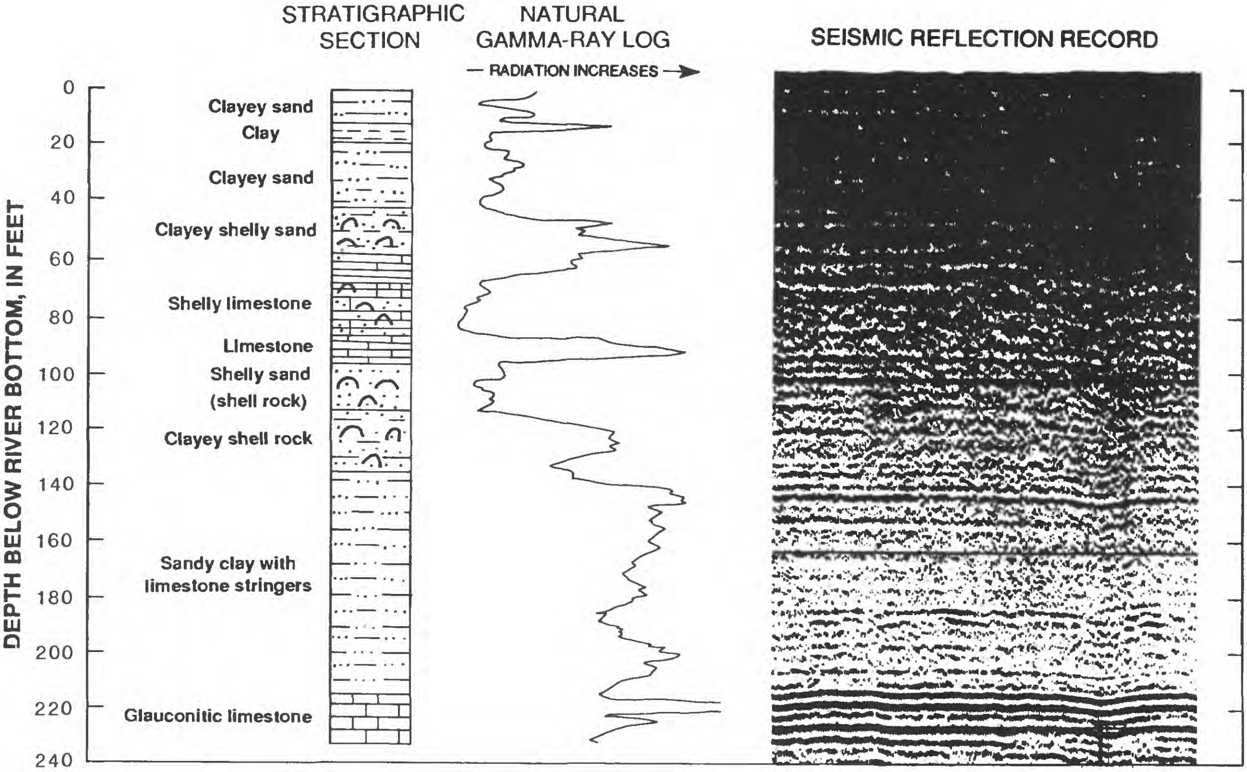


Figure 7.--Well log, stratigraphic, and seismic reflection record correlations made at well site 2.

An average velocity curve was calculated for the Hadnot Point Research Station well using procedures outlined in Dobrin (1976, p. 229-236). Acoustic velocities were determined for 5-ft intervals of the sedimentary section. The determinations were made from the acoustic velocity log and estimates for the upper 100 ft of the section. The average acoustic velocities for the sedimentary sections were calculated by dividing cumulative thickness by cumulative travel time for each 5-ft interval down to a depth of 500 ft below land surface (the estimated thickness of the freshwater section at the Base). Typical interval velocities ranged from about 4,400 ft/s for poorly consolidated sediments to about 9,000 ft/s for well-consolidated sediments. The resultant average velocity values were converted to two-way travel times and plotted against depth. The resultant average velocity curve was compared to a family of depth-acoustic velocity curves with average velocity plots for 5,000 ft/s, 6,000 ft/s, and 7,000 ft/s in figure 8. The calculated values closely match the 6,000 ft/s curve and are in close agreement with the results of other studies (McKinney, 1985).

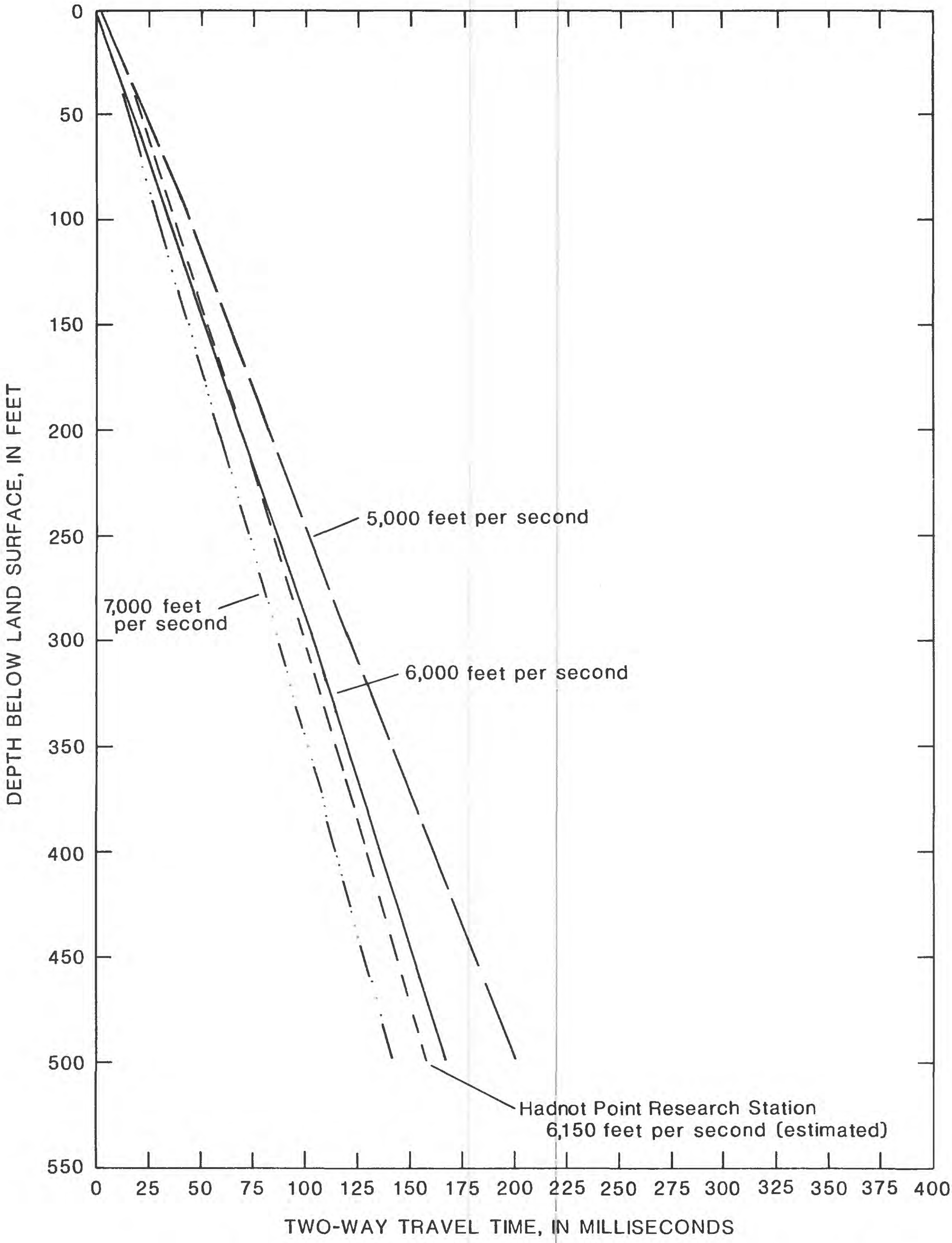


Figure 8.--Average acoustic velocity curve plot for sediment at Hadnot Point Research Station well.

Because the seismic profiling was done in 3 to 15 ft of water with an average acoustic velocity of about 5,000 ft/s, and the estimated average velocity for the first 500 ft of sediment from the research station well was 6,150 ft/s, an average velocity of 6,000 ft/s was selected for the time-to-depth conversion of the seismic reflection records discussed in this report. The seismic wavelet-borehole correlations (fig. 7) match up well with the resultant time-to-depth conversions generated with this 6,000 ft/s sediment velocity estimate.

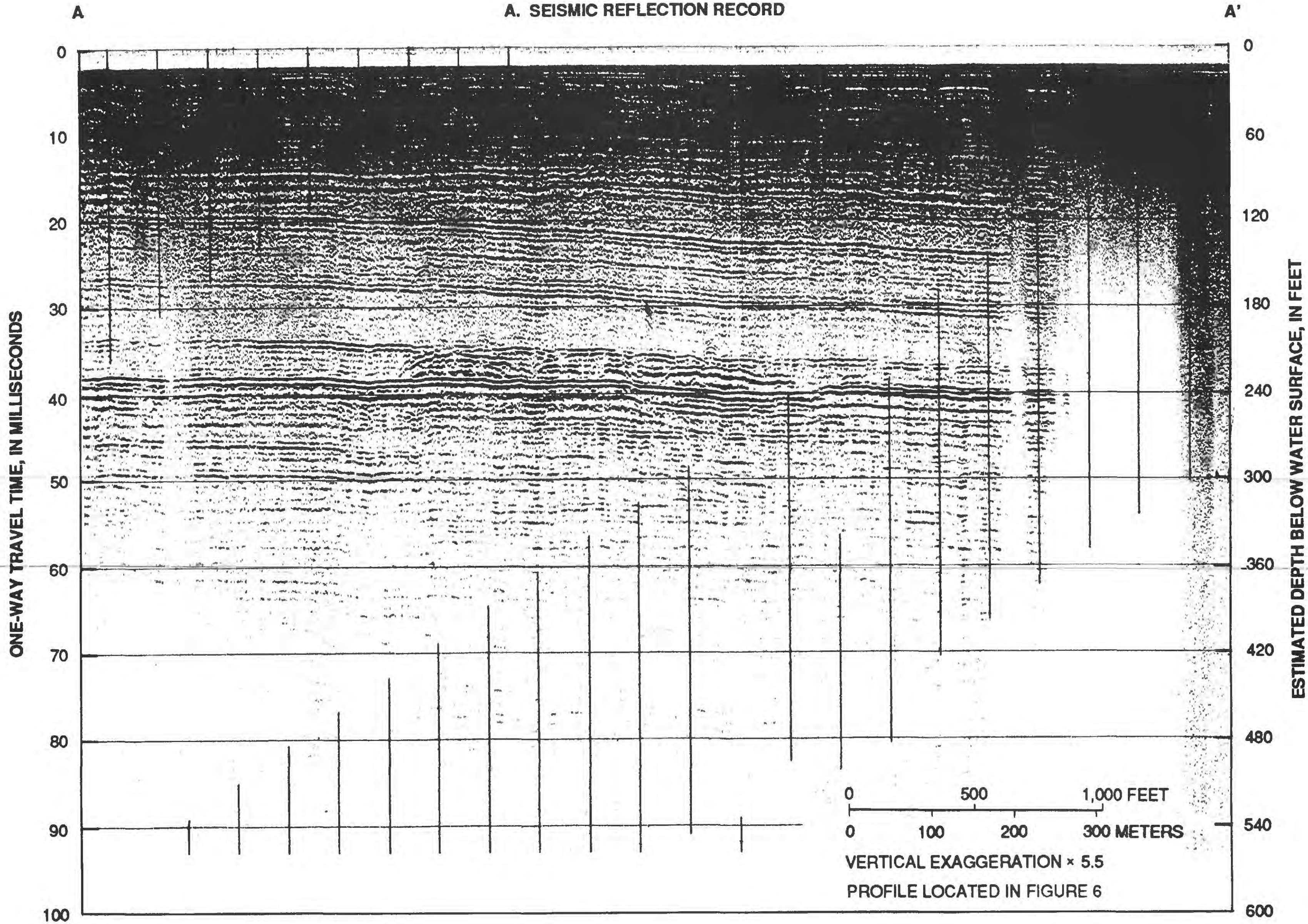
Seismic Reflection Records

Typical of the seismic records collected during the survey is profile segment A-A' shown in figure 9. Figure 9B is the interpretation of the reflection record in figure 9A. The vertical exaggeration is about 6 times the horizontal scale. The first 50 to 60 ft of record consist of discontinuous reflections and probably represent undifferentiated Quaternary sands and clays. The paleochannel identified in the upper part of the seismic record in figure 9B represents an abandoned Quaternary channel that has been subsequently infilled with sediments. The record from about 60 ft to approximately 240 ft represents older Eocene sediments (Harned and Lloyd, 1988), principally the Castle Hayne aquifer. These reflectors are continuous and represent interbedded clays, carbonates, and sands. These beds dip gently to the southeast, generally left to right in figure 9. A small slump feature in these sediments has been identified in figure 9B. This feature was most likely formed by sediment loading, differential subsidence, or a combination of these two mechanisms.

The strong series of reflectors at about 240 ft may represent the boundary between the Castle Hayne aquifer and the underlying Beaufort aquifer. Attenuation of seismic energy with depth makes it difficult to trace deeper reflectors because they are not as strong as the overlying reflectors. However, these deeper reflectors, when traceable, (1) are continuous, gently dipping to the east, (2) show no evidence of bed offset due to faulting, and (3) may represent Paleocene and latest Upper Cretaceous sediments.

The acoustic attenuation by the central channel river-bottom sediments is illustrated in seismic profile segment B-B' (fig. 10) by the poor acoustic penetration and lack of interpretable record in that part of this

A. SEISMIC REFLECTION RECORD



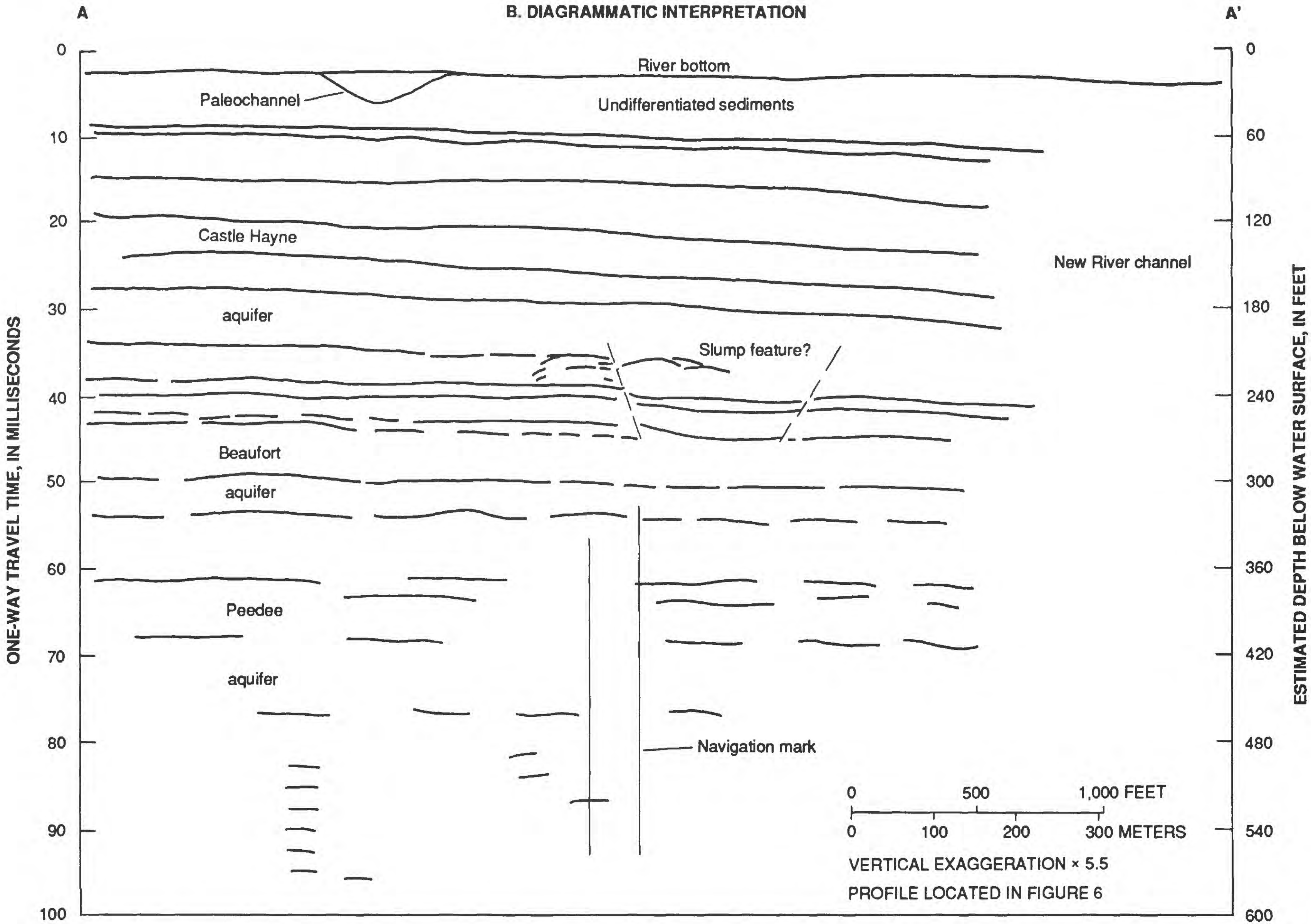
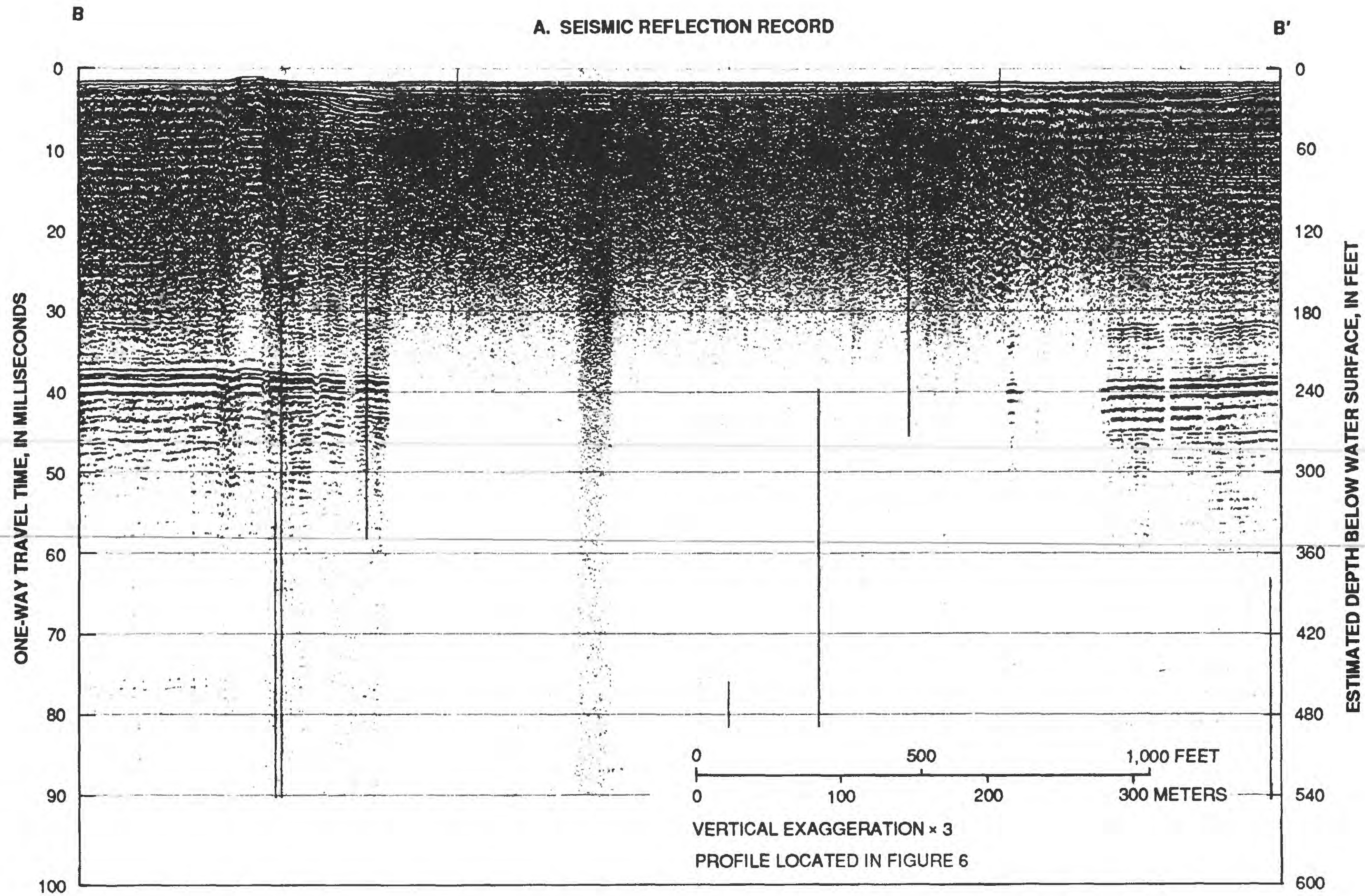


Figure 9.--(A) Seismic reflection record, and (B) diagrammatic interpretation for profile segment A-A'.


B
A. SEISMIC REFLECTION RECORD
B′
ONE-WAY TRAVEL TIME, IN MILLISECONDS
0
10
20
30
40
50
60
70
80
90
100
ESTIMATED DEPTH BELOW WATER SURFACE, IN FEET
0
60
120
180
240
300
360
420
480
540
600
0
500
1,000 FEET
0
100
200
300 METERS
VERTICAL EXAGGERATION × 3
PROFILE LOCATED IN FIGURE 6

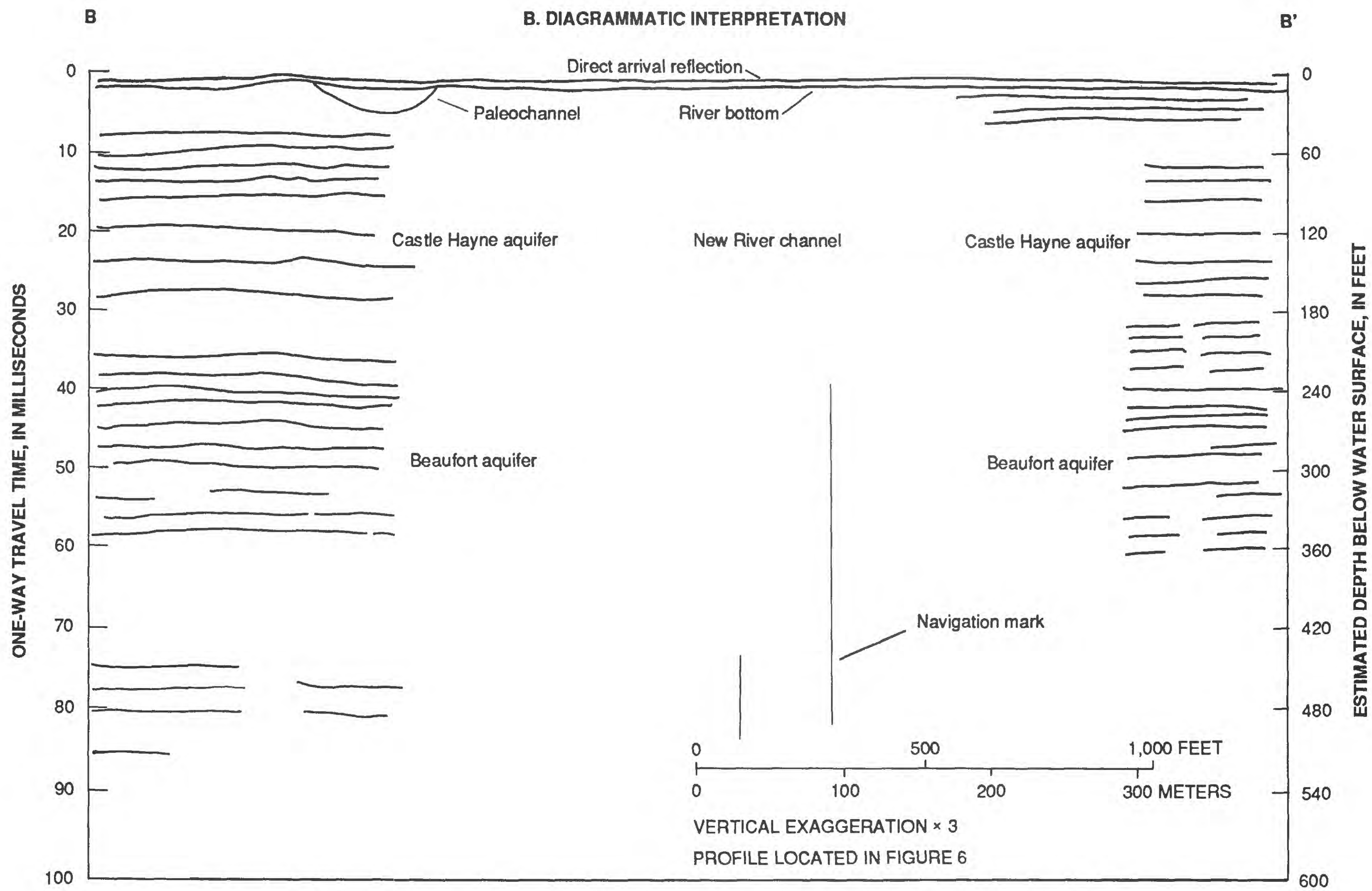


Figure 10.--(A) Seismic reflection record, and (B) diagrammatic interpretation for profile segment B-B'.

profile. Key reflectors in the older sediments can be interpreted across the central channel with little or no offset. This line segment of record was collected in a northeast direction paralleling the strike of the beds; therefore, no apparent dip is seen in this section.

The upper 50 ft of record are surficial aquifer sediments, including a small Quaternary paleochannel (fig. 10B); whereas reflectors from 50 to 240 ft represent the Castle Hayne aquifer. The reflectors below 240 ft decrease in strength and are the Paleocene (Beaufort aquifer) and latest Upper Cretaceous (Peedee aquifer) sediments.

A large, approximately 1,180-foot wide Eocene paleochannel is seen in a segment of seismic record collected in Wallace Creek near Hadnot Point (section C-C', fig. 11). This is the largest paleochannel discovered during this survey and probably represents local paleodrainage features. Smaller Eocene-age paleochannels were found near Montford Point and in Stones Bay. Two small paleochannels are also inferred in the Quaternary sediments in this profile (fig. 11B).

A part of the seismic record collected in the Intracoastal Waterway with filter setting between 300 and 1,200 hertz is shown as section D-D' in figure 12. For this profile, the recording time between trigger pulses was 100 ms, the repetition rate of the sound source was 200 ms for less penetration, and the power setting of 105 J in order to get a detailed look at the first 250 to 300 ft of sediment. Water depths in the Intracoastal Waterway were generally 2 to 3 times deeper (8 to 14 ft) than in the New River, making it possible to identify the river-bottom reflector from the direct arrival from the sound source to the hydrophone on the seismic record.

Sand waves are seen on the bottom of the Waterway and were formed by wind-generated currents. The older, more continuous sediments representing the Castle Hayne aquifer begin at about 25 ft below the waterway bottom on this record. Other than two Quaternary paleochannels at about 15 ft (fig. 12B), there is no evidence of any other structural features in this record.

An example of deeper seismic record collected in the Intracoastal Waterway is shown as section E-E' in figure 13. This seismic record was collected at a 200-ms sweep rate, a 400-ms repetition rate, and a power setting of 280 J. A small Quaternary paleochannel has been identified in the upper 20 feet of undifferentiated sediment in figure 13B. The sediments below 60 ft are flat and continuous. The bottom of the Castle Hayne aquifer is estimated to be at approximately 400 ft below river bottom.

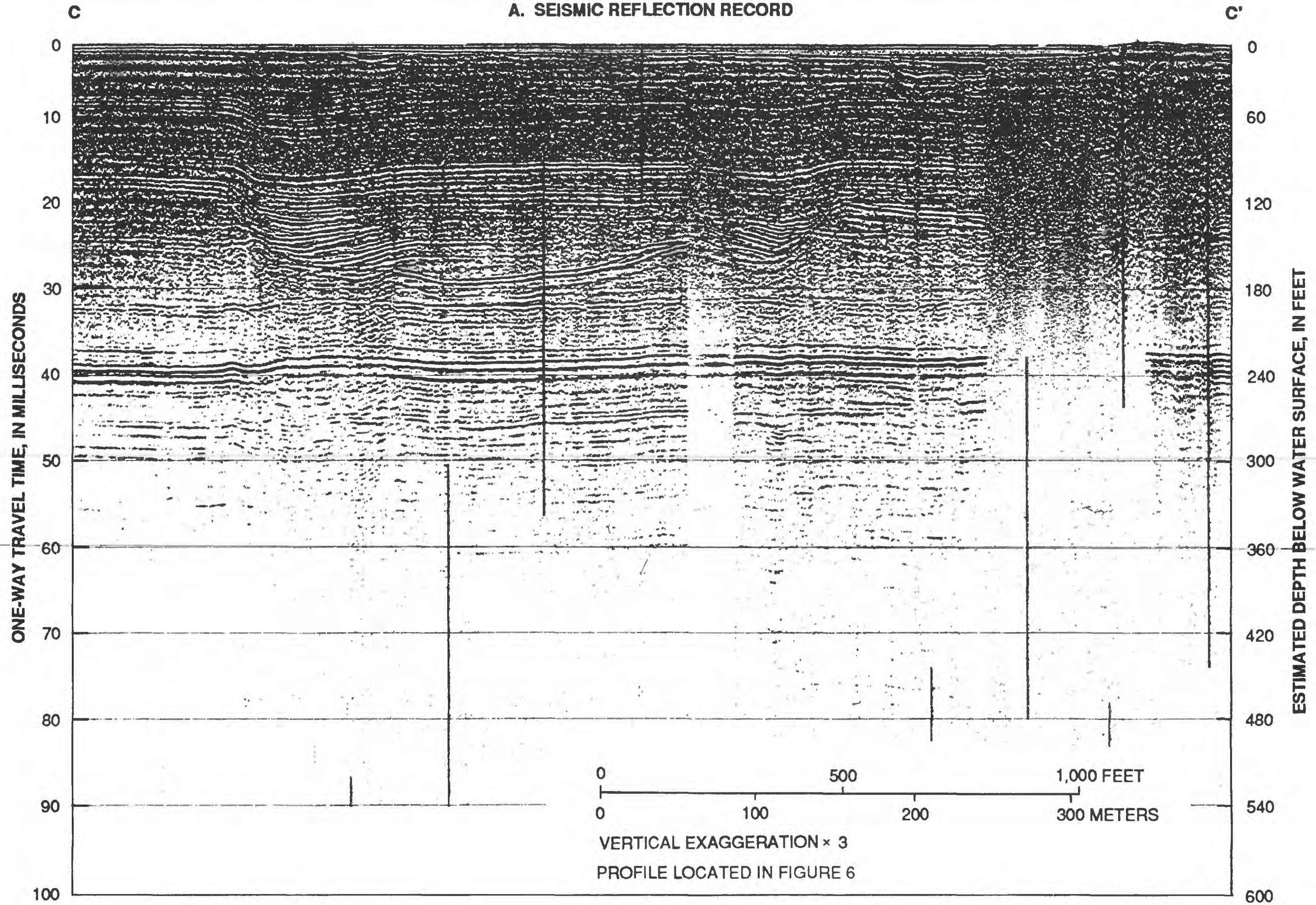
Hydrologic Implications

The continuous seismic reflection survey aided greatly in interpreting the hydrogeologic setting at Camp Lejeune because it significantly increases the knowledge of the subsurface geology under the New River and part of the Intracoastal Waterway and, by extension, beneath Camp Lejeune. Other than the localized slump feature in section A-A', the seismic sections do not show interruption or displacement of reflectors that could be interpreted as evidence of faulting as postulated in Harned and Lloyd (1988). Faults, if present, could serve as permeable vertical conduits for leakage of saltwater from depth. The apparent lack of faults indicates that the presence of saltwater within the Castle Hayne aquifer most likely occurs by some other mechanism.

The survey results confirmed the lateral continuity of older sediments throughout the study area. These sediment reflectors were easily traced on either side of areas of poor signal reception. The survey data were especially useful in determining the hydrogeologic framework below the Intracoastal Waterway where no well-log data exist. The geologic sections presented by Harned and Lloyd (1988) correlated some clay layers in older rock formations in the Camp Lejeune area, but these beds were usually no more than 20- to 40-ft thick and often thinner. The seismic reflection survey results also support the correlation of multiple, thin-bedded layers made by them.

Harned and Lloyd (1988) also interpreted the post-Castle Hayne sediments to be thinly layered and discontinuous. The seismic profiles confirm this interpretation beneath New River, and likely throughout the Camp Lejeune area. Therefore, it is reasonably inferred that the lack of thick, continuous clay beds in this younger series of sediments allows the underlying Castle Hayne to be vulnerable to contamination from surface or near-surface spills, dumps, or landiflls. Conversely, the Camp Lejeune area may be considered a good recharge area for the Castle Hayne aquifer.

A. SEISMIC REFLECTION RECORD



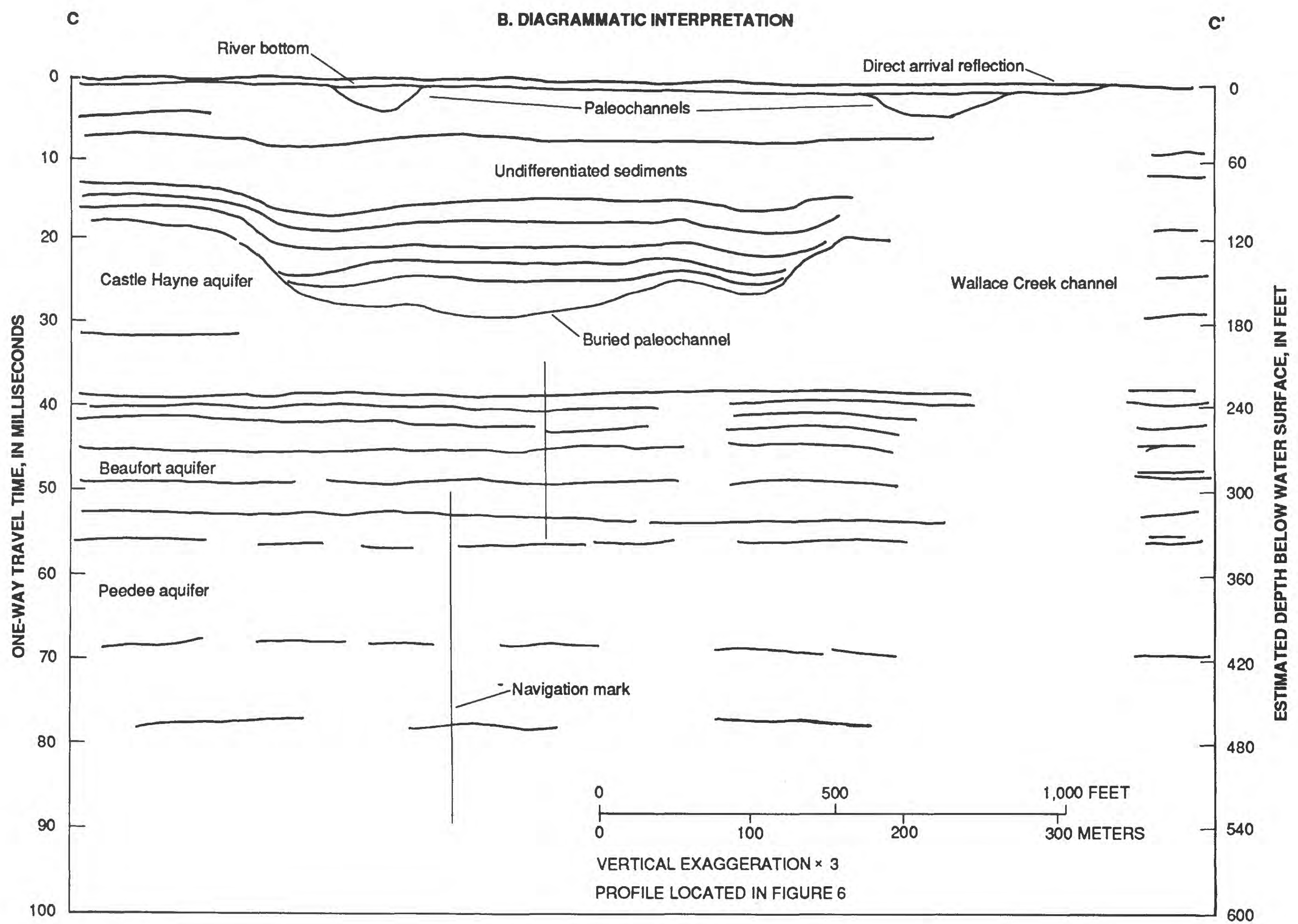
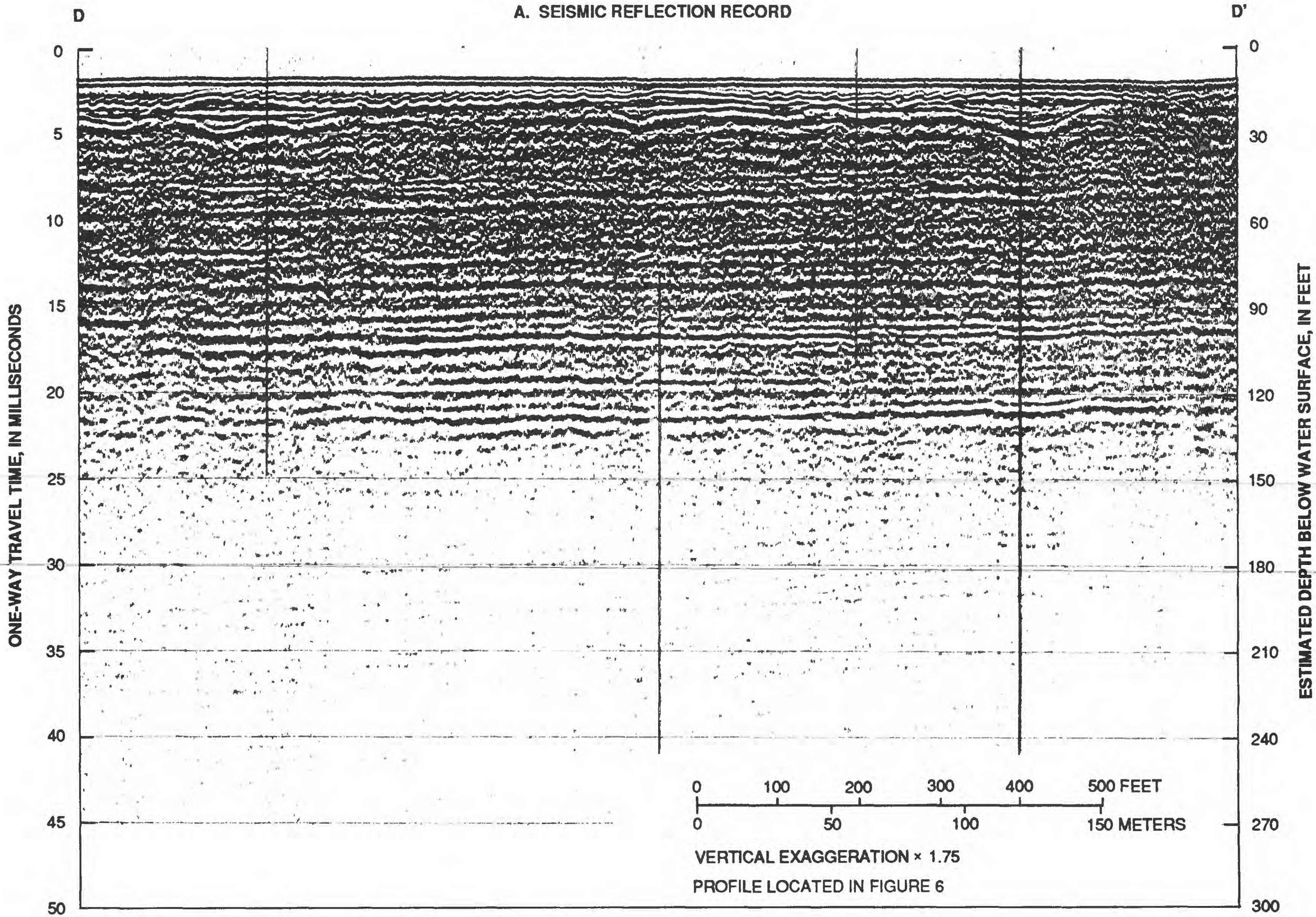


Figure 11.--(A) Seismic reflection record, and (B) diagrammatic interpretation for profile segment C-C'.

A. SEISMIC REFLECTION RECORD



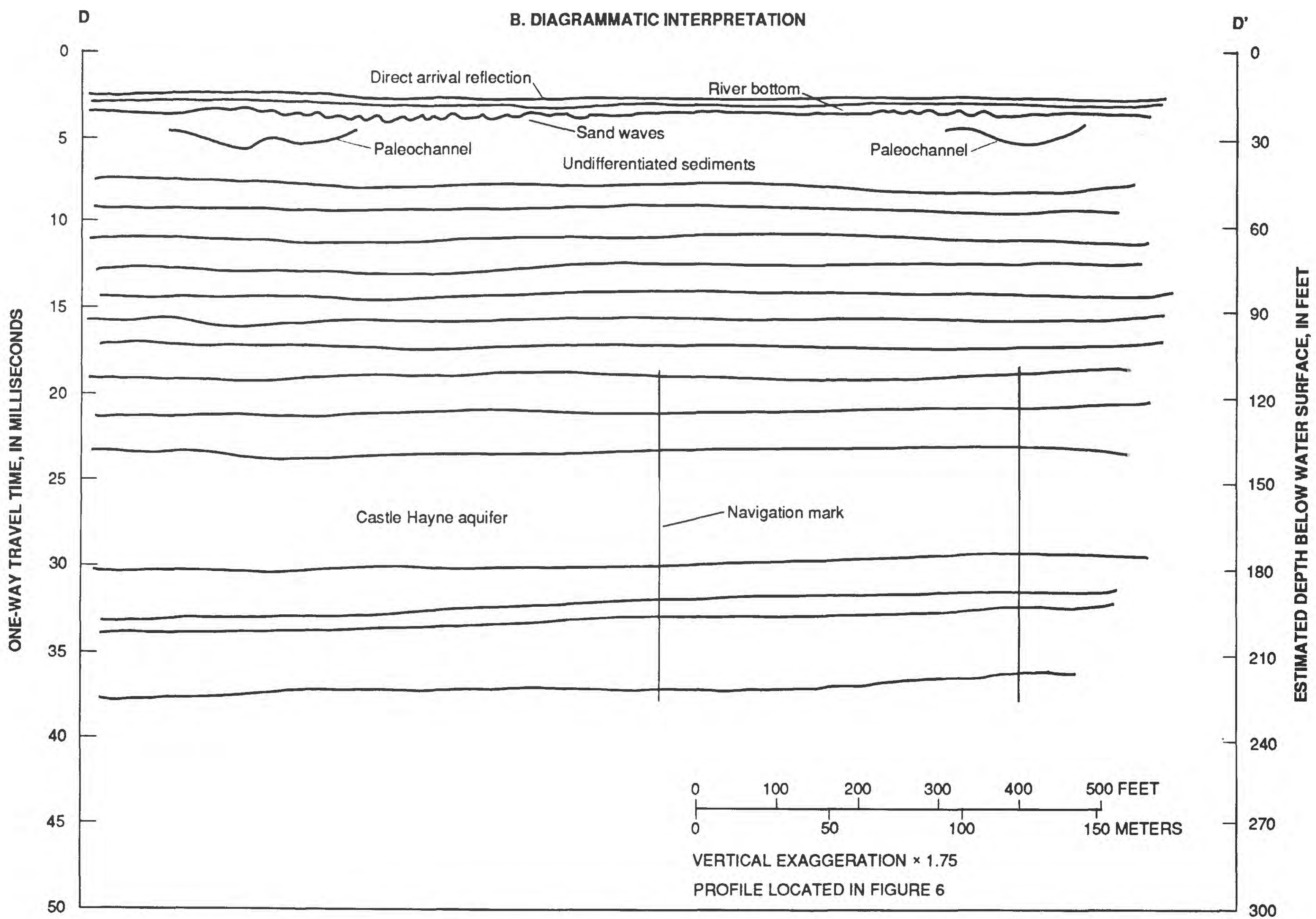
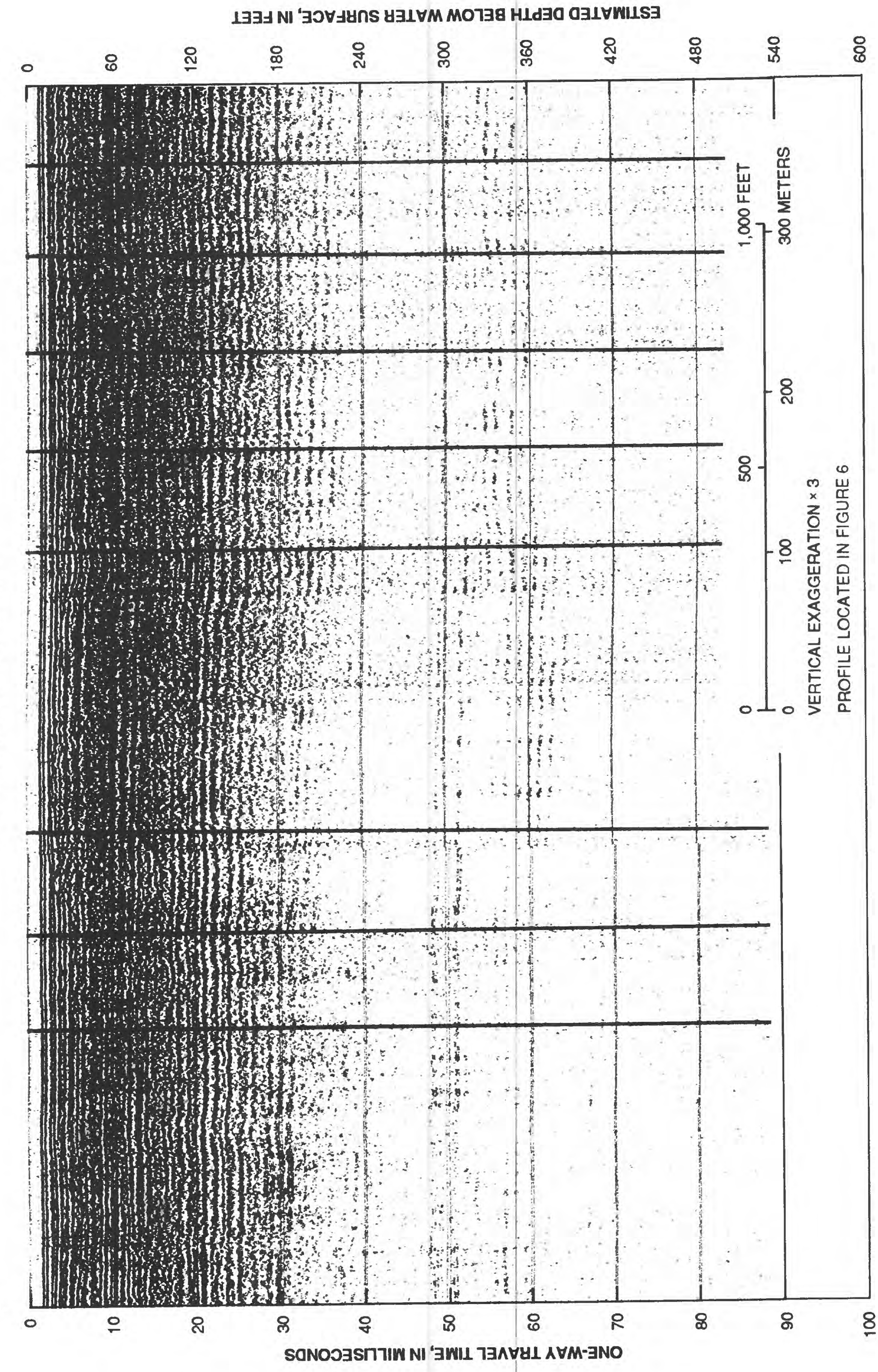


Figure 12.--(A) Seismic reflection record, and (B) diagrammatic interpretation for profile segment D-D'.

A. SEISMIC REFLECTION RECORD



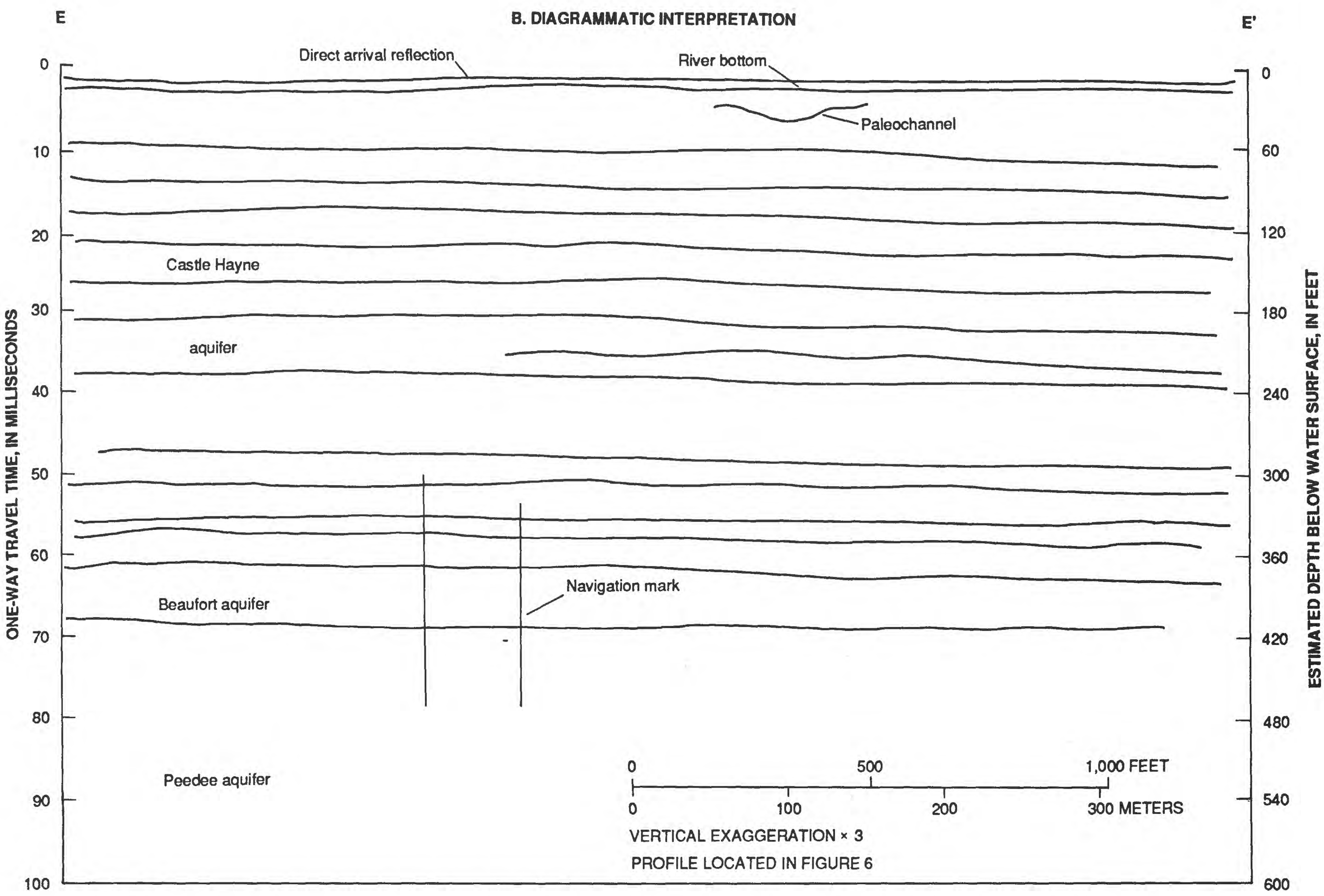


Figure 13.--(A) Seismic reflection record, and (B) diagrammatic interpretation for profile segment E-E'.

The seismic sections show evidence of Quaternary paleochannels and pockets of undifferentiated sediments (lacking defined layering) in some segments of the New River. If such channels are filled with permeable sediments and if they are also present beneath land areas of the Base, they may also serve as conduits for ground-water flow, movement of contaminants, or flow of saltwater from the New River estuary.

Although much information was obtained using seismic reflection profiling techniques, there are limits to the use of these data. Making accurate depth determinations of key hydrogeologic units on the seismic record depends on the accuracy of acoustic velocity data, borehole geophysical well-log data, and available lithologic and paleontological information. It is not possible to identify lithology and facies changes from the reflection record alone; nor will seismic reflection records supply qualitative information on hydraulic parameters, such as porosity and permeability of key units. In order to determine hydrologic information and to confirm what the reflection records indicate the hydrogeologic setting to be, the physical data mentioned needs to be obtained from wells, borings, and test wells.

SUMMARY AND CONCLUSIONS

A seismic reflection survey of the New River was made as part of a program to collect data needed to describe and model the ground-water flow system of Camp Lejeune. The survey provided data that can be used to trace, with greater assurance, the subsurface horizons associated with the Castle Hayne aquifer and other hydrogeologic units.

The New River area comprises approximately 20 percent of the Base. Therefore, marine seismic reflection offered a rapid and inexpensive method of producing continuous profiles of geologic units over a substantial area of the Base. The single-channel, analog system was successfully used to obtain good quality seismic records to depths of 300 ft with little or no data enhancement. Poorer quality but often useful data was obtained for depths as great as 600 ft.

The continuous seismic profiling equipment used in this study included a rapid-pulse source, a single-channel group of hydrophones, a signal processor, a graphic recorder, a magnetic tape recorder, and an integrated navigation system. This equipment was operated from a barge boat in shallow water along a 25-mile stretch of the New River and Intracoastal Waterway.

River-bottom sediments in the central channel of the New River, at the mouth of tributaries, and within tributaries inhibited penetration of the seismic signal. Soft sediments and organic mud within the central channel account for the attenuation of the seismic signal in most problem areas. Deposition of organic sediment near the mouths of tributaries and within tributaries also may account for seismic penetration problems. The best and most continuous records were obtained near the banks of the New River where the river-bottom sediments were sandy and the river bottom was flat.

Depth to reflectors on the seismic records was estimated by using a combination of an average-sediment velocity curve generated from borehole geophysical and lithologic data and correlation of the seismic wavelet character of the reflection records with nearby borehole data. The resultant depth estimates matched up well with depths generated on hydrogeologic sections.

The survey revealed that aquifers contained in older Tertiary rocks, such as the Castle Hayne, have continuous reflectors in the study area. There is no evidence of faulting across the New River. The seismic reflectors in the older formations represent facies boundaries of clay, sand, and (or) carbonate deposits. These older formations dip gently to the southeast. The overlying reflectors, which are associated with younger sediments, lack the lateral continuity of the underlying older reflectors. There is no evidence to support the presence of faults in these younger sediments. Paleochannels were found at several locations and depths in the study area. If paleochannels filled with permeable material exist beneath the present land surface, these features could act as conduits for ground-water flow or movement for contaminants.

Although much information was obtained on the hydrogeologic setting beneath the New River with seismic reflection profiling techniques, there are limits to the use of these data. It is not possible to identify hydrogeologic units, depths to key units, or quantative information on hydraulic parameters from reflection records alone. Actual physical data that could be obtained from existing or new wells are needed to determine hydrologic information and to confirm the hydrogeologic findings from this seismic reflection profiling survey.

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