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**Seismic facies analysis and depositional history of an incised
valley system, Galveston Bay area, Texas**

Smyth, Wendy Clifton, M.A.

Rice University, 1991

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SEISMIC FACIES ANALYSIS AND DEPOSITIONAL HISTORY OF AN
INCISED VALLEY SYSTEM, GALVESTON BAY AREA, TEXAS

by

WENDY CLIFTON SMYTH

A THESIS SUBMITTED
IN PARTIAL FULLFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE

MASTER OF ARTS

APPROVED, THESIS COMMITTEE



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ABSTRACT

SEISMIC FACIES ANALYSIS AND DEPOSITIONAL HISTORY OF AN INCISED VALLEY SYSTEM, GALVESTON BAY AREA, TEXAS

by Wendy Clifton Smyth

The history of the incised river valley underlying Galveston Bay was determined by examining the distribution of depositional units and the relationships between them. Initial incision of the valley occurred after the previous interglacial stage 5, substage 5e sea level highstand (120 ka, +6m relative to today). Fluvial terraces, present within the incised valley, were left behind by this incision and by subsequent 20 ky sea level cycles. These terrace deposits are bound by sequence boundary unconformities associated with falling sea level, which ultimately fell to 120m below its present level, approximately 18-20 ka.

The sediments within the incised valley are associated with the Holocene rise in sea level. They consist of aggradational fluvial deposits overlain by marsh and estuarine sediments. Initial flooding of the estuary occurred 8-10 ka. Maximum flooding occurred at 4 ka. These events appear to represent rapid flooding.

ACKNOWLEDGEMENTS

My interest in Galveston Bay stems from being a native of the area and from having studied the Tertiary geology of the bay as an explorationist. John Anderson's idea of using high resolution seismic data to study the drowned river valley which underlies Galveston Bay struck my imagination. I appreciate his participation in acquiring all of the seismic data for this thesis, as well as his patience and support as the project went on. Andre Droxler and Peter Vail provided helpful suggestions and assistance, and their interest is also appreciated.

Thanks to those who helped collect the seismic data, especially to Mark Thomas, who went out every time I did to collect data. Discussions with Mark and with Fernando Siringan helped me to understand the morphology of the incised valley and the development of the present day shoreline features, all of which turned out to be considerably more complex than we had originally expected.

I also wish to thank Barbara Larson of Northwind Exploration, Houston, Tx, for help well beyond the call of duty. She drafted the figures in this thesis.

My husband, Brian, and daughters, Louise and Amy, lived with this project. Its completion would not have been possible without their acceptance, good humor, and support.

TABLE OF CONTENTS

ABSTRACT	i
ACKNOWLEDGEMENTS	ii
LIST OF FIGURES	iv
LIST OF TABLES	vii
 CHAPTER 1: INTRODUCTION	 1
 CHAPTER 2: BACKGROUND	 5
Gulf Coast tectonic setting	5
Quaternary stratigraphy	8
Beaumont formation	9
Ingleside shoreline trend	16
Deweyville formation	20
Quaternary sea level studies	22
Studies of Quaternary shelf deposits	26
Depositional environments of the modern Trinity	
River and Galveston/Trinity Bay estuary	27
The Trinity River	27
The Trinity Bayhead Delta	34
The marsh	39
The Galveston/Trinity Bay estuary	42
Sediment sources	42
Estuarine circulation and deposition	
of sediments	43
Fauna	47
 CHAPTER 3: METHODS AND DATA	 49
Sediment cores	49
Seismic data	53
Interpretive procedures	55
 CHAPTER 4: RESULTS OF SEISMIC STUDIES: FACIES ARCHITECTURE	 58
OF GALVESTON/TRINITY BAY AS AN INCISED VALLEY SYSTEM	
Seismic expression of the incised valley	59
Recognition of unit boundaries	59
Seismic facies	88
Morphology of the incised valley	102
 CHAPTER 5: RESULTS OF SEISMIC STUDIES: RESPONSE OF THE	 138
GALVESTON/TRINITY BAY INCISED VALLEY TO CHANGES IN SEA	
LEVEL	
Sea level signals in the pre-flood valley	138
Response of the incised valley to the Holocene	
rise in sea level	143
 CHAPTER 6: CONCLUSIONS	 158
 REFERENCES	 160

LIST OF FIGURES

	<u>page</u>
Fig. 2-1. Gulf Coast tectonic and location map (modified from Martin, 1978).	7
Fig. 2-2. Texas and Louisiana Quaternary depositional surfaces, as mapped by Doering (1935).	11
Fig. 2-3. a) Quaternary formations of Texas and Louisiana (from Bernard et al, 1962), and b) Their relationships to glacial epochs as determined by Fisk (1944).	14
Fig. 2-4. Pleistocene channel stages of the Trinity and Brazos Rivers with Ingleside shoreline deposits (from Aronow, 1971; Wilkinson, 1975; and Winker, 1979).	18
Fig. 2-5. (modified from Bard et al., 1990) Sea level record derived from U-Th dating of corals (A. Palmata).	25
Fig. 2-6. Galveston Bay Area with associated depositional systems (from Fisher et al, 1972).	29
Fig. 2-7. Quaternary terraces and modern floodplain along the lower Trinity River, as mapped by Aten (1983).	33
Fig. 2-8. Channel stages and locations of Trinity bayhead delta since 2.6 ka (from Aten, 1983).	38
Fig. 2-9. Modern marsh systems, Trinity River and Bayhead Delta (from Fisher et al, 1975).	41
Fig. 3-1. Data used in this thesis.	51
Fig. 4-1. Segment of Umbrella Point Line 1.	62
Fig. 4-2. Descriptions of sediment cores along Umbrella Point Line 1.	64
Fig. 4-3. Locations of Umbrella Point Line 1 and Dollar Point Line 1.	66
Fig. 4-4. Segment of Dollar Point Line 1.	70

	v
Fig. 4-5. Descriptions of sediment cores along Dollar Point Line 1.	72
Fig. 4-6. Locations of Bolivar Line 1, Trinity Delta Line 8, and Red Bluff Line 1	76
Fig. 4-7. Deweyville terraces on Bolivar Line 1.	78
Fig. 4-8. Deweyville terrace deposits on Trinity Delta Line 8.	80
Fig. 4-9. Deweyville terrace deposits on Red Bluff Line 1.	83
Fig. 4-10. Descriptions of sediment cores along Red Bluff Line 1.	85
Fig. 4-11. Beaumont and Deweyville terraces on Red Bluff Line 1.	87
Fig. 4-12. Locations of Trinity Delta Line 2 and USGS Line 22.	90
Fig. 4-13. Fluvial deposits bound by Sequence Boundary 6 on Trinity Delta Line 2.	92
Fig. 4-14. Fluvial deposits bound by Sequence Boundary 6, with subsequent ravinement surface on USGS Line 22.	94
Fig. 4-15. Locations of Dollar Point Line 1 and Williams Line 1.	97
Fig. 4-16. Middle estuary deposits with buried oyster reef on Dollar Point Line 1.	99
Fig. 4-17. Flood tidal delta deposits overlying Beaumont sediments on Williams Line 1.	101
Fig. 4-18. Locations of cross-sections (Figs. 4-19 through 4-23).	105
Fig. 4-19. Umbrella Point cross-section.	107
Fig. 4-20. Red Bluff cross-section.	109
Fig. 4-21. Smith Point cross-section.	111
Fig. 4-22. Dollar Point cross-section.	113
Fig. 4-23. Bolivar cross-section.	115
Fig. 4-24. Summary view of cross-sections across the incised valley.	119

	vi
Fig. 4-25. Structure contour map on Sequence Boundary 2.	122
Fig. 4-26. Distribution of terrace deposits; and isopach thicknesses of Deweyville and Holocene sands. (Each considered separately.)	124
Fig. 4-27. Isopach of fluvial sands. (Deweyville and Holocene sand thicknesses considered together.)	127
Fig. 4-28. Distribution of marsh deposits with isopach thicknesses.	130
Fig. 4-29. Isopach of estuarine sediments.	133
Fig. 4-30. Isopach of bayhead delta and flood tidal delta deposits.	135
Fig. 5-1. Proposed history of Trinity/San Jacinto River valley.	142
Fig. 5-2. Holocene sea level curves from the Gulf of Mexico (Curry, 1960; Rehkemper, 1969; Nelson and Bray, 1970; and Frazier, 1974) and the Caribbean (Fairbanks, 1989).	145
Fig. 5-3. Structure contour map on top of the flooding surface, with radiocarbon dates from Rehkemper, 1969.	149
Fig. 5-4. Summary of response of the Galveston/Trinity Bay estuary to the Holocene rise in sea level.	151
Fig. 5-5. Summary of fluvial-estuarine response to sea level changes. Emphasis is on depositional units and surfaces as they relate to sequence stratigraphy.	155

LIST OF TABLES

	<u>page</u>
Table 2-1. Channel dimensions, Trinity River floodplain and terraces (from Aten, 1983).	35
Table 2-2. Sediment facies characteristics in Galveston and Trinity Bays (from Rehkemper, 1969).	46
Table 3-1. Radiocarbon dates from Galveston and Trinity Bays (from Rehkemper, 1969).	54

CHAPTER 1 : INTRODUCTION

Incised valleys have long been recognized beneath Texas and Louisiana bays and estuaries. Fisk (1944) recognized the probability that these valleys are associated with late Pleistocene low stands of sea level, and that they continue offshore, carved into the continental shelf. Incised valleys are important for understanding the history of shelf sedimentation because of the high preservation potential of the valley-fill sediments (Belknap and Kraft, 1981). In recent studies, high resolution seismic data has been used to map the incised valleys on the Texas and Louisiana shelf (Nelson and Bray, 1970; Suter and Berryhill, 1985; Suter and Penland, 1985; Pearson, et al., 1986; Suter et al, 1987; and Thomas, 1990). These studies reveal a complex system of Quaternary incised valleys, deltas, and estuaries on the continental shelf. Seismic data has also been used extensively to develop a sequence stratigraphy of Quaternary shelf sediments. In this thesis, the seismic facies that comprise incised valley and valley-fill sediments of the modern Galveston Bay estuary are presented and analysed.

Studies of present day Texas estuaries have provided information about Quaternary sea level fluctuations. Fisk (1944) recognized that deep river valleys were cut when sea level fell in the late Pleistocene, and they are known to be filled with Pleistocene and Holocene fluvial and estuarine sediments. Ladd et al (1957) characterized modern bay faunal assemblages in Central Texas estuaries, and tied them to salinity. Parker (1960) studied such assemblages down-core in central Texas estuaries (San Antonio, Mesquite, and Aransas Bays). He concluded that these estuaries were initially flooded between 9 and 8 ka, and that barrier island formation began less than 5ka. Numerous studies of Texas and Louisiana bays and estuaries attest to their origin as incised valleys which were flooded during the Holocene to become estuaries. (Fagg, 1957; Kane, 1959; Parker, 1959; Shepard and Moore, 1960; Behrens, 1963; Byrne, 1975; Wilkinson and Byrne, 1977; Morton and McGowen, 1980).

The purpose of this study is to describe the facies architecture of Galveston Bay as an incised valley. This is done by characterizing fluvial and estuarine deposits within the valley and mapping their distribution. Once accomplished, this leads to an understanding of the evolution of the bay with respect to sea level. The complexity of the sea level fluctuations is reflected in the

multiple generations of sequences present in the valley and in their distribution.

Galveston Bay was chosen as the location for this study for several reasons. Its accessibility allowed considerable flexibility in the acquisition of the seismic data. Thus, good weather conditions, so important in the collection of this high resolution seismic data, could be used to full advantage. In addition, the Trinity River is a low sediment supply system, allowing transgressive deposits within the valley to be distinguished more readily. Information from numerous borings was available to anchor the seismic interpretation. Also available was good previous work on Galveston and Trinity Bays by Rehkemper (1969), including careful sedimentological and paleontological studies of cores in the bay, many radiocarbon dates, and a basic understanding of the estuary's morphology and history.

While previous work in Galveston Bay was very good, this study will further the understanding of this fluvial/estuarine system. The morphology of the incised valley can more accurately be characterized with seismic data. This study demonstrates the utility of using high resolution seismic data to identify depositional environments and to determine their distribution. Lastly, this incised valley system is more complex than indicated in previous work. A careful study of the stratigraphic

framework for this system impacts the understanding of its formation history.

CHAPTER 2 : BACKGROUND

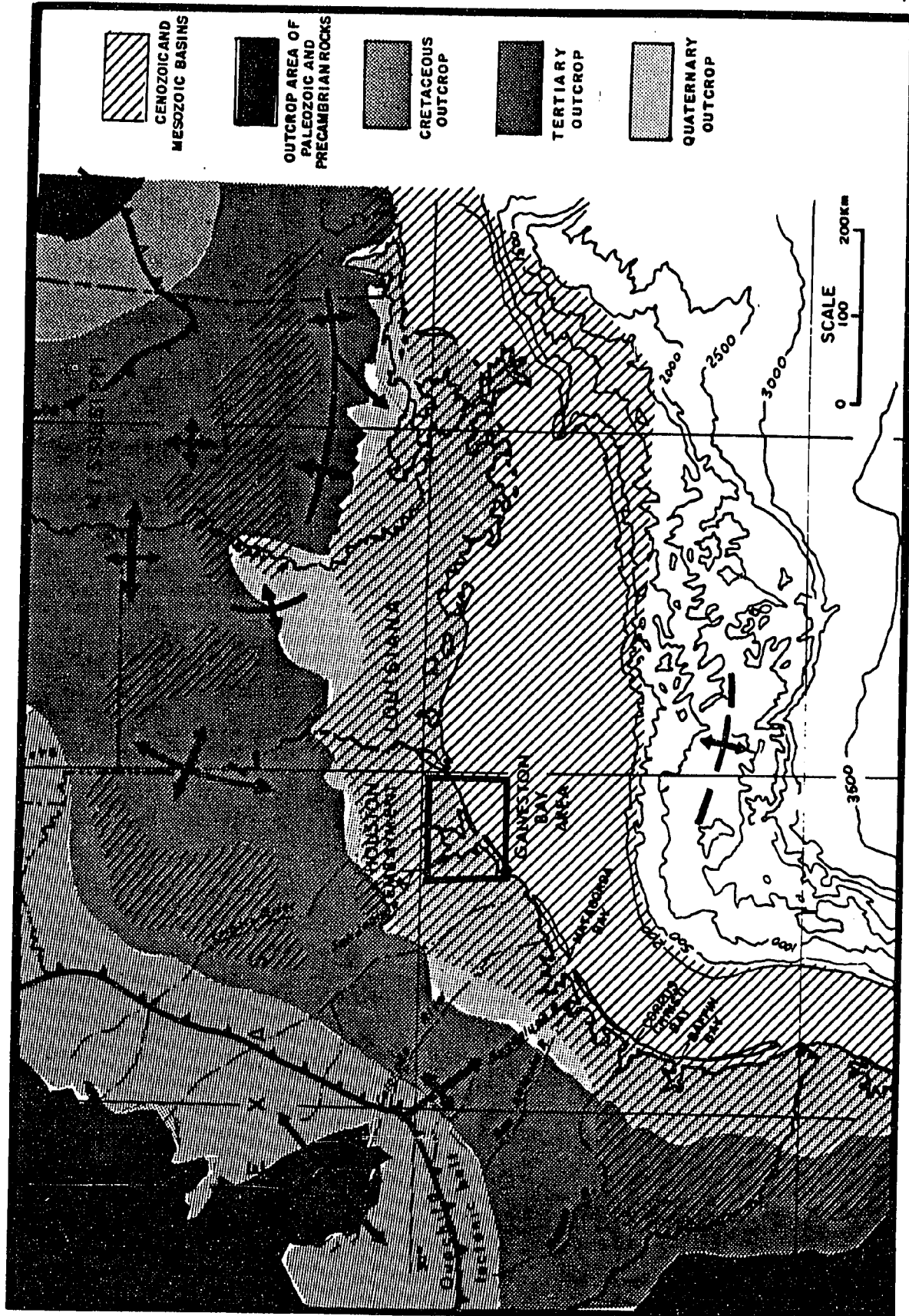
GULF COAST TECTONIC SETTING

The continental margin of the northern Gulf of Mexico (Fig. 2-1) extends from the Paleozoic Ouachita fold and thrust belt to the continental slope. It is underlain by the Jurassic Louann Salt and Cretaceous deposits, which are mostly platform carbonates. The series of arches and embayments seen in Fig. 2-1 formed by differential subsidence. The basins and embayments were the site of major Tertiary sediment accumulation. Sediments then prograded across the Texas-Louisiana shelf, forming the Gulf Coast Basin (Martin, 1978).

Although the sediment wedge of the Gulf Coast Basin reaches a thickness of up to 15 km (Martin, 1978), the continental margin is relatively stable tectonically. Subsidence along the margin is due to sediment loading, and the long-term rate is estimated to be approximately .1m per 1000 yrs (Winker, 1979). Locally, salt and shale diapirs and growth faults can be important tectonic features affecting sedimentation.

The Galveston Bay area is located within the Houston Embayment and lies above a thick accumulation of Tertiary sediments. Diapirs and growth faults are numerous and

Figure 2-1. Gulf Coast tectonic and location map (modified from Martin, 1978).



important within the Tertiary section underlying the Galveston Bay area. However, they are not present near or at the surface anywhere beneath the bay itself. Local subsidence in the area has increased in recent years to .24 cm/yr for 1948-59 and .6 cm/yr for 1959-71, measured at Galveston by Swanson and Thurlow (1973). It has increased locally over the same time period to 5-7 cm/yr in industrial areas, such as Texas City and the Houston Ship Channel portion of the San Jacinto River, due to fluid withdrawal (Gabrysch and Bonnet, 1975; Kreitler, 1977; and White et al, 1985).

QUATERNARY STRATIGRAPHY

Interpretation of Texas Gulf Coast Quaternary stratigraphy is not definitive. Clearly defined ages, genetic origins, and thicknesses of formations have been difficult to establish. Each stratigraphic interpretation depends on the stratigrapher's concepts of Quaternary fluctuations of eustatic sea level and deposition of sediments within eustatic cycles. Stratigraphic relationships were first determined onshore by the study of outcrops, soils, and topography. Ages and genetic origin of sediments were tied to the concept that Gulf Coast Pleistocene sea level was controlled by four major continental glaciations. More detailed sea level information, together with a more detailed knowledge of the

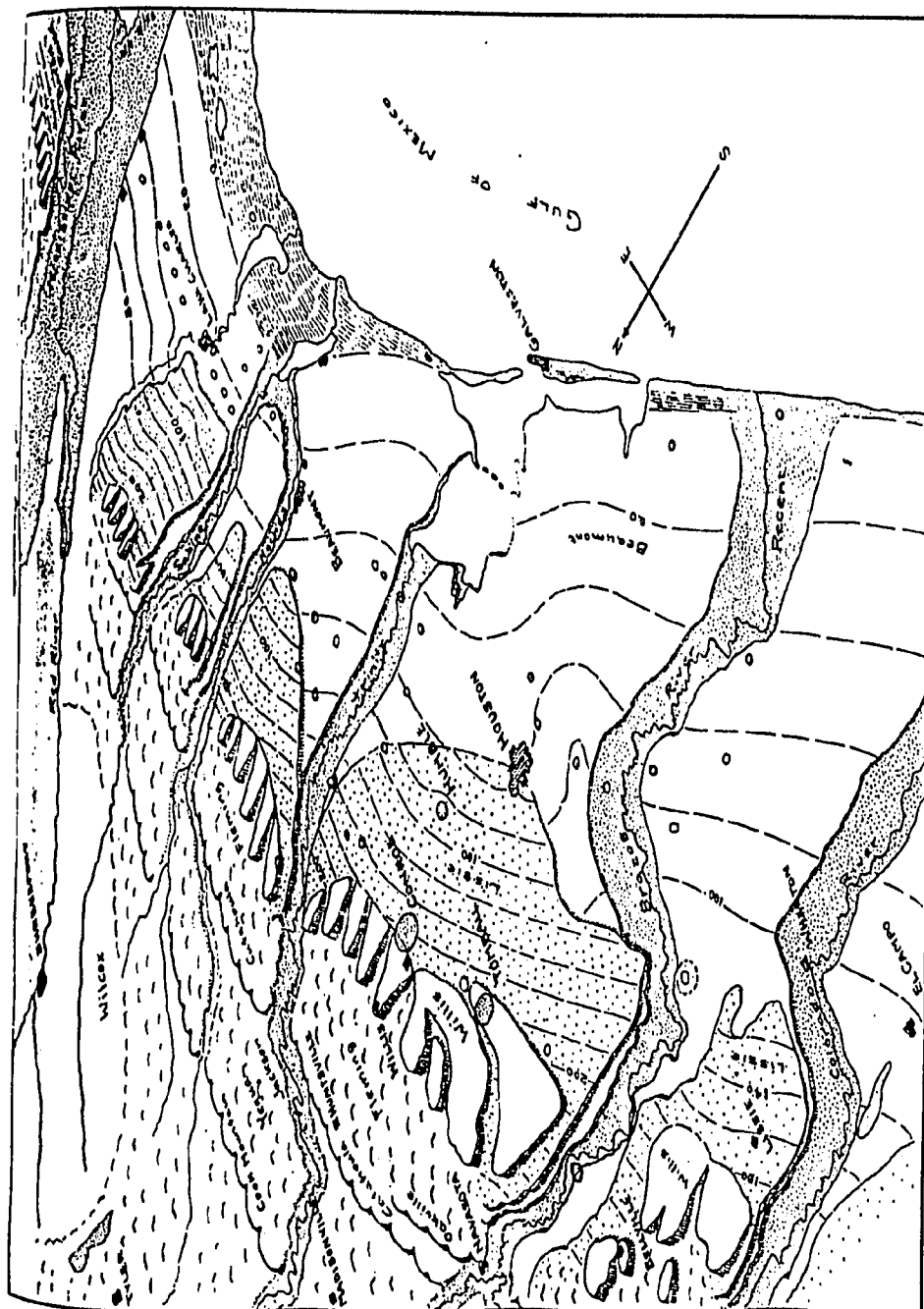
response of depositional systems to sea level fluctuations has changed the understanding of Quaternary stratigraphy. Recent offshore seismic studies modify the earlier work, though the relationship between the onshore and offshore data has not been clearly established.

Beaumont Formation

The Beaumont clay was first named and described by Hayes and Kennedy (1903). Deussen (1914) described and named the Lissie gravel. Doering (1935, 1956) distinguished between the two on the basis of dip and recognized that the sediments were originally deposited on a gentler slope and subsequently tilted by sediment loading in the basin. Working along the Brazos, Colorado and Trinity Rivers, he traced Beaumont and Lissie coastal surfaces up dip to their corresponding river terraces (Fig. 2-2). Barton (1930) first described the Beaumont as a Late Pleistocene interglacial delta plain.

Fisk (1938 and 1940) named the Williana, Bentley, Montgomery, and Prairie (Beaumont equivalent) terraces in La Salle and Grant parishes and later in other parishes in Louisiana. He concluded that these terrace deposits were separate stratigraphic units, each one constituting a separate formation. Bernard (1950) extended Fisk's work into Newton, Jasper and Orange counties, especially along the Neches and Sabine rivers. In addition to the four

Figure 2-2. Texas and Louisiana Quaternary depositional surfaces, as mapped by Doering (1935). This map shows the relationships between Beaumont, Lissie, and Willis terraces and their coast-wise plains.



terraces identified and named by Fisk, Bernard found a fifth, lower terrace, which he named Deweyville. He noted the absence of any coastwise equivalent to this terrace.

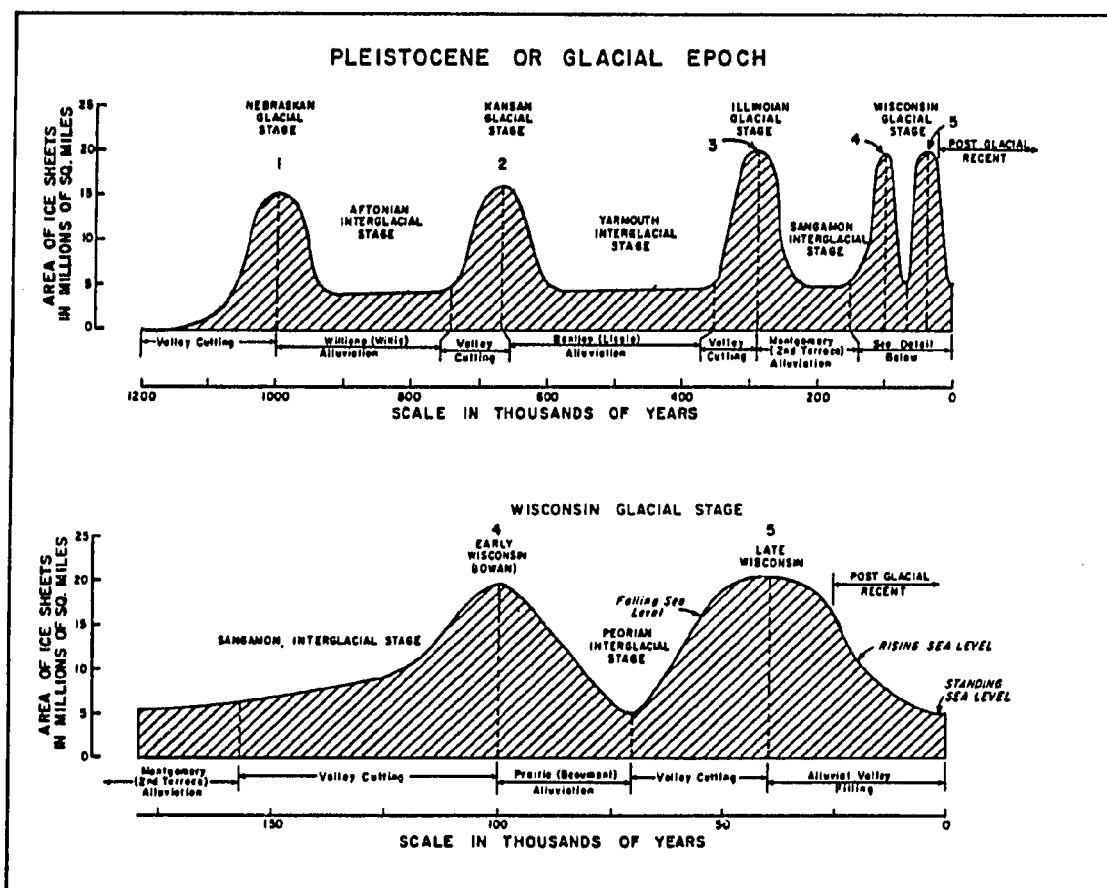
Fisk (1944) recognized that river entrenchment and deltaic deposition advancing into the basin accompanied each fall in sea level. During glacial lowstands most sediment bypassed the shelf and was transported into the basin through the entrenched valleys to be deposited offshore. Transgressive deposits onlapped unconformities, and entrenched valleys were filled with sediment as sea level rose during interglacial stages (Bernard et al, 1962). Correspondence between the formations as mapped in Texas and Louisiana was disputed by many geologists. Fig. 2-3 illustrates this and summarizes the correlation between four Gulf Coast Quaternary formations and four Pleistocene glacial epochs, as hypothesized by Fisk (1944).

The Beaumont formation has been mapped and described all along the Texas coast. Clays of various colors are common: blue, purple, yellowish or pinkish gray, yellowish green or green, tan, and, from Lavaca Bay to Galveston Bay, deep red (from Permian-Triassic red beds in west Texas carried to the Gulf by Brazos and Colorado Rivers). The clays contain limonite streaks, carbonaceous material, and lenses of brown silt. Selenite flakes and crystals occur from south Texas to at least the Galveston Bay area and are more prevalent in South Texas (Price, 1934). Beaumont clay

Figure 2-3. a) Quaternary formations of Texas and Louisiana (from Bernard et al, 1962), and
b) Their relationships to glacial epochs, as determined by Fisk (1944).

Hays and Kennedy (1903)	Deussen (1914 and 1924)	Doering (1935)	Doering (1956)	Bernard (1950) (East Texas)	Fisk (1938, '40, '44) (Louisiana)	This Paper 1962
Beaumont *	Beaumont	Beaumont	Eunice *	Prairie	Prairie *	Beaumont
			Oberlin *			
Columbia	Lissie *	Lissie	Lissie	Montgomery	Montgomery *	Unnamed 2nd Terrace
				Bentley	Bentley *	Lissie
Lafayette	Reynosa	Willis *	Citronelle	Williana	Williana *	Willis

* Denotes original definition



exposed at the surface is commonly covered by prairie grasses (Bernard, 1950).

The weathered surface of the Beaumont clay is more distinctive than the sediments beneath the surface. Stiff, mottled, oxidized, and leached clays are commonly seen at the upper surface (Bernard and LeBlanc, 1965). Also common are ferric oxide concretions in the Beaumont of the upper Texas coast. These are thought to have formed in a climate similar to that of today, one of alternating wet and dry seasons. Calcium carbonate concretions and caliche soil, indicative of an arid or semi-arid climate, are also characteristic of the Beaumont weathered surface (Price, 1934). This is more prevalent toward south Texas and not seen east of the Sabine River (Graf, 1966).

Reported thicknesses of the Beaumont vary. The base of the Beaumont is considered to be graveliferous sands that lie at depths of from 25 - 75 meters, as reported in Jasper and Orange counties, Texas (Bernard, 1950), to 40 - 225 meters in south Texas (Price, 1934).

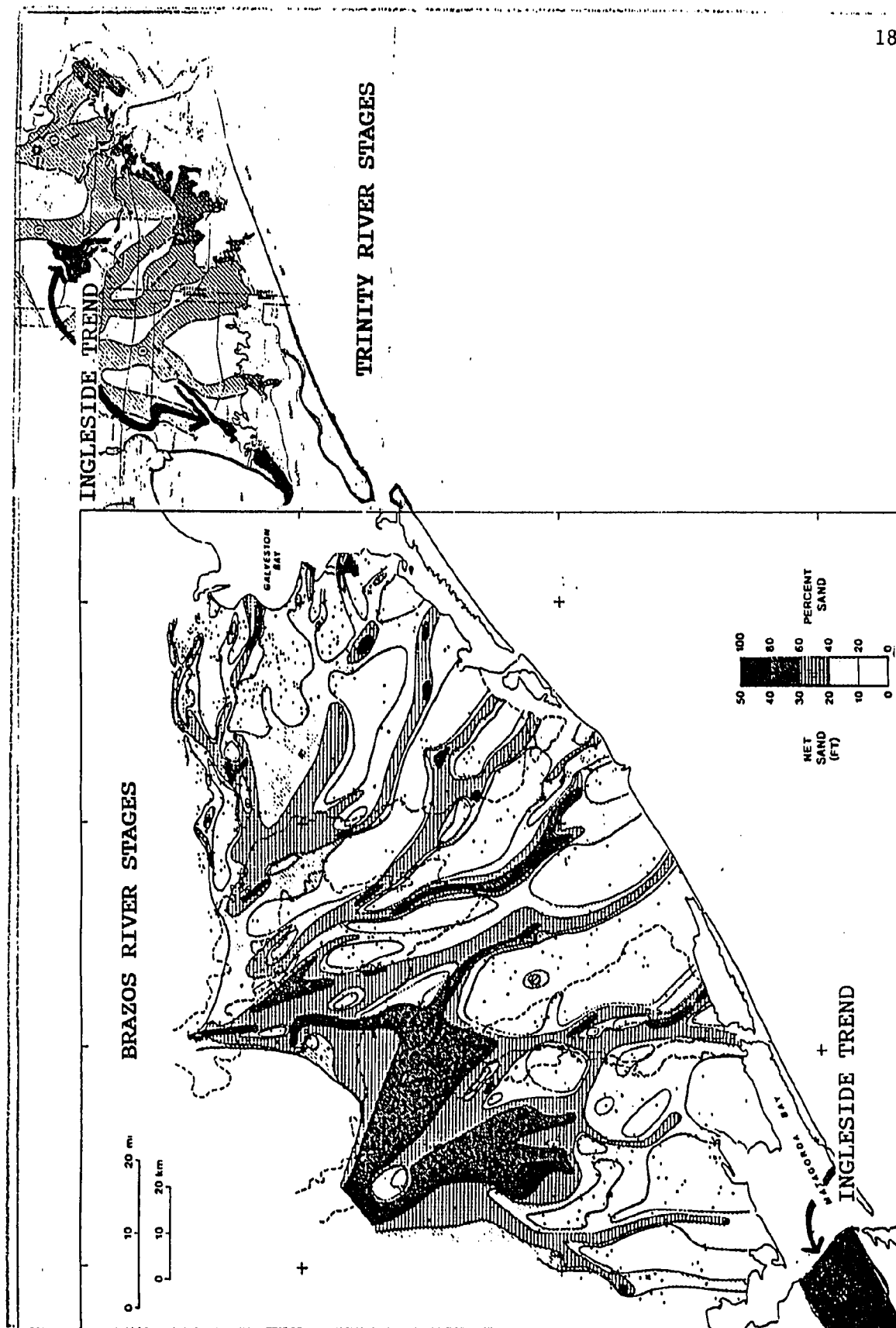
The Beaumont clay is now thought to represent stage 5, substage 5e deposition because that was the last time sea level was higher than it is presently (Winker, 1979). Attempts to date the formation using radiocarbon dating (McFarlan, 1961) have been unsuccessful, as the material was found to be outside the range of that method.

The Pleistocene (Beaumont age) deltas of the Brazos and Trinity rivers in the Galveston Bay area (Fig 2-4) have been of interest since Barton (1930) first suggested that the Pleistocene Trinity delta was huge. Aronow (1971) has suggested, however, that the remnant Pleistocene Trinity delta actually represents a series of small deltas, each one about the size of the present Trinity delta. Winker (1979) noted that the relict channels of the Pleistocene Brazos delta are too sinuous to be distributary channels. He suggested that these relict channels may also represent a series of river channels, each ending in a small delta. These ideas are more in line with the evidence presented by the morphology of the relict Pleistocene Brazos and Trinity Rivers as seen in Fig. 2-4.

Ingleside Shoreline Trend

A shoreline trend, known as Ingleside in Texas, was first mapped by Price (1933). It occurs along the Gulf Coast intermittently from southwest Louisiana to Tamaulipas, Mexico, 150 kilometers south of the Rio Grande River (Price, 1958) (For the Ingleside trend in proximity to the Galveston Bay area, see Fig. 2-4). Sandy deposits up to 25 meters thick are reported, and accretionary beach ridges and nearshore marine fauna have been found along the trend (Morton and Price, 1987). Winker (1979) observed updip sands interbedded with Beaumont mud, forming a beach -

Figure 2-4. Pleistocene channel stages of the Trinity and Brazos Rivers with Ingleside shoreline deposits (from Aronow, 1971; Wilkinson et al, 1975; and Winker, 1979).



shoreface sequence which thins seaward. Some progradation is evident in the sediments (Morton and Price, 1987), which is thought to correspond to the lowering of sea level. Where exposed, Ingleside deposits are covered by pines and hardwoods, especially oaks (Bernard, 1950).

The age of the Ingleside deposits is disputed. A commonly held viewpoint is that Ingleside represents the stage 5e highstand shoreline trend (Winker, 1979; Morton and Price, 1987). Wilkinson et al (1975) interpret Ingleside to have formed later than stage 5e, possibly during a more recent high stand of sea level. Finally, the interpretation of Graf (1966), who studied the Ingleside deposits adjacent to Galveston Bay, is that Ingleside sands represent a shoreline that formed during the fall of sea level that followed the stage 5e high stand.

Deltas prograded beyond the shoreline trend (Aronow, 1971), and incised river valleys cut through it (Winker, 1979). (See Fig. 2-4.) This evidence supports an earlier age for Ingleside deposits. The river stages seen in Fig. 2-4 would pre-date the incised Trinity River valley, in which the river is still confined. The shoreline deposits could have pre-dated the river stages that cut through them, or the river stages and shoreline trend could represent contemporaneous deposition.

Deweyville Formation

Barton (1930) first noticed the well-preserved meander scars of the Deweyville formation that are much larger than either present-day or Beaumont meanders. Since Bernard (1950) first described and named Deweyville terraces along the Neches and Sabine Rivers, they have been identified and studied along many Atlantic and Gulf Coast rivers (Bernard, 1950; Gagliano and Thom, 1967; Aronow, 1967 and 1971; Saucier and Fleetwood, 1970; Looney and Baker, 1977; Baker and Penteado-Orellana, 1977 and 1978; Otvos, 1980; Saucier, 1981; Aten, 1983; Alford and Holmes, 1985). Generally, the terraces are sandy, unconsolidated deposits of various colors, blue-gray, gray, or brown. Limonite and brown silt streaks are common; sands may be oxidized, and there is some quick-sand present (Bernard, 1950; Pearson et al, 1988).

While those who have studied Deweyville deposits can agree on some aspects of their deposition, other aspects are disputed. There is agreement that Deweyville sediments were deposited at a time when sea level was lower than present. There is no Deweyville coastwise equivalent (Bernard, 1950), and modern fluvial systems cover it in the lower reaches of the rivers (Gagliano and Thom, 1967). Except for Pearson et al (1986), most investigators agree that there has been reincision since its deposition. Upon examination of Pearson et al's data, it appears that some of the sediments

that they interpret to be Deweyville terrace are actually Holocene estuarine sediments.

Dating of Deweyville deposits has yielded results of from 9ka to 36ka for time of deposition (Bernard and LeBlanc, 1965; Slaughter, 1965; Gagliano and Thom, 1967; Saucier, 1968 and 1981; Aronow, 1971; Smith and Saucier, 1971; and Otvos, 1980). Most of these investigators suggest a stage 3 age for Deweyville deposition. The younger, Holocene dates cited by Pearson et al. (1986) and Aten (1983) actually represent flooding dates from peats that overlie Deweyville terrace deposits within incised valleys. The older dates are not likely to be accurate either. Terrace deposits are difficult to date, due to the younger material often found in the channel fill deposits and the inclusion of reworked older material. An additional consideration must be the independently derived sea level data. It is considered unlikely that sea level rose high enough during the stage 3 highstand to cause significant aggradation as far upstream as Deweyville deposits are found (Bloom, 1983). Thus, the precise age of Deweyville deposits is still unknown.

Morphological differences in the Deweyville terraces, especially the coarser sediment and the larger meander scars, are attributed by most authors to climate. A discharge rate of from five to seven times the present rate would be necessary to account for the size of the Deweyville

channels, according to Gagliano and Thom (1967) and Saucier and Fleetwood (1970). Increased rainfall (Bernard, 1950; Gagliano and Thom, 1967) and decreased evaporation (Alford and Holmes 1985) are thus seen as likely aspects of the climate during Deweyville deposition.

Baker and Penteado-Orellana (1977) caution that it is not just the amount of discharge that affects the wavelength of meanders. This also depends on the type of sediment carried. Larger wavelengths are associated with bed load streams, as indicated by Schumm (1969). Thus, Deweyville deposits could actually represent rarely occurring phases of high magnitude flooding in an arid climate.

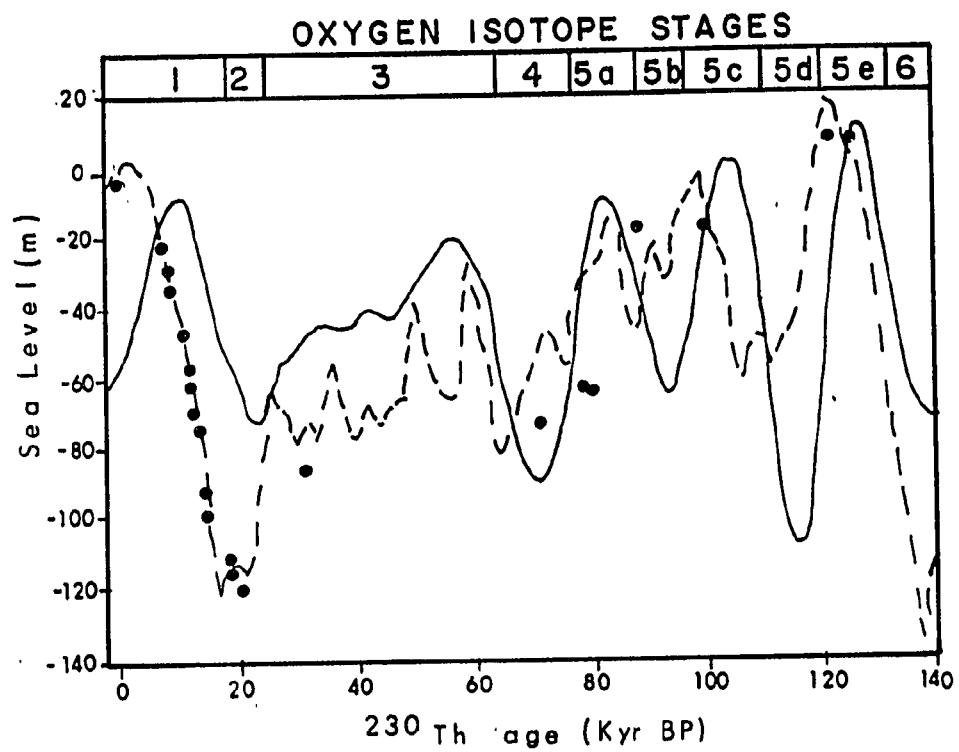
Quaternary Sea Level Studies

The use of oxygen isotope stratigraphy from planktonic and benthic foraminifera (Emiliani, 1955; Shackleton and Opdyke, 1973) and sea level records obtained from dated coral terraces (Fairbanks and Matthews, 1978) changes the understanding of Gulf Coast Quaternary stratigraphy. These methods provide a much more detailed record of sea level fluctuations, and they depict a sea level curve that is much more complex than was originally thought. Recent studies of offshore Gulf of Mexico sediments utilize this detailed sea level information to more accurately portray Gulf Coast Quaternary stratigraphy.

Correspondence between shifts in oxygen isotope ratios and Pleistocene glacial and interglacial stages was first proposed by Emiliani (1955). He established the concept of isotopic stages, assigning even numbers to glacial stages, when oceans were enriched in ^{18}O , and odd numbers to interglacials, when ^{18}O content of sea water was depleted and sea level was higher. Shackleton and Opdyke (1973) dated the isotope stages using paleomagnetic data. Emiliani's work on a number of different species from various cores established the oxygen isotope changes as world-wide phenomena. It is currently believed that 70 - 90% of the $\delta^{18}\text{O}$ signal is due to ice volume waxing and waning of continental ice sheets. The remainder is thought to be due to local temperature changes or local variation in precipitation and evaporation.

Radiometric dating of coral terraces demonstrates the relationship between sea level and the $\delta^{18}\text{O}$ signal (Fairbanks and Matthews, 1978). Sea level records for the last 140 ky, as determined by dated coral terraces and oxygen isotope records, are shown in Fig. 2-5. During the stage 5e highstand at 120 ka, sea level is thought to have been 6m higher than at present. Substages 5a and 5c are thought to represent sea levels at approximately 15m below present. Williams et al (1981) place the stage 3 highstand at approximately -40m. Values for the maximum sea level lowering of stage 2, which occurred 18 - 20 ka, vary from 90

Figure 2-5. (modified from Bard et al., 1990) Sea level record derived from U-Th dating of corals (*A. palmata*) (solid line). Dashed line is normalized $\delta^{18}\text{O}$ curve from Labeyrie et al. (1987).



to 175m below present (Mix, 1987). Bard et al. (1990) (Fig. 2-5) indicate a depth of -120m for stage 2 sea level, and this is corroborated by Fairbanks (1989).

Studies of Quaternary Shelf Deposits

Several studies of offshore Texas and Louisiana have incorporated detailed Pleistocene sea level information with analyses of sediments, paleontology, and seismic data (Winker, 1979; Suter et al., 1987; Morton and Price, 1987; McFarlan and LeRoy, 1988; Coleman and Roberts, 1988, Thomas, 1990). The outcome of three of these studies, (Winker, 1979; Coleman and Roberts, 1988; and Thomas, 1990) equates Beaumont deposition with the stage 5, substage 5e highstand, and deposition of Ingleside deposits within stage 5. Thomas (1990) correlates Deweyville deposits with stage 5c. These studies have not yielded consensus concerning the number of sequences since the Sangamon high stand or their correlation to sea level cycles (Thomas, 1990). Onshore work along the Texas Gulf Coast that is based on the continental glacial stages still needs to be re-evaluated. It is especially difficult to equate the pre-Sangamon glacial epochs and their corresponding formations (Fig. 2-3) to the $\delta^{18}O$ curves at this time.

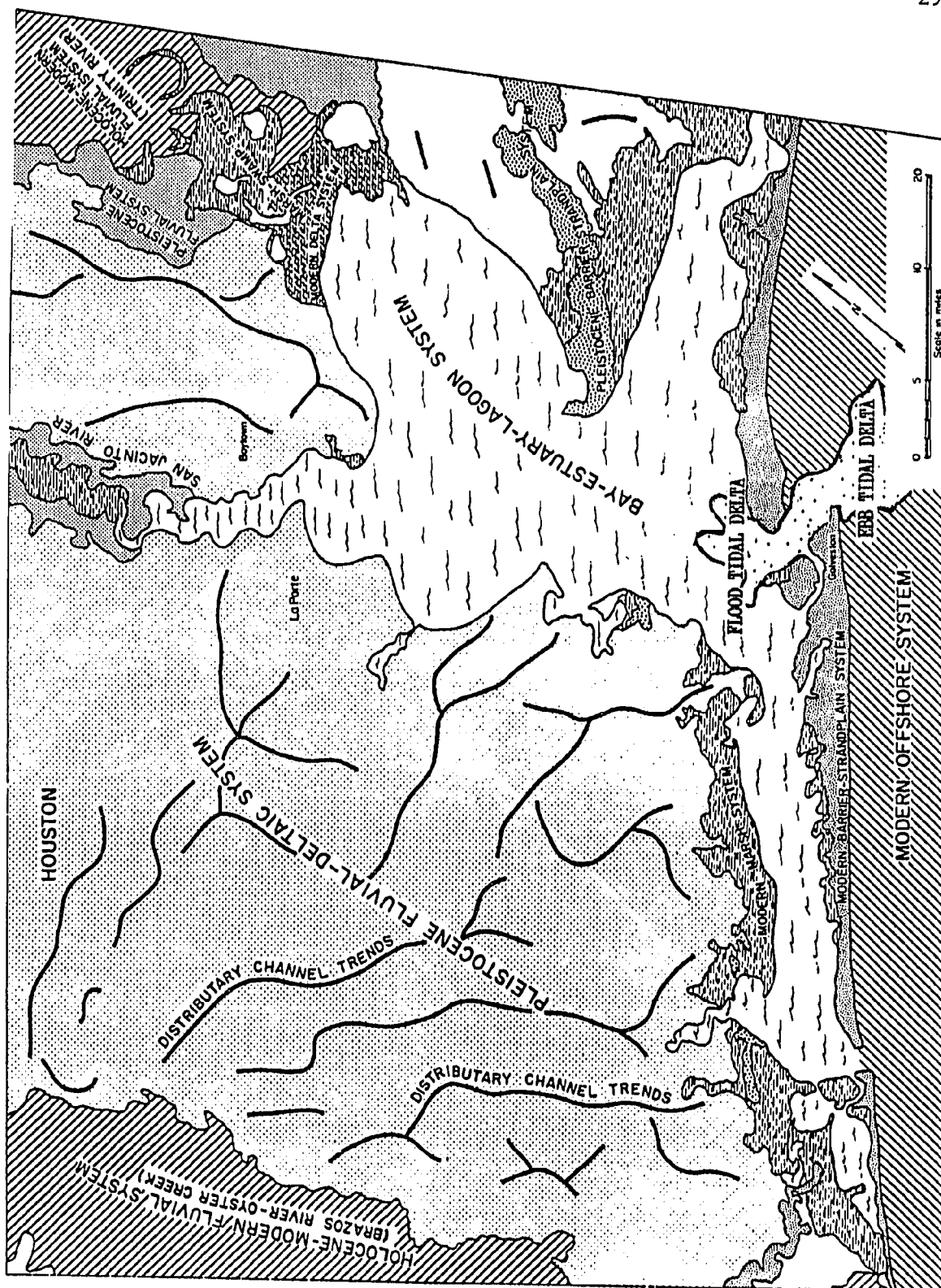
DEPOSITIONAL ENVIRONMENTS OF THE MODERN TRINITY RIVER AND GALVESTON/TRINITY BAY ESTUARY

The modern Galveston/Trinity Bay estuary is comprised of many depositional environments representing complex interactions between fluvial, estuarine, and marine processes (Fig. 2-6). In this section, the components of this system will be discussed individually. An understanding of the modern river and estuary is essential to understanding the makeup of the incised Trinity River valley and the sediments that fill the valley.

The Trinity River

The Trinity River flows through east Texas toward the south southeast, from north of the Fort Worth-Dallas area to Trinity Bay (Fig. 2-1). The sediment discharge rate for the Trinity River is relatively low compared to that of some other Texas coastal rivers, and it is confined to its incised valley. Trinity River sediments can be distinguished from those of other Texas rivers by comparing heavy mineral assemblages. The river delivers some of its sand to the Trinity bayhead delta, and much of the sand is deposited upstream from the Delta (Rice, 1969). Finer sediments are deposited in Trinity Bay. The morphology of the modern river valley reflects the history of the Trinity River from Late Pleistocene time to the present day.

Figure 2-6. Galveston Bay Area with associated depositional systems (from Fisher et al, 1972).



The Trinity River has the highest discharge rate of all the Texas rivers, but it has a small drainage area. Thus, with an annual silt load of approximately five to six million metric tons (Rice, 1969; LeBlanc and Hodgson, 1959), the Trinity River is considered to have a relatively low sediment load. A significant portion (eighty percent in 1965) of this sediment load is delivered during flood stages (Rice, 1969). Increased reservoir capacity along the Trinity River in the 1950's and 60's has decreased the river's sediment load to somewhere below 1,676,000 metric tons per year in the 1970's (Paine and Morton, 1986).

Like other smaller rivers in Texas, such as the Neches, Sabine, Guadalupe, and the San Antonio Rivers, the Trinity River drains a small area within and just adjacent to the coastal plain. Its sediment supply was not high enough to keep up with rising sea level during the last 10 k yrs. Thus the valley was flooded, forming the present-day estuary, and it is still confined to its incised valley. Other larger rivers (the Rio Grande, Brazos, and Colorado in Texas) have filled their valleys and are not presently associated with estuaries.

The Trinity River flows across sedimentary strata, and its heavy mineral assemblage is dominated by durable minerals (Bullard, 1942; Van Andel, 1960), predominantly zircon and kyanite (Cole and Anderson, 1982). Quaternary and Cretaceous sediments in the drainage area contribute

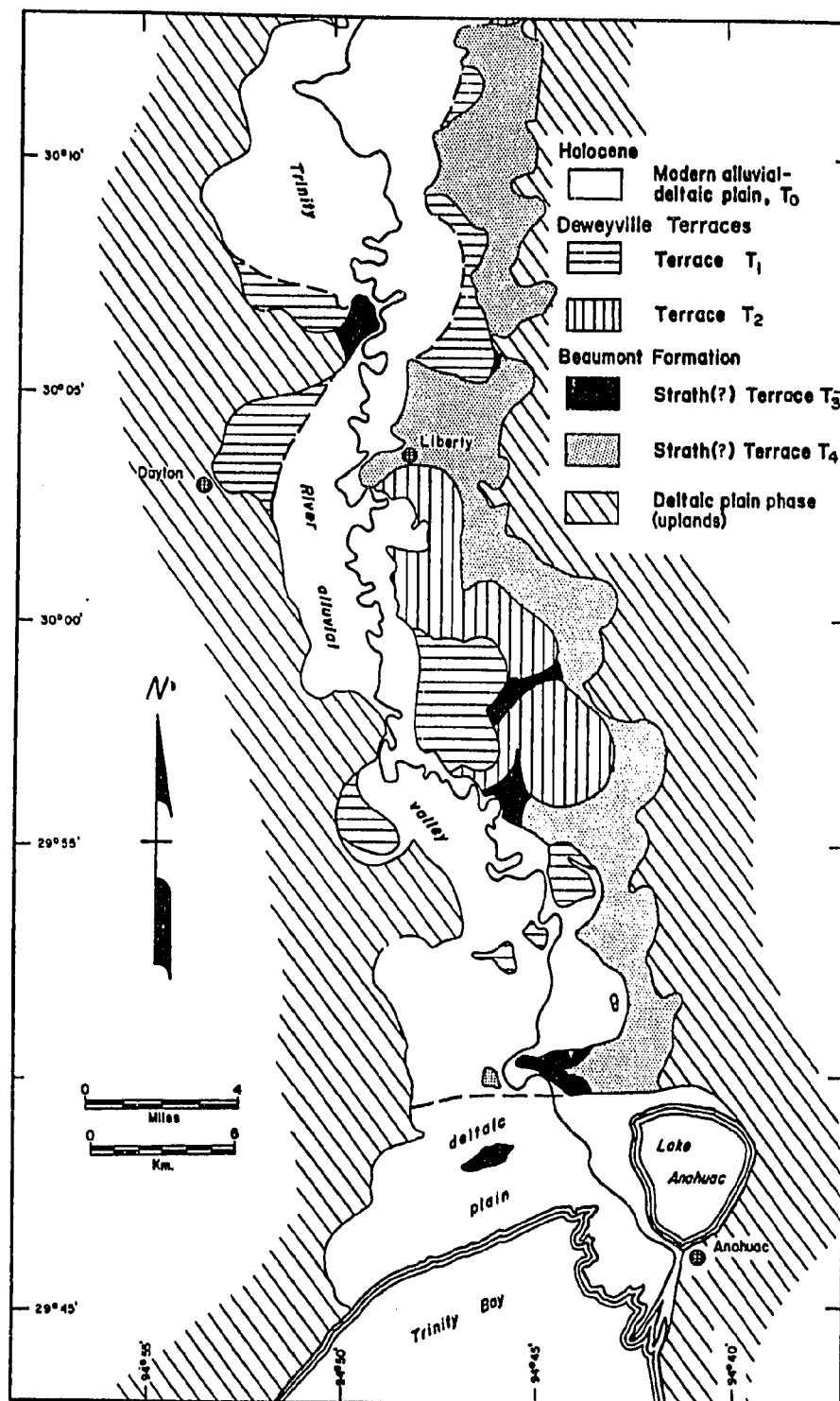
zircon and tourmaline to the sediment load. The kyanite comes from lower Tertiary sediments, along with staurolite and epidote. The light mineral assemblage of the Trinity River is quartzose (Van Andel, 1960).

Suspended sediments of the mixed-load Trinity River (25% sand, 30% silt, 45% clay) are deposited at or near the mouth of the river. Much of the clay is deposited in Trinity Bay. Some sand feeds the bayhead delta (McEwen, 1963), and much of the sand has been deposited in the lower Trinity river channel, contributing to the aggradation of the lower portion of the river (Rice, 1969).

Morphology of the lower Trinity River channel is shown in Fig. 2-7. Aten (1983) distinguished two Beaumont terraces and two Deweyville terraces on the basis of elevation, slope rates, and preserved geomorphic features. He considered the Beaumont terraces to be strath terraces, cut as sea level fell. The highest one is present along the entire east side of the valley. The lower one is only present intermittently. Meander scars and abandoned channels on these terraces are poorly preserved, and sediments are oxidized (Aronow, 1971).

Deweyville and Beaumont terraces along the Trinity River differ in elevation, gradients, channel geometry, preservation of geomorphic features, sediment textures, and origin. Aten's 1983 map shows two distinct Deweyville terraces. Other authors mapped additional Deweyville

Figure 2-7. Quaternary terraces and modern floodplain along the lower Trinity River, as mapped by Aten (1983).



terraces along the same stretch of the river (Aronow, 1971; Gagliano and Thom, 1967). Thus, these terraces are multilevelled, and their configuration varies from place to place along the river. Slope rates and statistics concerning channel geometry are presented in Table 2-1. Deweyville slope is greater than Beaumont (Aten, 1983), and the two fluvial surfaces merge 12 to 18 km inland (Gagliano and Thom, 1967).

The Trinity River apparently had much larger erosional capability, both laterally and vertically, during Deweyville time than it does presently, or than it had in Beaumont time. Meander scars from Deweyville time are very large (Table 2-1) compared to Beaumont and modern meander loops. Deweyville sediments have been found by investigators to be generally coarser than Beaumont or Recent sediments and less weathered. These terraces are thought to be constructional in origin (Gagliano and Thom, 1967; Aronow, 1971; Aten, 1983).

The Trinity Bayhead Delta

Bayhead delta deposits in the Galveston/Trinity Bay estuary are principally seen at the head of Trinity Bay, and are associated with the Trinity River. The San Jacinto River has no bayhead delta facies, because its lower reaches are so often dredged in order to maintain the Houston Ship Channel (Fisher et al, 1972). The subaerial portion of the

Geomorphic surface	Channel width (m)	Radius of meanders (m)
Present channel (T_0)	68	205
Younger Deweyville Terrace (T_1)	457	1195
Older Deweyville Terrace (T_2)	445	1320
Beaumont Formation Terrace (T_4)	155	594

Table 2-1. Channel dimensions, Trinity River floodplain and terraces (from Aten, 1983).

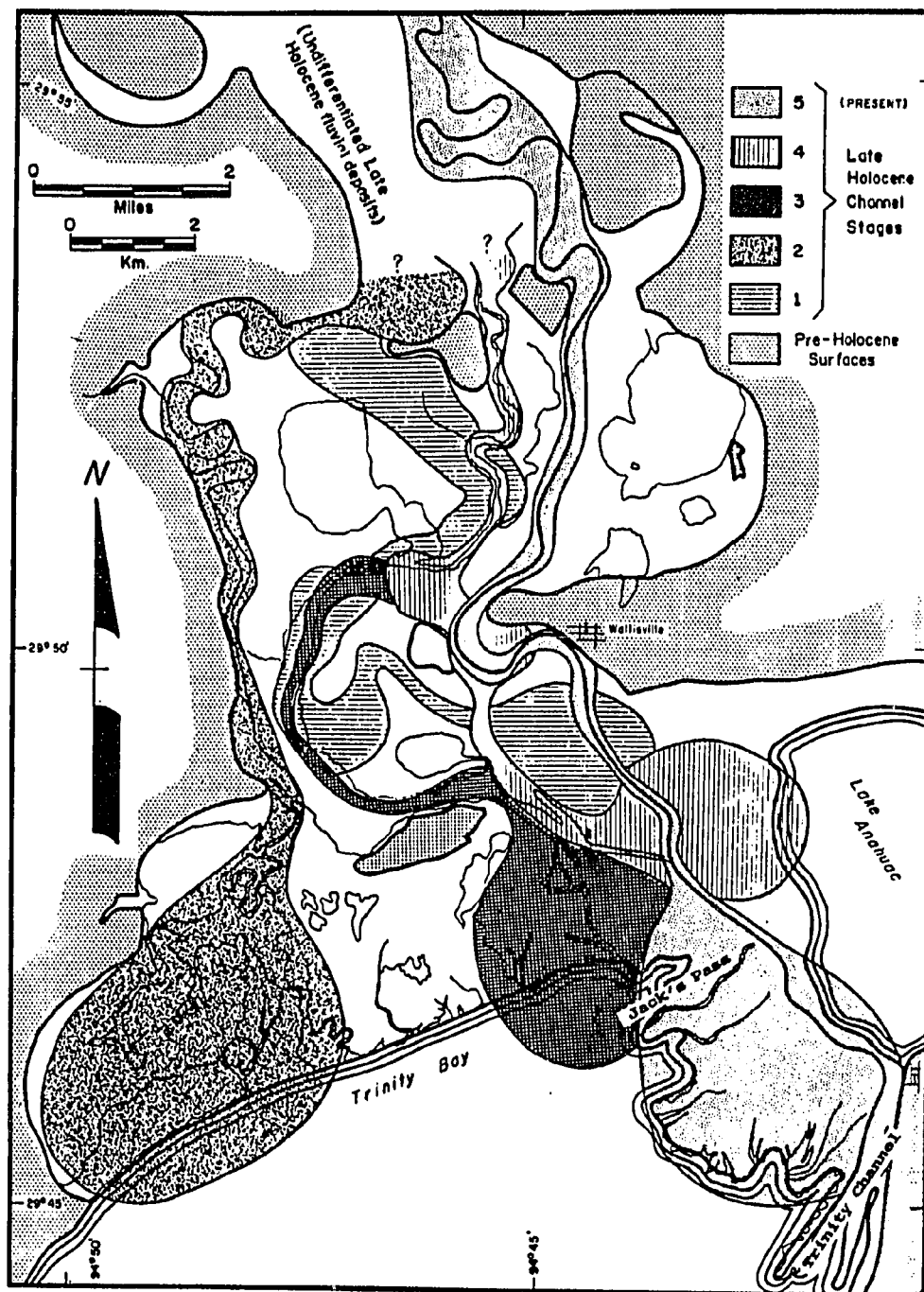
modern Trinity Delta (Fig. 2-8) covers approximately 16 km². The delta is only centimeters above sea level at the delta front and just less than a meter above sea level at the upstream portion (McEwen, 1963).

The present-day delta actually represents the last of five different locations of the delta in the last 2.6 k yrs, as mapped by Aten (1983). He compiled a map of the five channel stages from air photos, topographic maps, field work, and subsurface data from archaeological excavations and engineering borings. The five channel stages were dated by archaeological material found overlying the stage deposits.

There is little active flow through the Trinity Delta at the present time. The Trinity Channel is dredged well out into Trinity Bay, and most of the present-day flow is through this channel. With the exception of Jack's Pass, all other distributary channels are blocked by logs or filled with sediment. Thus, most of the sand delivered to the delta is dredged away, and the delta front receives very little new sand (McEwen, 1963).

McEwen (1963) studied approximately 175 short cores (less than one meter in length) to describe the facies of the modern Trinity Delta. To summarize, he found that the delta is comprised of a coarsening up sequence of dark muds. Wood fragments are present locally throughout the sequence, and there is abundant shelly material in the pro-delta and

Figure 2-8. Channel stages and locations of bayhead delta deposits of the Trinity River since 2.6 ka (from Aten, 1983).



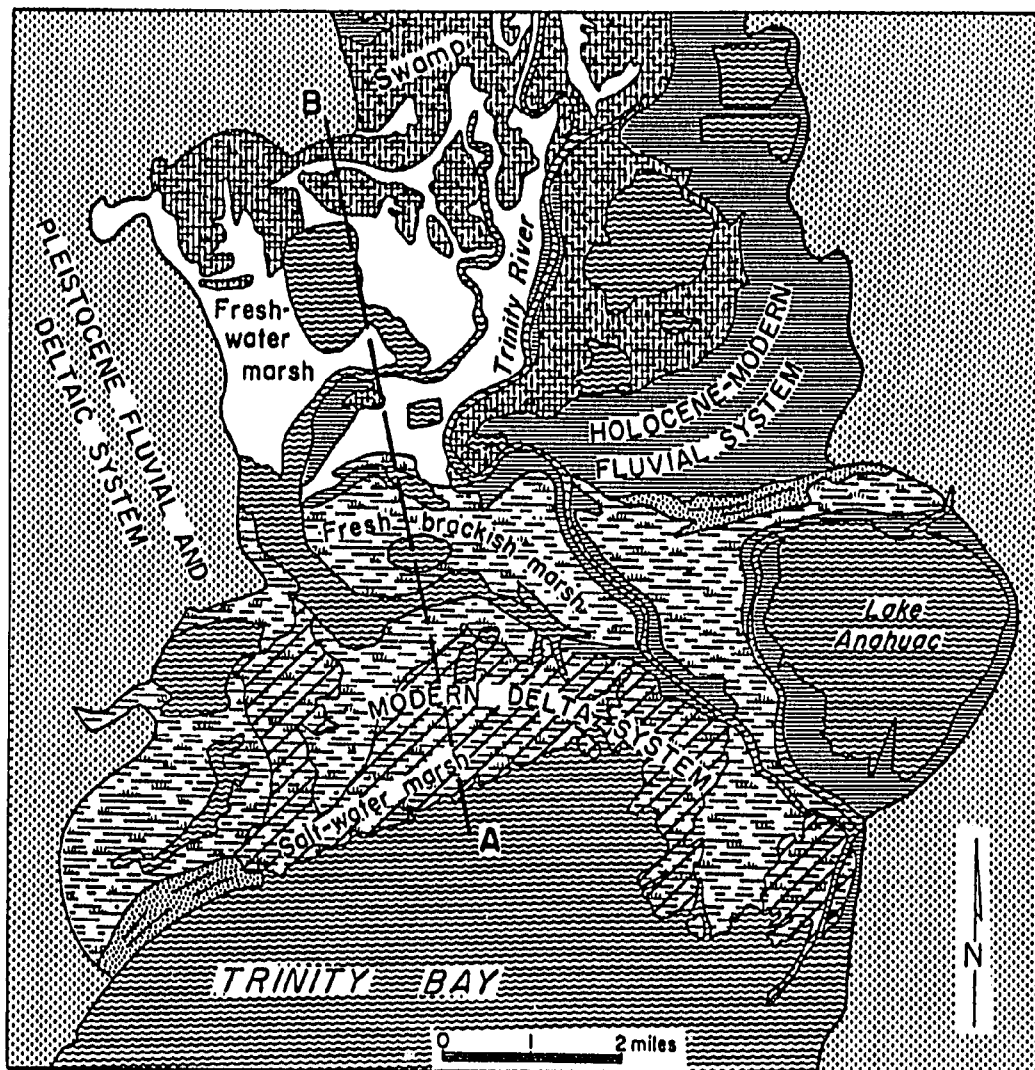
delta front environments. Most of the contacts between environments are gradational, except for the estuary - pro-delta boundary. These two environments are virtually alike, and no boundary can be distinguished between them.

McEwen's 1963 study also included an interpretation of the lateral and vertical relationships between deltaic facies, based on data from 121 longer cores (10-12m in length). He saw a relatively thick (2-3 m) delta front sand body covered by a thin but extensive veneer of marsh deposits. In the northeast part of the delta, as well as in Lake Anahuac, some of the cores encountered Pleistocene deposits at depths of approximately 16 m, overlain by fluvial and estuarine deposits, which in turn lie below the present-day delta. Of the seven radiocarbon dates obtained from these cores, the oldest dates were 810 and 750 years B.P. obtained from sediments underlying the delta front in the northwest part of the delta.

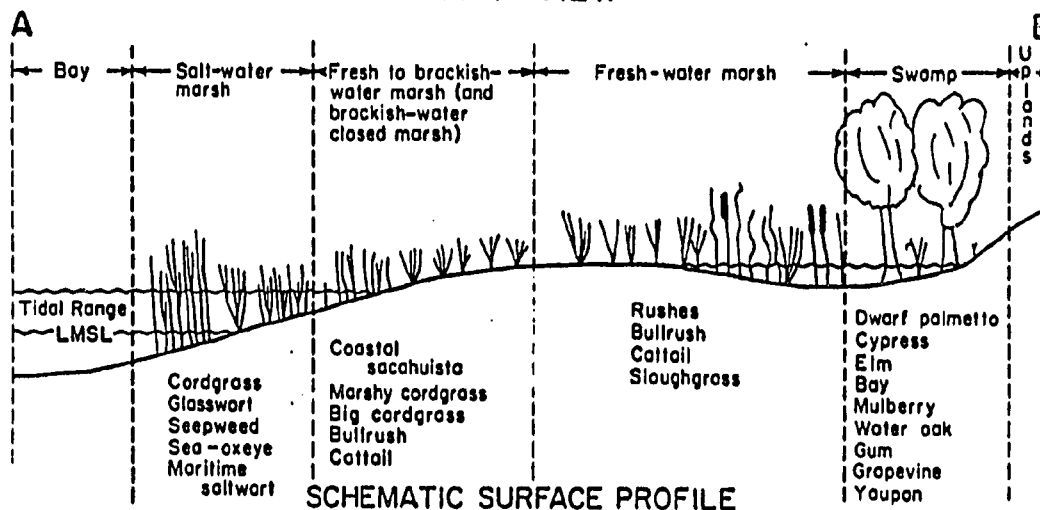
The Marsh

Marshes and swamps occur in low lying areas (usually less than two meters above sea level) all around the margins of the Galveston/Trinity Bay estuary. Of interest for this study are the marsh and swamp areas which overlies the Trinity bayhead delta. As can be seen in Fig. 2-9, there is very little area of the modern delta and the lower reaches of the river that is not covered by marsh or swamp. Salt

Figure 2-9. Modern marsh systems, Trinity River and Bayhead Delta (from Fisher et al, 1975).



MAP VIEW



SCHEMATIC SURFACE PROFILE

water thru brackish-water and fresh-water marshes overlie the delta. Fresh water marshes and swamps are found along the flood plain, and in the abandoned channels and cutoffs of the terrace deposits (Fisher et al, 1972).

The Galveston/Trinity Bay Estuary

In Galveston and Trinity Bays (as well as East and West Bays), fluvial and marine environments meet to create the estuary, which is a unique entity. Receiving sediments from a variety of sources, and affected by coastal wind, wave and tide conditions, the estuary has its own unique circulation pattern, salinity gradients, seasonal conditions, flora and fauna, and depositional environments. Distribution of sediments, flora, and fauna are most important for this study. An explanation of the processes that operate within the estuary is also provided so that the system can be understood as a whole. This allows comparisons to be made between Galveston and Trinity Bays and estuaries that exist under various other conditions of climate, tidal influence, sedimentary input, etc.

Sediment Sources

There are three principle sediment sources for the estuary: 1) The most abundant sediments are those eroded from the bay margin (LeBlanc and Hodgson, 1959). The fine particles are carried by circulating waters, and the sands

often form shoals along the bay margin. 2) Fluvial sources include the Trinity and San Jacinto Rivers and other small streams and creeks. 3) Marine sediments are found mainly in washover fans and flood-tidal deltas, but may be picked up and circulated by estuarine currents (Paine and Morton, 1986).

Estuarine Circulation and Deposition of Sediments

Many physical factors contribute to the water circulation and deposition of sediments within the estuary. Wind, waves, tides, and fluvial input exert continual influence on estuarine circulation. Seasonal variations in storm and salt-wedge activity modify circulation and deposition within the estuary. Other modifying factors include human activities, such as dredging, bulkheading, and the building of obstructions. Despite modern interference with depositional patterns, the present estuary can be used as a model to understand older estuarine deposits found within the incised valley.

Winds are most important for bay circulation because the bay is very shallow, averaging 2-3m in depth over most of the bay area, and the tidal inlets are small (McGowen and Morton, 1979). Winds generate waves known as wind tides, which often pick up and resuspend bottom sediments, thus reinitiating them into circulation. Shoreline deposits down wind from principal wind tides are common. Southeasterly

winds predominate for most of the year, but northerly winds are prevalent in winter months.

Tidal effect is mostly seen at the tidal inlet, where marine sediments are carried into the estuary, and sands are deposited at the inlet, forming the flood tidal delta. Fine sediments are carried into the Gulf to be transported downdrift by longshore currents (Morton and McGowen, 1980).

Fluvial-influenced fresh-water surface currents are important during periods of high river discharge. At these times, a fresh-water head occurs at the bayhead, which decreases toward the Gulf. The result is strong surface currents at ebb tide.

Salinity within the estuary varies seasonally. There is greater marine influence during the dry summer months when there is less runoff and fluvial input. The position of the salt wedge, dense salt water that under-rides the lighter brackish water of the bay, varies with the climate, moving up or down the estuary as the conditions become drier or wetter, respectively. The salt wedge causes greater retention of sediment within the estuary.

Storms exaggerate patterns of erosion and deposition within the estuarine system. Hurricane storm surge erodes bay margins and carries sediment onshore into marshes and other low lying areas, where it is deposited. Breached barriers cause marine sediments to be introduced into the estuary. Storm surge additionally increases resuspension of

sediments. The surge changes direction as the storm moves on land, and the eroded and resuspended material is carried out to the Gulf. Heavy rainfall associated with hurricanes causes flooding of rivers, leading to increased deposition in the bay and a layer of fresh water and suspended sediments that moves out to the Gulf (Hayes, 1967, and McGowen and Scott, 1975). Winter storms are less intense than hurricanes but contribute significantly to erosion of the bay margin. Together, hurricanes and winter storms account for most of the shoreline erosion in the Galveston Bay area (Paine and Morton, 1986).

Sediments within the estuary are mostly homogenous to mottled silty clays that are locally sandy and/or shelly. Bay margins are sandy. Reef margin sediments are shelly and locally sandy. Tidal inlet deposits are interbedded fine sands and clays with shells (Rehkemper, 1969). Lateral accretion is characteristic for this environment.

Rehkemper (1969) studied and analysed sediment cores to describe the modern depositional environments within Galveston and Trinity Bays and the fluvial and estuarine environments of the Trinity/San Jacinto River incised valley. He distinguished between the environments by detailing the sediment characteristics and fauna of each one. Table 2-2 summarizes this aspect of his work. Much of the work of this thesis relies on his descriptions and interpretations of these sediment cores.

Sediment Facies	Types of Sediment	Textures	Sedimentary Structures	Coarse Fraction Constituents	Diagnostic Fossils
Fluvial	Sandy gravels, muds, silts, and clays	Gravelly sand to medium silt, well to very poorly sorted	Microcrossbeds, silt laminae, clay inclusions	Nearly 100% terrigenous; silt shell and plant fragments; calcareous, ferruginous nodules	Reworked and worn fragments of <i>Rangia</i> , <i>Crassostrea</i> ; and Cretaceous and Tertiary fossils: <i>Proceramus</i> prisms, <i>Radiolaria</i> , <i>Foraminifera</i>
Marsh	Medium to dark gray, silty clays with abundant plant material	Silty clay to clay, traces of sand, poorly sorted	Irregular beds of varying thickness, burrowed, whole to macerated plant layers	Inverse plant to terrigenous ratios, plants from 20% to 99%; calcareous, ferruginous and manganese nodules	Fresh to brackish water diatoms, rare <i>Ammonia</i> , <i>Elphidium</i> and <i>Trochammina</i>
Natural Levee	Variable, muddy sand to organic silty clay	Clayey sand to silty clay, moderately to poorly sorted	Homogeneous, nonbedded	Predominantly terrigenous; 1-14% plant material; calcareous nodules to 5%; rare ferruginous, manganese nodules, gypsum crusts	Similar to marsh subjacities, but lacks agglutinated <i>Foraminifera</i>
Upper Bay Transgressive	Medium gray silty clays, traces of sand	Silty clays and mixtures of sand-silt-clay, poorly sorted	Massive homogenized with some mottled beds, burrowed	Largely terrigenous; abundant plant fragments; relatively abundant <i>Foraminifera</i>	Abundant <i>Rangia</i> ; rare <i>Crassostrea</i> , <i>Brachidontes</i> , <i>Trochammina</i> , <i>Elphidium</i> , <i>Eponidella</i> , <i>Ammonia</i>
Upper Bay Regressive	Same as Upper Bay Transgressive	Same as Upper Bay Transgressive	Same as Upper Bay Transgressive	Predominantly terrigenous; rare plant fragments <i>Foraminifera</i> , relatively abundant diatoms, ostracods, and tube worms	Abundant <i>Rangia</i> ; rare <i>Crassostrea</i> , <i>Brachidontes</i> , <i>Ammonia</i> , <i>Elphidium</i>
Middle Bay	Medium gray silty and sandy clays, quite shelly	Silty clay and sandy clay, poorly sorted	Massive, homogeneous to mottled, oyster reefs	Characteristic large amounts of <i>Crassostrea</i> shells and fragments	<i>Crassostrea</i> , <i>Brachidontes</i> , <i>Bryozoa</i> , barnacles, abundant <i>Ammonia</i> , <i>Beccarii</i> , <i>Elphidium</i> <i>gunteri</i> , rare <i>E. poeyanum</i> , <i>E. matagordantum</i>
Lower Bay	Medium gray sandy mud	Silty clay, clayey silt and sand-silt-clay, poorly sorted	Homogenized to mottled, burrows common	Relatively abundant <i>Foraminifera</i> ; rare echinoid fragments	<i>Elphidium</i> <i>gunteri</i> , <i>E. discoidale</i> , <i>E. poeyanum</i> ; diverse milleolids
Inlet-Beach	Tan to gray muddy sands	Silty sand to clayey sand, moderately sorted	Typically homogeneous but with occasional thin interbeds of clay, sand, and shell	Abundant terrigenous sand; relatively common glauconite, worn shells, <i>Foraminifera</i> , echinoid fragments	Diverse macro- and micro-fauna, mixture of marine and lagoonal genera and species

Table 2-2. Sediment facies characteristics in Galveston and Trinity Bays (from Rehkemper, 1969).

Fauna

A good estimation of relative position within an estuary can be based on fauna. Modern bay faunal assemblages are mostly tied to salinity and temperature. Important bay species that live within a definite salinity range are *Rangia* and *Crassostrea* (oysters). Oysters do best within a salinity range of 10-30 ‰. Salinities greater than 36 ‰ affect their growth, and they are killed by fresh water. Oyster reefs are usually elongated perpendicular to the shoreline. *Rangia* are found in low salinity (<9‰) waters usually indicative of upper estuary-to-bayhead environment (Ladd et al, 1957).

Wantland (1964) characterized salinity variations within Trinity Bay by studying the ratio of agglutinated to calcareous forms of foraminifera. The agglutinated river-influenced species, *Ammotium salsum*, dominates the bayhead population, while *Ammonia beccarii*, the dominant marine-influenced calcareous species is most abundant in the lower portion of Trinity Bay. *A. beccarii* has optimum growth within a salinity range of 20-40‰. No reproduction occurs in this species below 7‰, and no growth occurs above thirty-five degrees Centigrade (Wantland, 1964).

Other species of foraminifera, *M. fusca* and the various species of the genus *Elphidium*, are indicative of certain environments within Galveston and Trinity Bays. While *M. fusca* has been considered a marsh species (Phleger, 1960),

it was found to be restricted to marginal areas of the Trinity Delta by Brann (1969). *Elphidium* appears to be associated with marine water, as its distribution is similar to that of *A. beccarii* (Wantland, 1964).

CHAPTER 3 : METHODS AND DATA

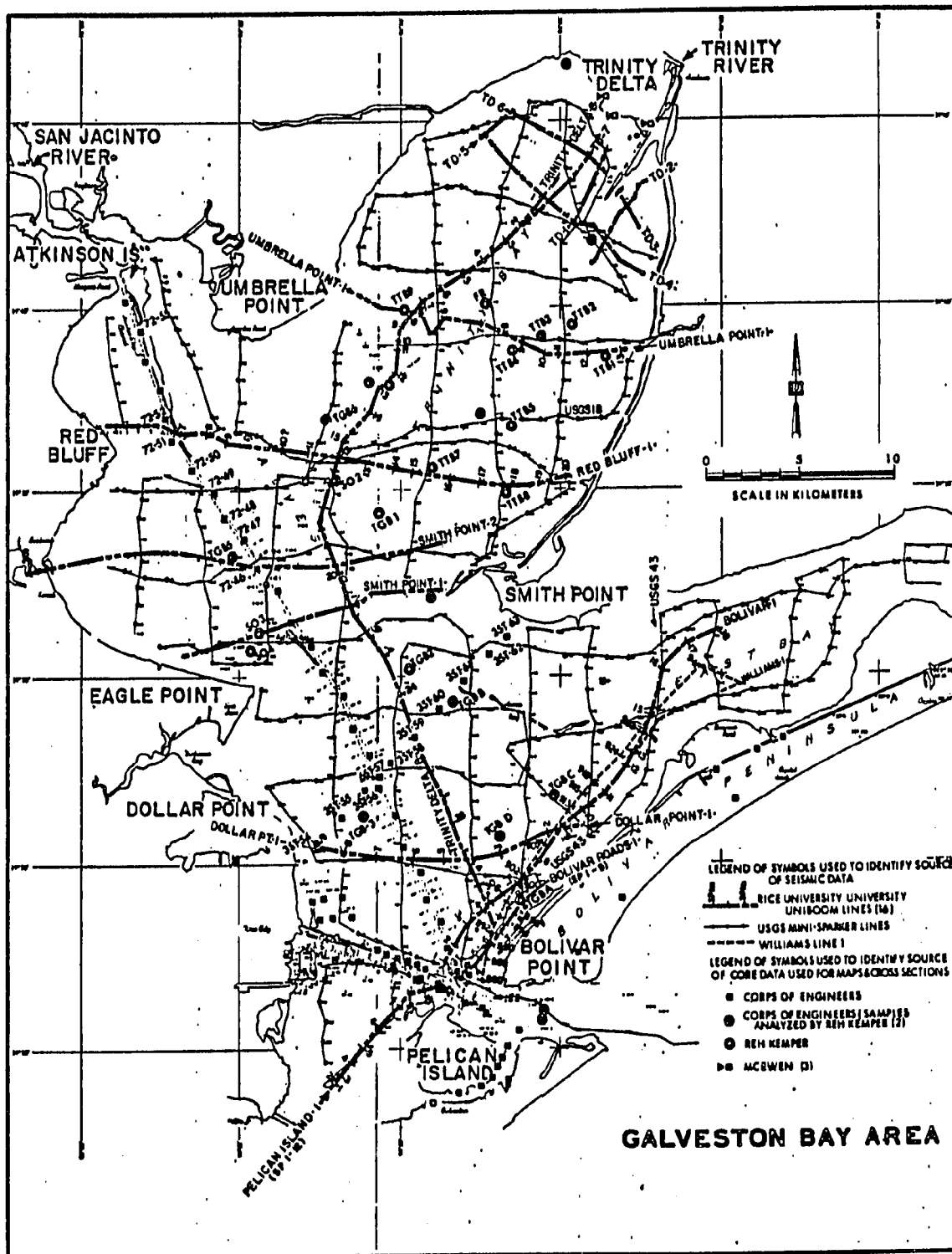
This study began with a set of uninterpreted seismic lines and many core descriptions (Fig. 3-1). Depositional environments were interpreted using the core descriptions, and this information was tied to the seismic data. Some features, especially modern depositional environments, were initially identified on the seismic data. All of this information was used together, and the interpretation evolved in an iterative fashion, as each new understanding shed light on the project as a whole.

SEDIMENT CORES

Sediment core descriptions were studied first for an overall view of the incised valley and its fill. Core information was from two sources:

- 1) The U.S. Army Corps of Engineers in Galveston, Texas provided lithologic descriptions and stiffness measurements from foundation and platform borings.
- 2) Similar information came from Rehkemper's (1969) dissertation. He used cores collected specifically for his study as well as samples provided by the U. S. Army Corps of Engineers and McClelland Engineers, Inc. In addition to sediment descriptions and stiffness measurements,

Figure 3-1. Data used in this thesis.



Rehkemper's work on his sediment samples included grain size analysis, coarse fraction analysis, foraminifera population counts, carbon-14 dating, and x-ray radiographs of selected cores. Core depths varied from nine to fifty-four meters. Thus, many cores penetrated the entire incised valley-fill sequence and went into Pleistocene sediments.

Rehkemper's (1969) interpretations (See Table 2-2.) were adhered to in choosing environments of deposition down-core when such interpretations were the result of sedimentological and paleontological analysis on sediment samples from those cores. Some of Rehkemper's borings did not have sedimentological studies to back up his interpretations, and he studied most of the Corps of Engineers boring logs without access to samples. In such cases, the following interpretative scheme was used:

estuary - soft muds, usually gray, possibly silty or sandy, usually with vegetation and/or shells, especially clams or oysters, possible *Rangia* in upper estuary, sand lenses and sandy near tidal pass.

marsh - dark peaty clay, carbonaceous mud

floodplain/overbank - stiff, very sandy silty clay,
often with wood and/or other organic material

fluvial - fine to coarse sand with gravel

Pleistocene - stiff brown, blue, tan, gray, or olive
clay with calcareous nodules.

Rehkemper's radiocarbon dates were used in this study to understand the timing of the formation of Galveston and Trinity Bays. Dates used are listed in Table 3-1.

SEISMIC DATA

Mini-sparker data, which has resolution of up to 5-10 m and penetration of 200-300 m, was used to study the shape of the incised Trinity River valley. An extensive grid of mini-sparker lines, shot in 1977, was obtained from the U.S. Geological Survey in Corpus Christi, Texas. These half-second records provided good penetration through and well beyond the Pleistocene surface.

Uniboom lines, collected aboard Rice University's research vessel R/V Matagorda, provided information about the sediments filling the incised valley. An additional uniboom line from the Williams et al (1979) study of the continental shelf in the Galveston area was used. The Rice University seismic records are 120 msec in length, and band-pass filters were set at 300 and 2500 Hz. Radar was used to mark shot point locations. Identifiable points of land and/or channel markers, production platforms, or other fixed objects were sighted on the radar screen, and the boat's location was determined in reference to those points. Thus, considerable error is involved in the location of shot points on the seismic lines.

Core Location	Depth (Subsea)	Age (yrs BP)	Description
TGB-C	23m	10,207	peat
TGB-A	23m	9,370	peat
TGB-A	22m	7,975	peat
TGB-D	16m	7,968	<i>Rangia</i>
TGB-5	16m	7,646	peat
TGB-6	14m	7,689	peat
TTB-4	6m	4,353	<i>Crassostrea</i>
TTB-5	6m	3,920	<i>Rangia</i>
TGB-2	7m	3,690	T.O.C.
TTB-2	5m	1,372	<i>Rangia</i>
TTB-3	5m	2,588	<i>Rangia</i>

Table 3-1. Radiocarbon dates from Galveston and Trinity Bays (from Rehkemper, 1969).

The uniboom was chosen as the most suitable seismic source for studying near surface sediments. It has no bubble pulse, thus sediments at and near the surface can be imaged without interference. The resolution of the uniboom allows the study of near-surface sedimentary environments in detail.

Rapid motion of a flat aluminum plate against the water produces the acoustic signal of the uniboom. The uniboom is towed on a catamaran behind the boat, so wave motion affects the quality of the recorded seismic data. Calm days and steady maneuvering of the boat were, therefore, important elements of good quality uniboom data collection. Source and receiver parameters were varied depending on the weather and on water bottom conditions. Output of the power supply varied from 200 to 500 joules. Very shallow water, frequently encountered in upper Galveston and Trinity Bays, posed an especially difficult problem for data acquisition. Sometimes an eight element streamer was used, but often the best data resulted from the use of a single hydrophone receiver. The resulting data has resolution of up to 50 cm, allowing sedimentary structures to be clearly seen on many segments of these seismic lines.

INTERPRETIVE PROCEDURES

The interpreted core information was tied to the seismic data, and the two sets of data were studied together

and compared. The correspondence between the USGS mini-sparker data and the Rice uniboom data was double-checked by measuring the time to a very distinctive feature seen on both sets of data, and the correspondence is excellent. A velocity of 1500 m/sec was used to tie the seismic and core data together.

Analysis of seismic sequences, according to the principles developed by Vail et al (1977), places the sediments in this study within the framework of Gulf Coast Quaternary stratigraphy. A sequence is a genetically related package of sediments bounded by unconformities. A sequence corresponds to deposition within a sea level cycle from the inflection point of one sea level fall to the next (Posamentier et al, 1988). Sequence boundary unconformities are related to falling sea level, and in the study area, to incision of the river valleys and subaerial exposure of alluvial plain and shelf sediments. Transgressive sedimentation is also evident within the incised valley, and it is seen in two forms. 1) There are aggradational deposits associated with the transgressions of a lowered sea level, when the Galveston/Trinity Bay area was considerably upstream from the shoreline. 2) The Holocene valley-fill deposits are fluvial and estuarine in origin. They are bound by flooding surfaces, which are evidence of a rapid deepening of water depth. Each transgressive sediment

package thus bound is a parasequence (Van Wagoner et al, 1988).

CHAPTER 4: RESULTS OF SEISMIC STUDIES: FACIES ARCHITECTURE OF GALVESTON TRINITY BAY AS AN INCISED VALLEY SYSTEM

The morphology of the deep river valley underlying Galveston and Trinity Bays is the result of fluvial incision and aggradation associated with the sea level cycles since the substage 5e highstand. These cycles followed the deposition of the Beaumont alluvial plain approximately 120 ka (Winker, 1979). Subsequent lowering of sea level resulted in deltaic sedimentation along the Gulf Coast and river incision. Deweyville aggradational fluvial sediments were deposited as sea level rose again, completing a sea level cycle, probably a 20k yr cycle during the stage 5 interglacial (Thomas, 1990). Reincision through these deposits left behind Deweyville terraces within the incised valley. Ultimately, the shoreline was translated to the present-day shelf margin, and the modern Trinity/San Jacinto incised river valley was carved, 18k yrs B.P, as sea level fell to approximately -120 meters below its present level (Fairbanks, 1989). The valley is bound by Sequence Boundary 2. The Holocene sea level rise caused the flooding

of the modern river valley and thus, formation of the Galveston/Trinity Bay estuary.

SEISMIC EXPRESSION OF THE INCISED VALLEY AND ITS FILL

The purpose of this section is two-fold. 1) Sediment descriptions and seismic lines are presented which support and clarify the seismic interpretation in this thesis. 2) Also presented are seismic lines that demonstrate the utility of using uniboom data to identify fluvial and estuarine depositional environments. Many seismic lines are included to provide the reader with examples of the seismic expression of various depositional environments. The data presented are representative of the data set as a whole. They are in most cases the best or most representative example of a given feature.

Recognition of Unit Boundaries

In this section, the seismic interpretation will be developed as a number of specific examples from the data set are presented. The interpretation began with the core descriptions. The Beaumont erosional surface is indiscernible on most of the seismic lines, so it was usually first picked in the cores. Cores were also relied upon for the depth to floodplain sediments and to the lower boundary of the river valley because sediments within the deep valley are not imaged on the seismic data. Once the

seismic character of the deep valley was understood, the seismic data could be used to identify the trace of the incised valley beneath the estuary.

The extent and nature of the terrace deposits were most readily identified using the seismic data. Deweyville deposits have a distinctive seismic character that was confirmed by cores to be sandy fluvial deposits. Fluvial terrace deposits bound by Sequence Boundary 6 are seen on many of the Trinity Bay seismic lines. These terraces are overlain by transgressive deposits which are terminated above by a ravinement surface. The relationship of these sediments to the Quaternary sea level curves was determined by careful interpretation of the seismic data.

The Beaumont surface, such as the one seen on the eastern portion of Umbrella Point Line 1 (UP1) (Fig. 4-1, Fig. 4-3 for location), was first interpreted by core information. Of the four core descriptions present along this segment of the seismic line (Fig. 4-2), three (TTB-1, TTB-2, and TTB-3) are very similar. In each of these cores, soft shelly clays overlie stiff yellow-gray clay, with shell lags at the top and caliche nodules throughout. The top of the stiff clay zone, interpreted by Rehkemper (1969) to be Beaumont clay, ranges in depth from four to seven meters.

The other cores seen in Fig. 4-2 are within the incised valley, and cores TTB-4 and TTB-9 are near the valley's edges. Core FR, which is near shot point 7 of Line UP1, is

Figure 4-1. Segment of Umbrella Point Line 1. Sediment cores TTB-1, 2, and 3 were used to determine the contact between Beaumont terrace and modern estuary deposits.

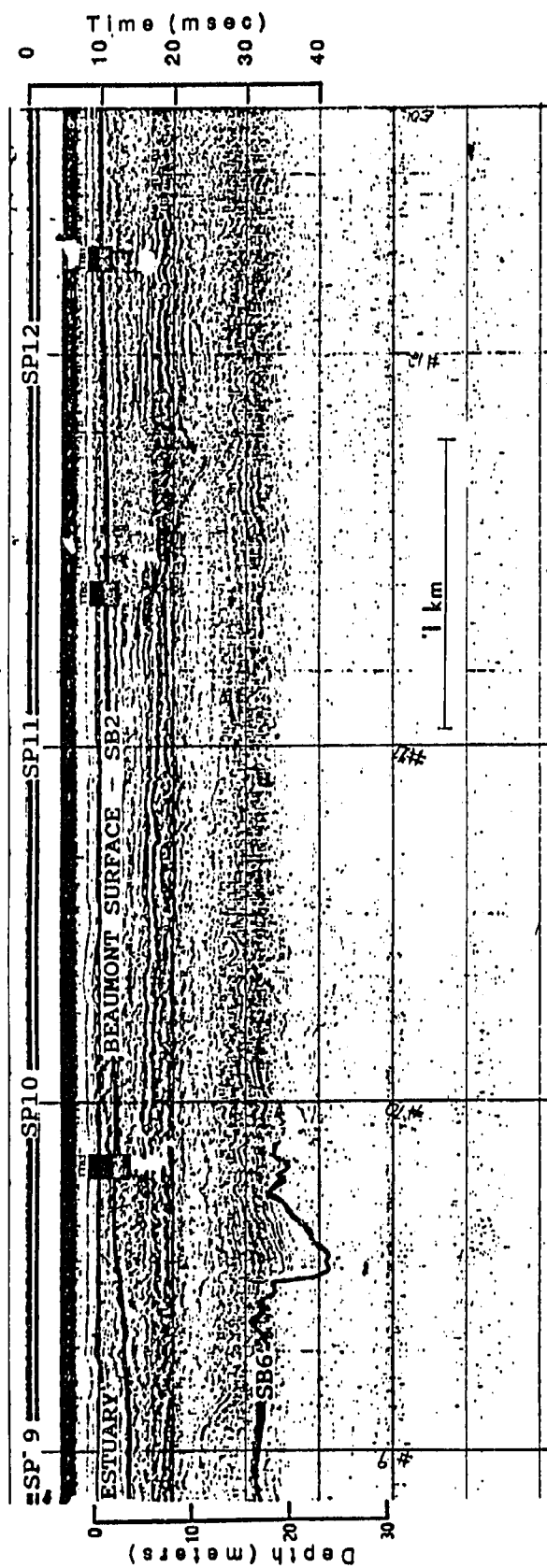
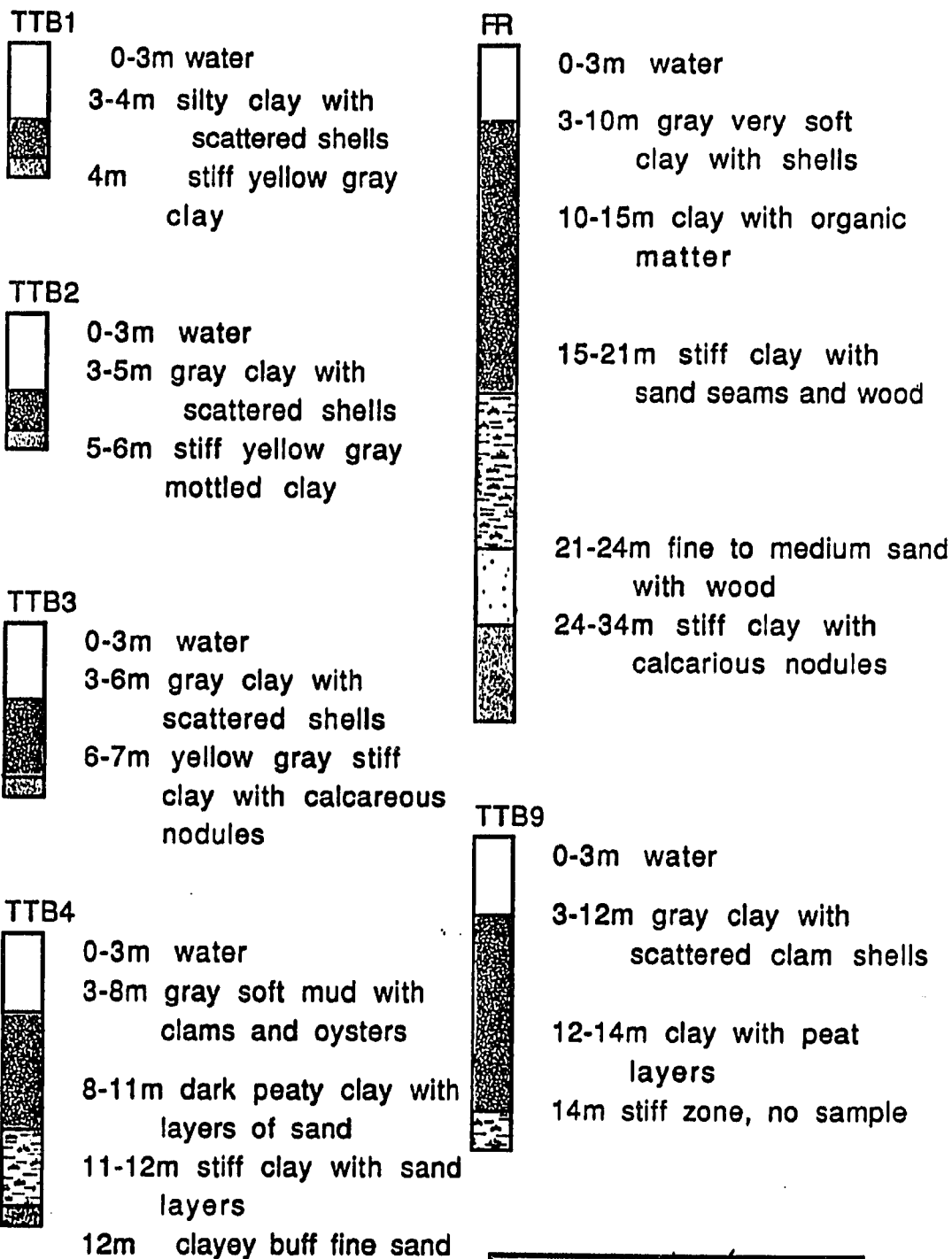


Figure 4-2. Descriptions of sediment cores along Umbrella Point Line 1.



ENVIRONMENTS



Estuary



Fluvial sand

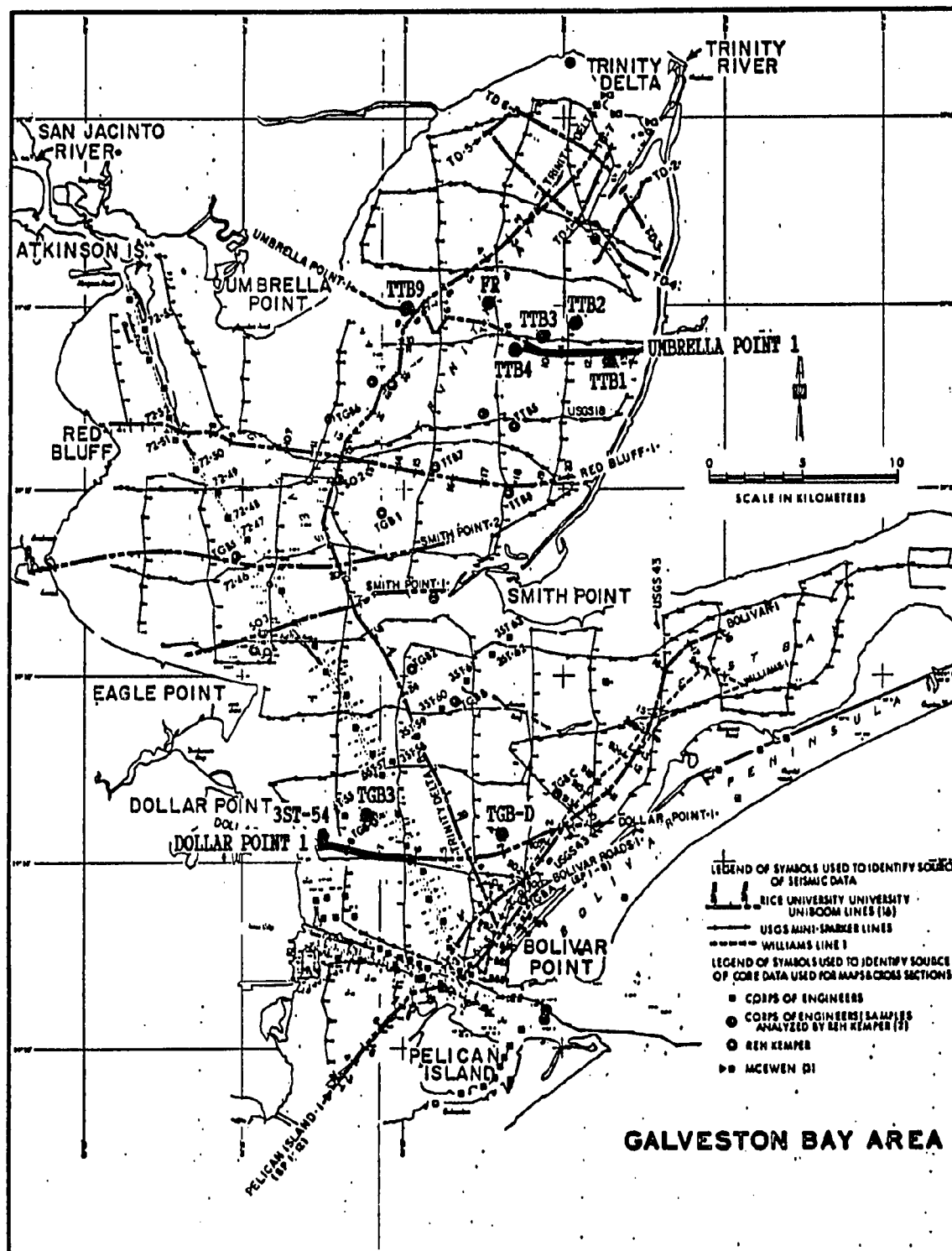


Marsh/Floodplain



Pleistocene clay

Fig. 4-3. Locations of Umbrella Point Line 1 and Dollar Point Line 1.



a deep core that encountered very stiff tan and gray clay at a depth of 24 m. Above this stiff zone, the sediments consist of 3 m of sand overlain by 7m of stiff clay with sand seams and wood, and then 14m of soft shelly mud with organic matter. This core probably represents estuary overlying marsh, then aggradational floodplain, fluvial sand, and then Pleistocene sediments. Stiff clay, probably Holocene floodplain, was encountered at a depth of 14 m in core TTB-9, and this was overlain by 2 m of peaty clay and 12 m of soft estuarine mud. Core TTB-4 has dark peaty clays and stiff muds from 8-11 m, then sand at the bottom of the core (12 m). Considering the depth to this sand, it is difficult to determine whether this is Deweyville or Holocene floodplain. These cores contrast with the sediment cores taken on the Beaumont terrace (TTB-1, 2, and 3), in which the estuarine muds lie directly above Beaumont clay at shallow depths.

Line UP1 (Fig. 4-1) illustrates the seismic character of the Beaumont terrace and the deeper valley. The seismic line is relatively featureless from s.p. 13 to 8, consisting of flat-lying reflectors with only slight changes in amplitude or frequency content. The unconformity between Beaumont deposits and estuarine sediments is difficult to see due to the similarity between the reflection character of the two units. Thus, cores TTB 1, 2, and 3 provided the

necessary information to accurately pick the Beaumont surface along this seismic line.

Core FR indicates the presence of Holocene floodplain deposits near s.p. 7 of line UP1. At s.p. 8, all seismic reflection character is lost. Dissolved methane gas in the interstitial waters of the floodplain deposits causes such a loss of seismic reflections, which is characteristic for the deeper part of the incised valley (Whelan et al, 1975).

The shallow erosional Beaumont surface can be seen on the west side of Galveston Bay on Dollar Point Line 1 (DP1). Notice the reflector which cuts into flat-lying reflectors on the line segment reproduced in Fig. 4-4 (Fig. 4-3 for location). The erosional Beaumont surface can be readily identified on Line DP1 near shot points 7 and 8, where the difference between the attitudes of the reflectors is clearly discernable. The contact is more difficult to see on this line between shot points 5 and 6, where bedding above and below the unconformity is flat-lying. In this portion of the line, the position of the erosional surface was determined by projecting information from other seismic lines onto this line.

Cores 3ST-54 and TGB-3, at shot points 9 and 7, respectively, indicate that soft muds overlies sandy sediments, which lie directly above stiff clays. Careful examination of the seismic reflectors suggests downlap in

Figure 4-4. Segment of Dollar Point Line 1. Sediment cores TGB3 and 3ST-54 confirm presence of erosional Beaumont surface, as seen on the seismic line.

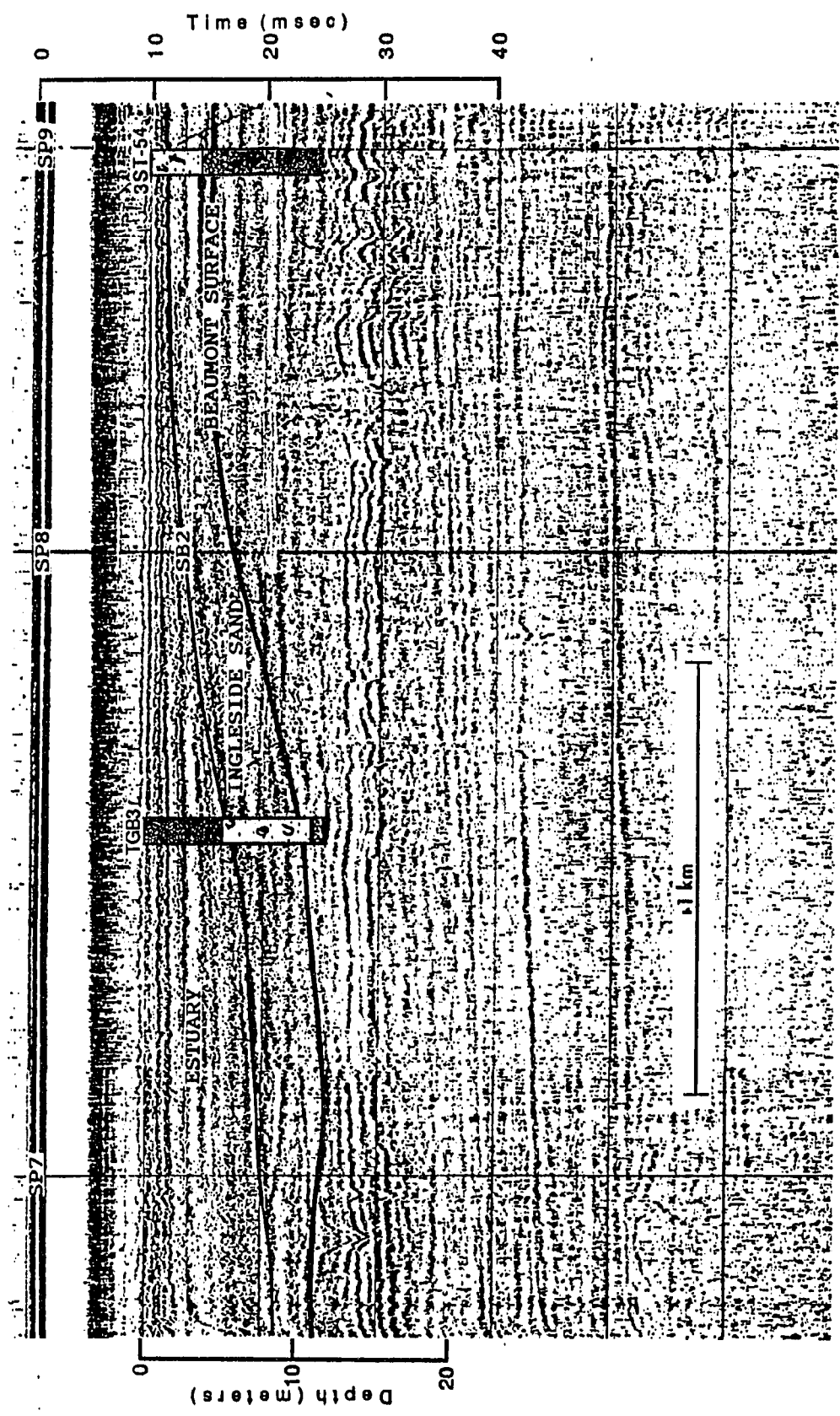
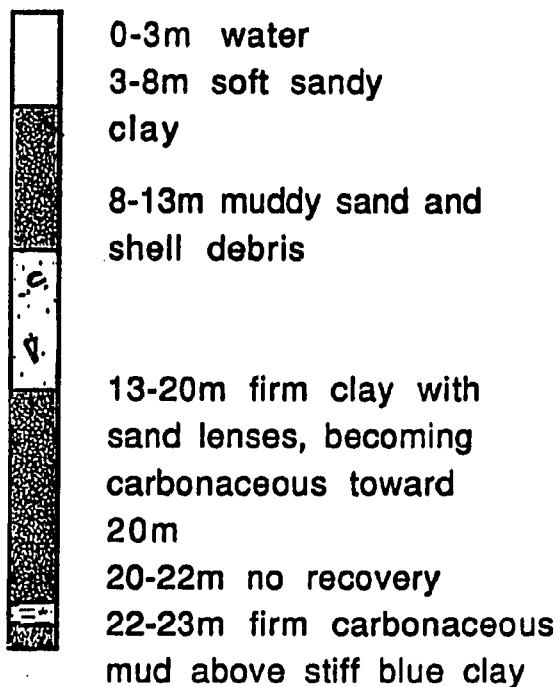
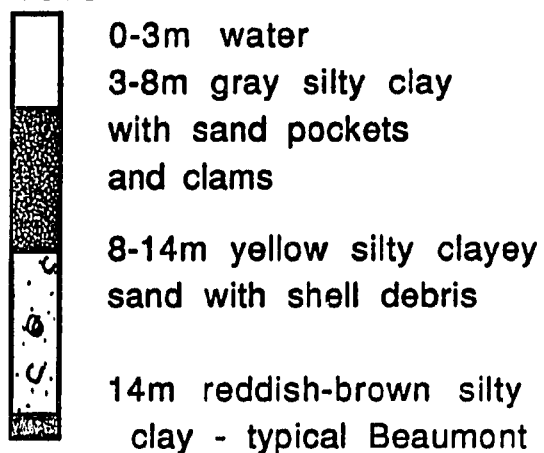


Figure 4-5. Descriptions of sediment cores along Dollar Point Line 1.

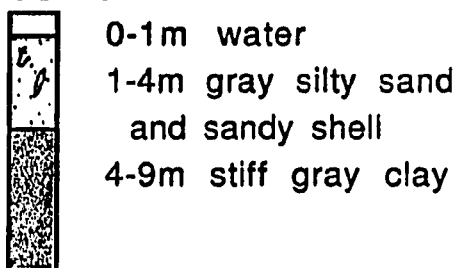
TGB-D



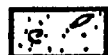
TGB3



3ST-54



ENVIRONMENTS



Marine-influenced sand



Marsh/Floodplain



Estuary



Pleistocene clay

the sandy part of the section near shot point 8 and a bar-shaped sand body geometry near shot point 7. Flat-lying reflectors can be seen onlapping the sandy section. The core descriptions (Fig. 4-5) provide the key to understanding these sediments. Rehkemper (1969) identified the stiff clay in Core TGB-3 to be Beaumont clay. He interpreted the sandy deposits to be tidal inlet deposits, based on the diversity and abundance of foraminifera and macroinvertebrates and to the relatively high percentage of glauconite in these sediments. F. Siringan (personal communication) has recently cored in this area and studied these same sand deposits. He has identified them as Ingleside sands. The soft muds are indicative of the estuarine environment.

Core TGB-D, which is located near shot point 3 of Line DP1, is interpreted to lie within the incised valley, as it encountered stiff Beaumont clay at a depth of 22.5 m. A loss of seismic reflection character from s.p. 5 to the end of line DP1 indicates the presence of the incised valley along this segment of the seismic line. Additionally, core TGB-D provides information concerning the valley-fill sediments. Directly overlying the stiff clay is a thin layer of carbonaceous mud, probably marsh deposits. Above this is 22 m of sandy estuarine mud interrupted by a 5 m thick sequence of muddy shelly sand, which represents, if not a tidal delta, at least proximity to a tidal inlet.

In this study, Deweyville terraces were first interpreted on seismic data, then confirmed by information about the sediments. The best example of a Deweyville terrace is on Bolivar Line 1 (BL1), Fig. 4-7 (Fig. 4-6 for location). Scour below the Deweyville deposits can be seen at shot point 14. The lower limit of the terraces is visible and approximately level across most of this section. The flat-topped terraces step down in discrete intervals from shot point 13 toward shot point 11. There are five levels in all. Thickness of the terrace deposits varies from approximately 10 m at shot point 13 to roughly 3 m at shot point 11. The chaotic reflection character suggests sandy deposits.

A good example of a Deweyville terrace above Beaumont clay is seen on Trinity Delta Line 8 (TD8), Fig. 4-8 (Fig. 4-6 for location). Between the flooding (onlap) surface at approximately 12 msec and the Beaumont contact, estimated to be at 21 msec, lies a beautifully preserved meanderbelt sequence. Channel dimensions and depth to the meanderbelt sediments suggest probable Deweyville origin.

A Deweyville terrace is interpreted on Red Bluff Line (RB1), at an average depth of 6 m (Fig. 4-9, Fig. 4-6 for location). Identified by its seismic expression, this interpretation was verified by sandy sediments in cores (Fig. 4-10). A strong reflector occurs at 12-15 msec on the seismic section, with a loss of reflection character below

Fig. 4-6. Locations of Bolivar Line 1, Trinity Delta Line 8, and Red Bluff Line 1.

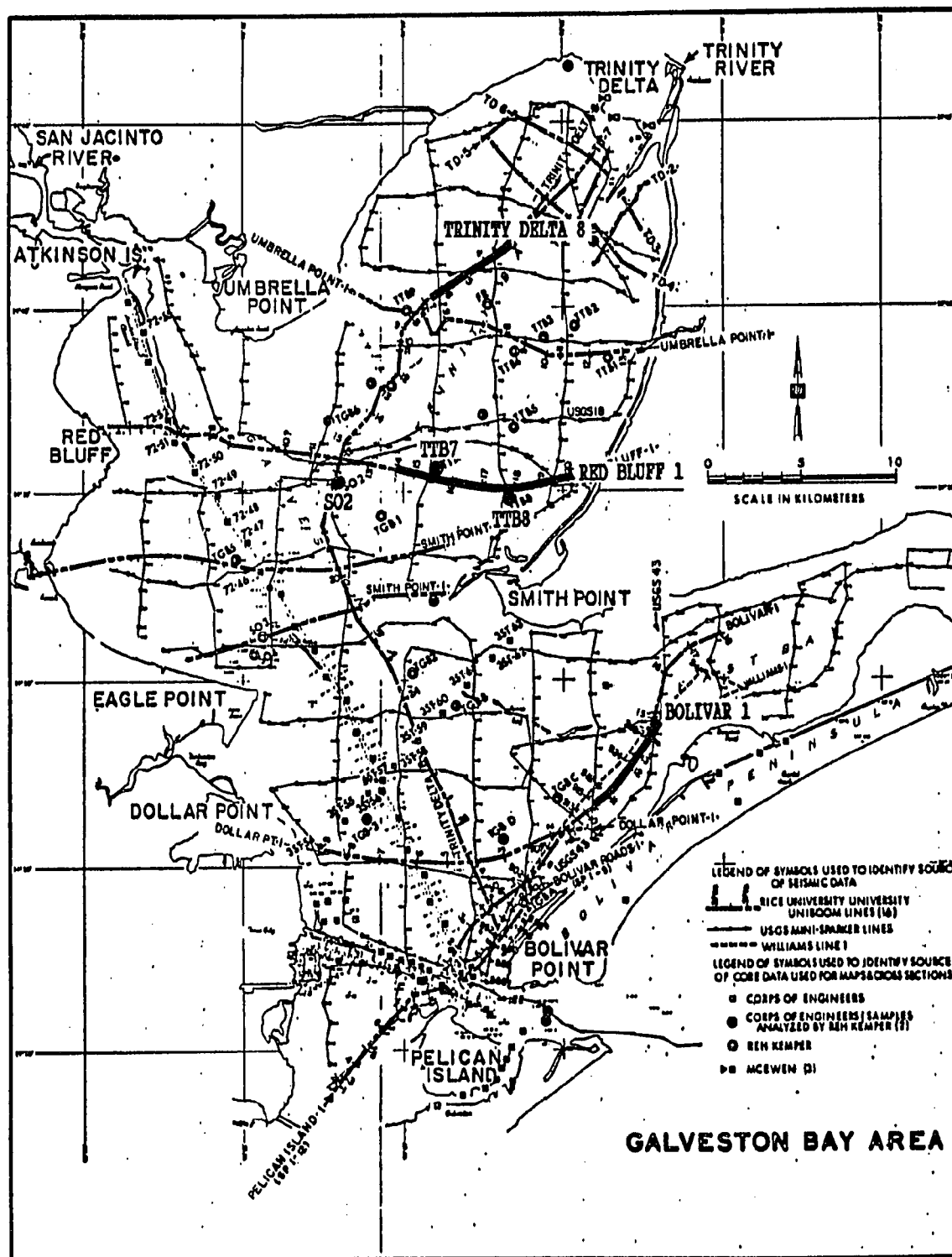


Figure 4-7. Deweyville terraces on Bolivar Line 1.

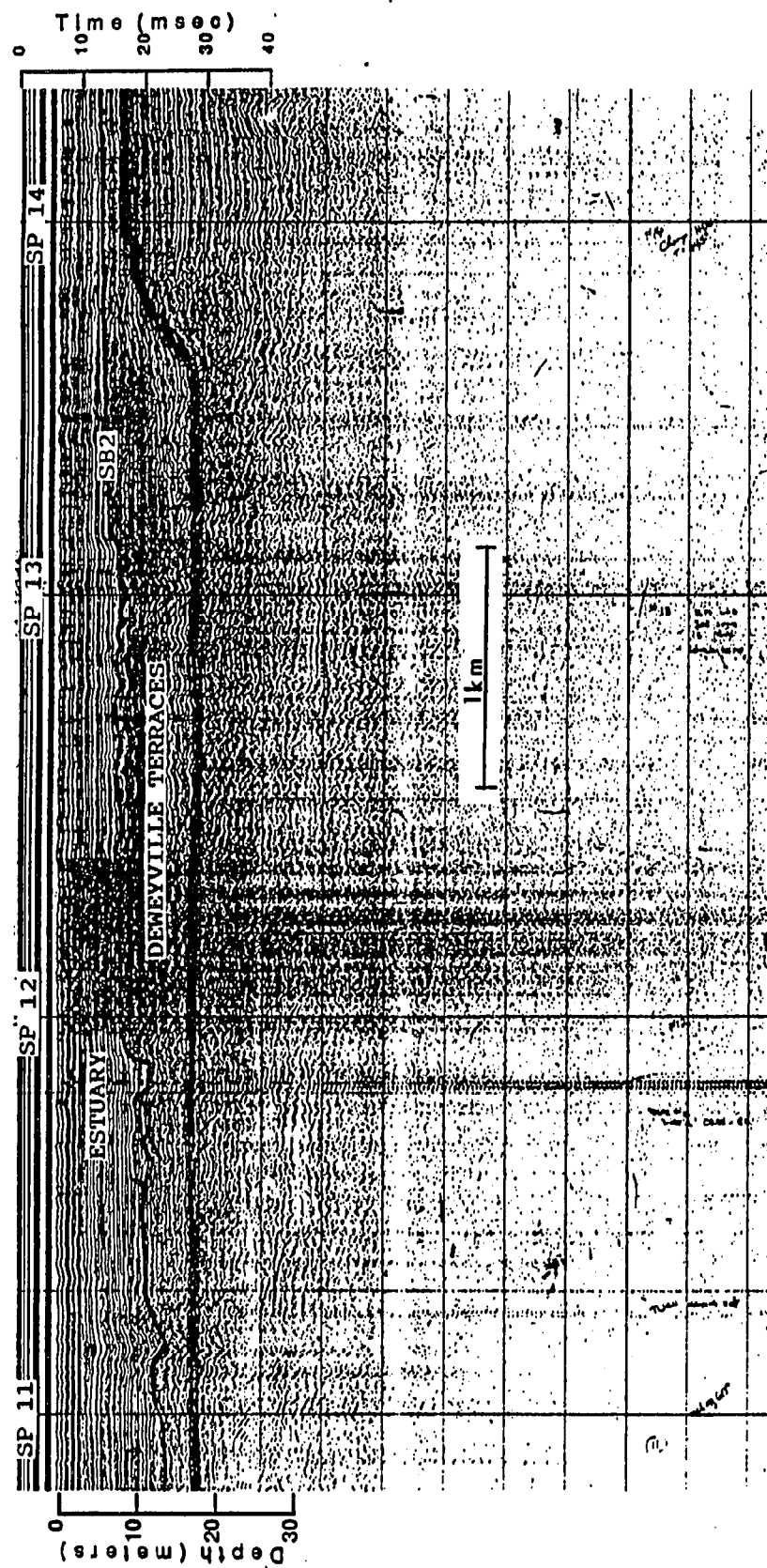
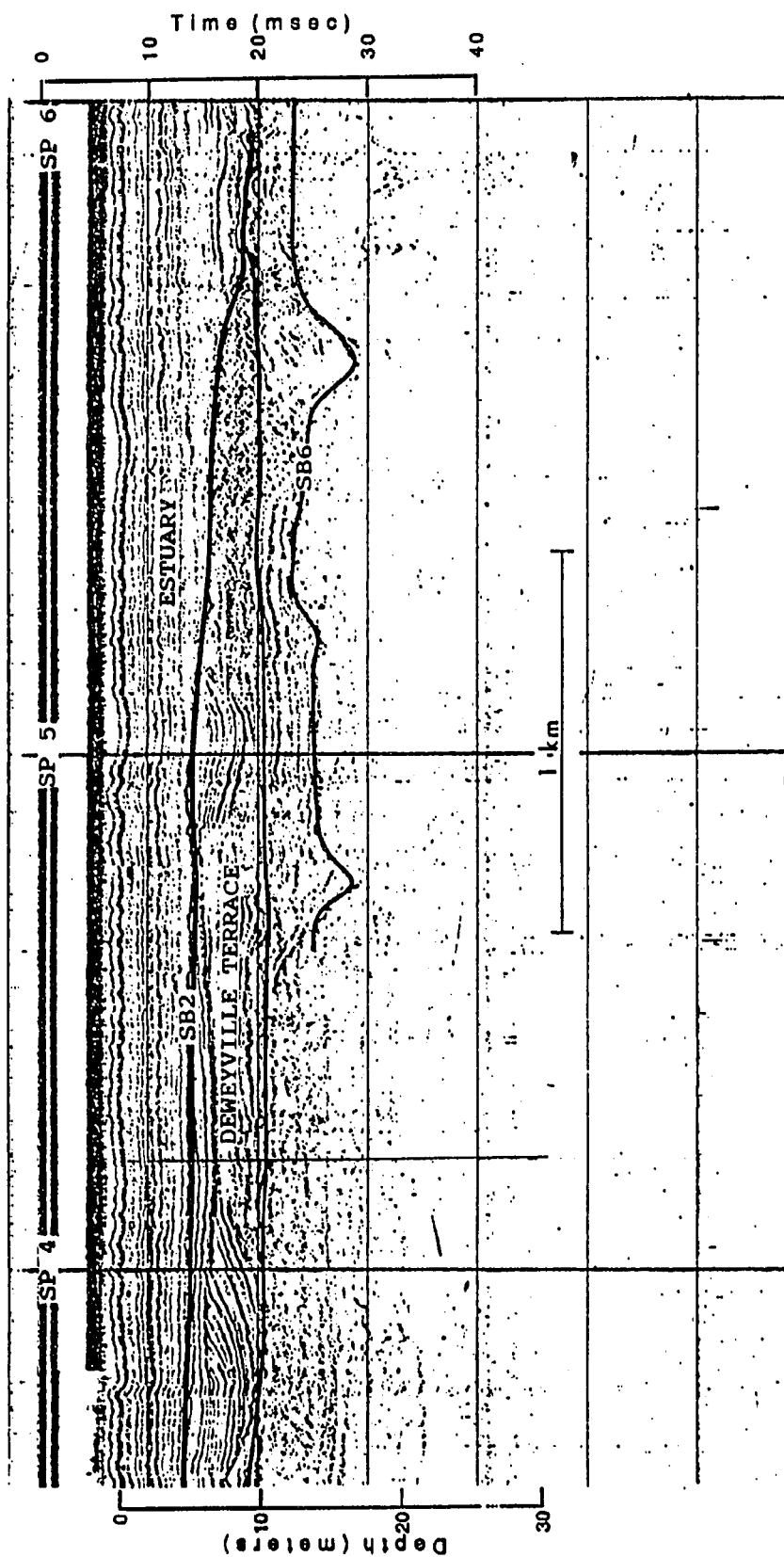


Figure 4-8. Deweyville terrace deposits on Trinity Delta
Line 8.



it. Along this surface, small mounds and channels occur. There is a large relict channel between shot points 15 and 16 which lies at the top of the Deweyville interval. This channel is approximately 500 m wide and has an approximate radius of curvature of 1220 m, which is consistent with the dimensions supplied by Aten (1983) for Deweyville channels along the Trinity River (Table 2-1). This entire segment of Line RB1 was determined to be a Deweyville terrace due to the depth of its upper surface and the dimensions of the relict channel. Chaotic reflectors and an indiscernable lower boundary characterize the seismic expression of this constructional terrace.

The core information supports the above interpretation. Core TTB-8 has sandy deposits, interpreted to be Deweyville terrace, below 8 m. Directly above the sand are peats and clays, which are marsh deposits representing the later flooding of the terrace. Soft estuarine muds overlie the clay. Core TTB-7, which has a similar sedimentary sequence to core TTB-8, is located within the relict Deweyville channel.

Seismic reflection character allows the distinction to be made between Beaumont and Deweyville terraces. Both are seen on Line RB1, Fig. 4-11. As previously discussed, the lower boundary of the Deweyville sediments (shot point 18 in Fig. 4-11) is not visible on this line, and reflection

Figure 4-9. Deweyville terrace deposits on Red Bluff Line

1. Core TTB-7 confirmed presence of sandy deposits recognized as Deweyville terrace on the seismic line.

Relict channel between shot points 15 and 16 has dimensions comparable to Deweyville channels exposed along the lower reaches of the Trinity River (see Table 2-1).

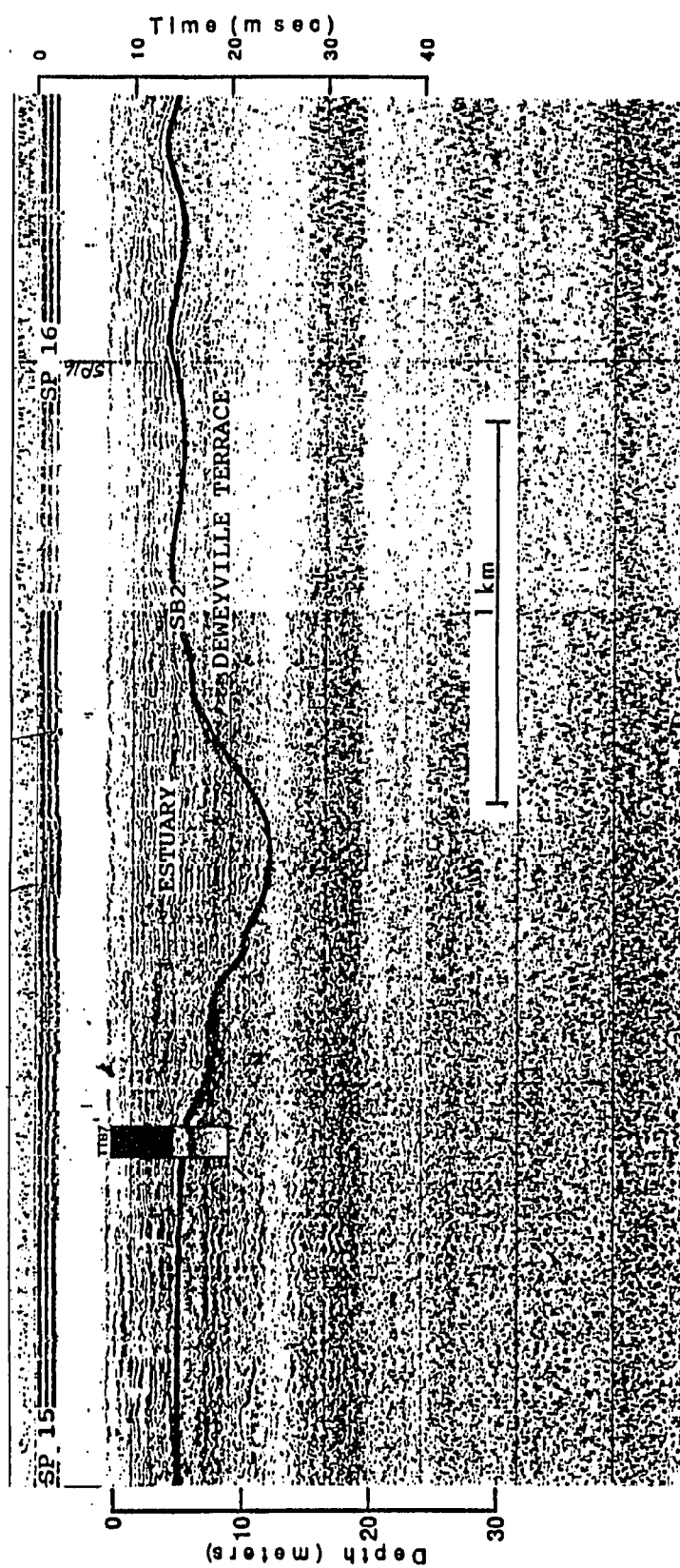


Figure 4-10. Descriptions of sediment cores along Red Bluff
Line 1.

SO2



0-3m water

3-17m gray
clayey silt and
sand with trace
of shell and
vegetation

17-21m gray
very sandy silty
clay

21-29m gray fine
to medium sand

29-45m brown
silty clay

TTB7



0-3m water

3-8m very soft
silty clay with
oysters and clams

8-9m stiff clay
with organic
material

9-10m no recovery

10-12m sand

TTB8



0-3m water

3-8m gray soft clay
with scattered clam
shells

8-10m peaty brown
clay

10-13m clayey sand

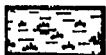
ENVIRONMENTS



Estuary



Fluvial sand

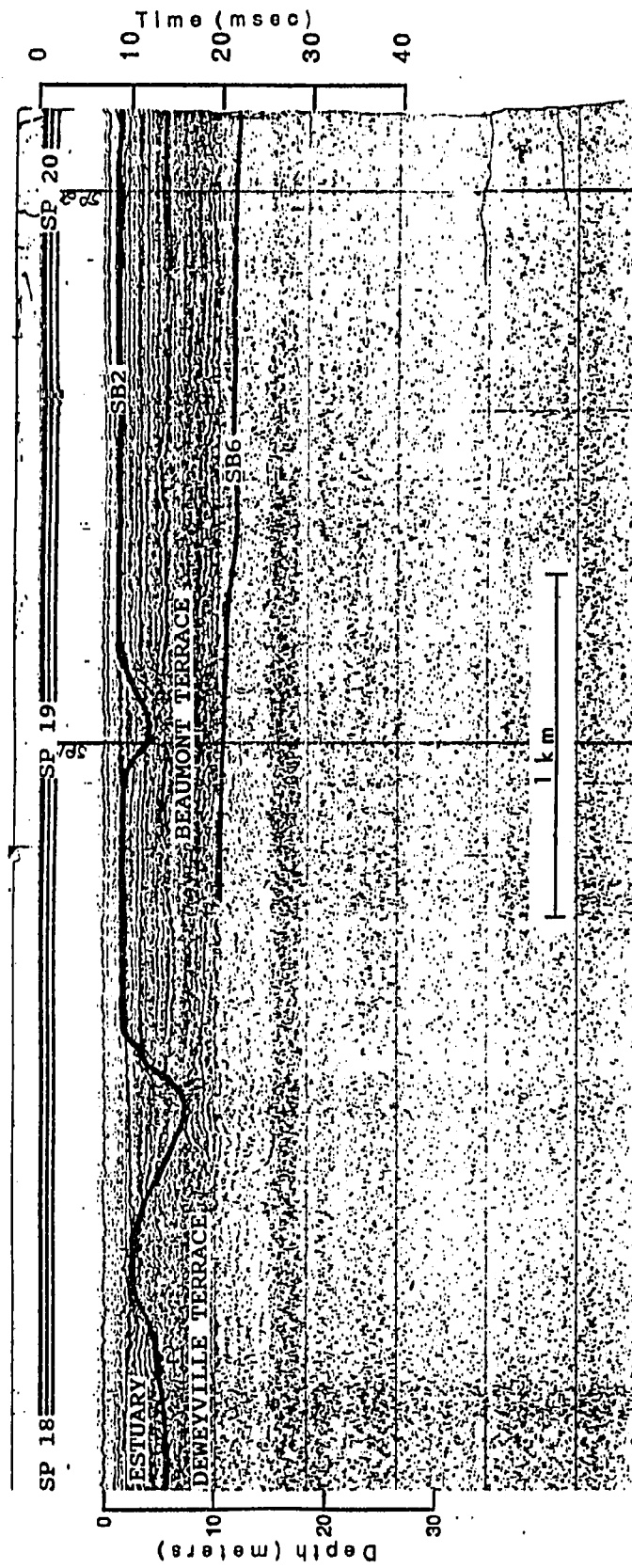


Marsh/Floodplain



Pleistocene clay

**Figure 4-11. Beaumont and Deweyville terraces on Red Bluff
Line 1.**



character is chaotic within the terrace deposits. Beaumont strath terraces near shot point 19 display flat-lying reflectors with high frequency content that are visible down to about 20 msec.

Fluvial terraces on Trinity Delta Line 2 (TD2) (Fig. 4-13, Fig. 4-12 for location) look very much like Deweyville terraces. These terrace deposits, however, pre-date Beaumont deposition, and their upper surface is bound by Sequence Boundary 6. This was determined by careful correlation of the seismic data in Trinity Bay. USGS Line 22 (Fig. 4-14, Fig. 4-12 for location) shows the same fluvial deposits and sequence boundary with overlying onlapping reflectors and a ravinement surface across the top. These same deposits can be seen on seismic lines all over Trinity Bay. Thus, fluvial systems occupied this area prior to Beaumont deposition. The presence of the probable transgressive deposits and ravinement surface on the Trinity Bay seismic lines supports a higher sea level for Sangamon time than for the present.

Seismic Facies

Some of the depositional environments present in the incised valley were identified and characterized by seismic data. Two of the modern estuarine environments have characteristic seismic signatures: the middle estuary and the flood tidal delta.

Fig. 4-12. Locations of Trinity Delta Line 2 and USGS Line 22.

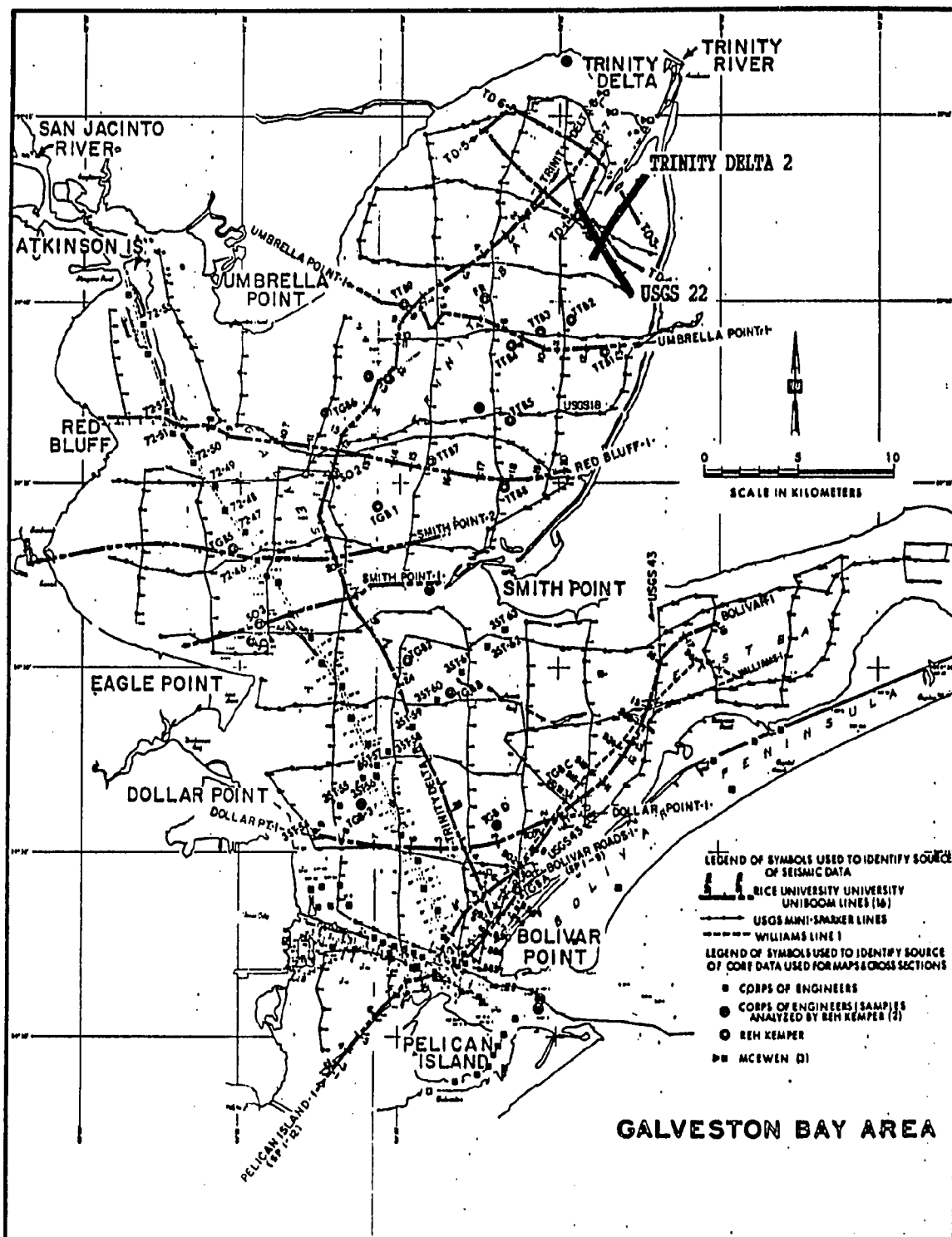


Figure 4-13. Fluvial deposits bound by Sequence Boundary 6 on Trinity Delta Line 2.

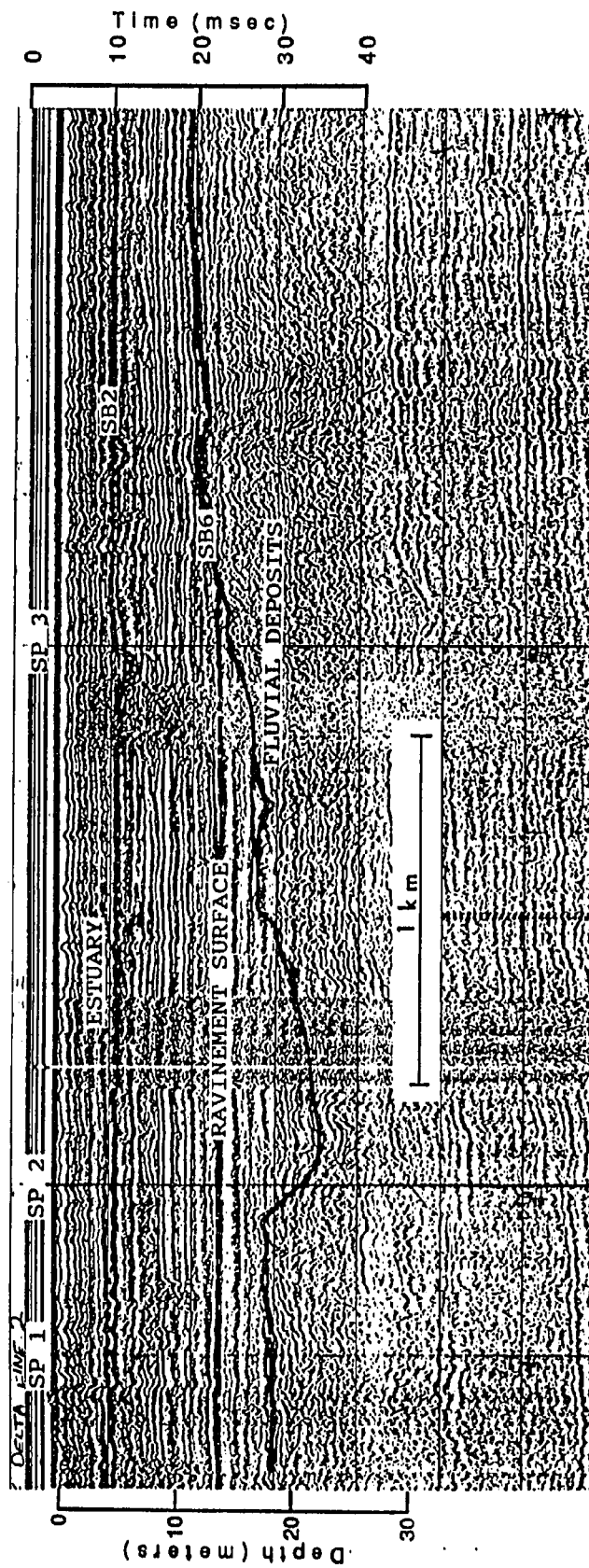
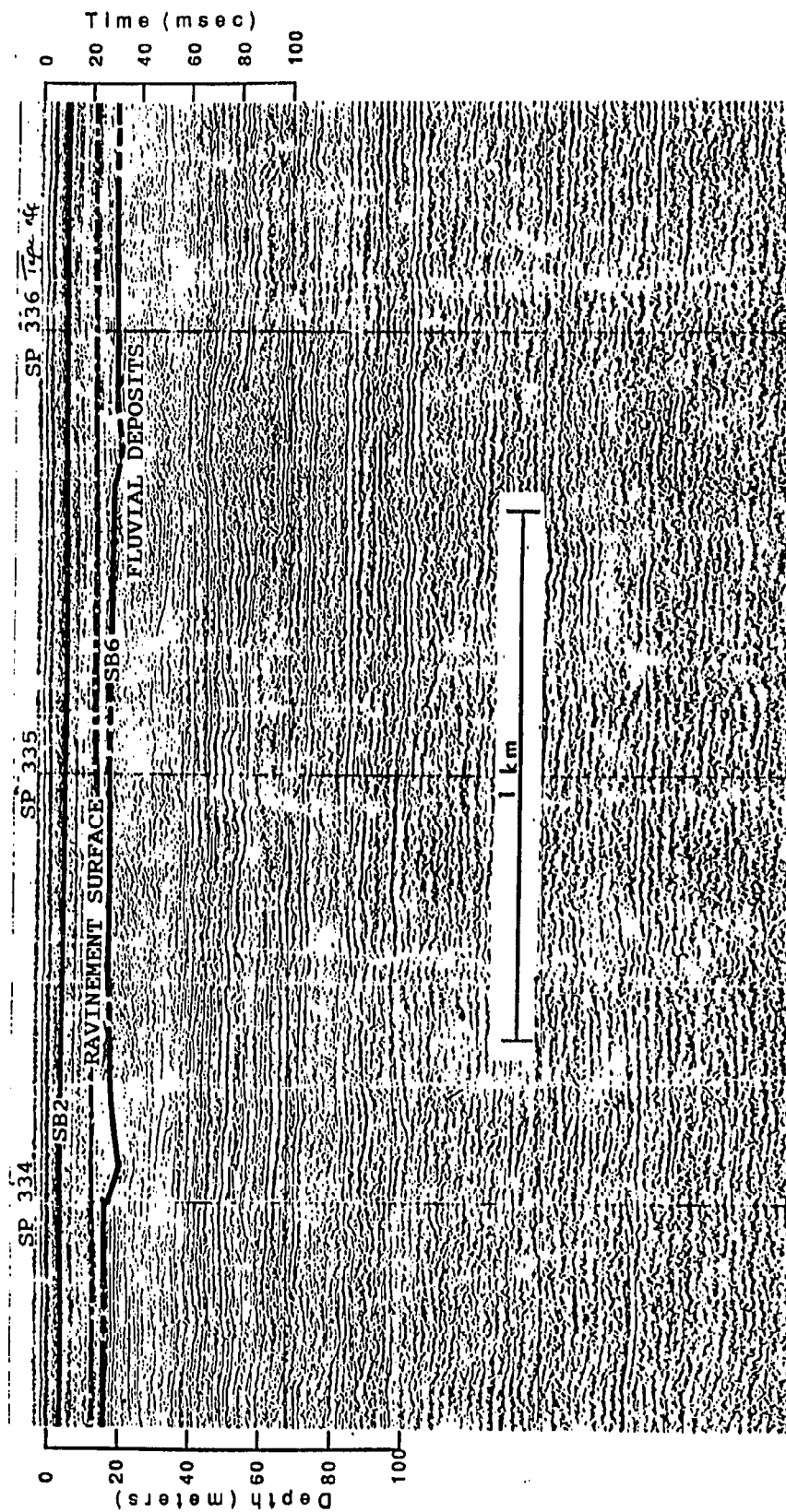


Figure 4-14. Fluvial deposits bound by Sequence Boundary 6, with subsequent ravinement surface and overlying Beaumont deposits on USGS Line 22.



The flat-lying reflectors seen on Dollar Point Line 1 (DP1), along with oyster reefs, like the one seen at shot point 5, characterize the middle estuary on the seismic data (Fig. 4-16, Fig. 4-15 for location). Oysters survive only within a narrow range of temperatures and salinities, which are found in the mid-estuarine environment (Ladd et al, 1957). A reef provides a sharp acoustic impedance contrast with the soft estuarine muds. Thus, a strong reflector is usually seen at the top of an oyster reef, and energy is scattered below. This results in loss of seismic reflectors directly below the reef.

The bedforms of the sandy flood tidal delta near Bolivar Point can be clearly seen on the uniboom data. Lateral accretion is characteristic of this environment and can be seen between 10 and 20 msec on Williams' Line 1 (Fig. 4-17, Fig. 4-15 for location). These deposits overlie and, in some places, scour into flat-lying estuarine and/or Beaumont sediments. Also on this line, the unconformity between Beaumont clay and estuary and/or tidal delta sediments can be seen quite clearly. Core 72-31, near shot point 888, corroborates the interpretation of tidally influenced estuarine sediments (soft sandy mud and muddy sand) directly overlying Beaumont clay at a subsea depth of 10 m.

Fig. 4-15. Locations of Dollar Point Line 1 and Williams
Line 1.

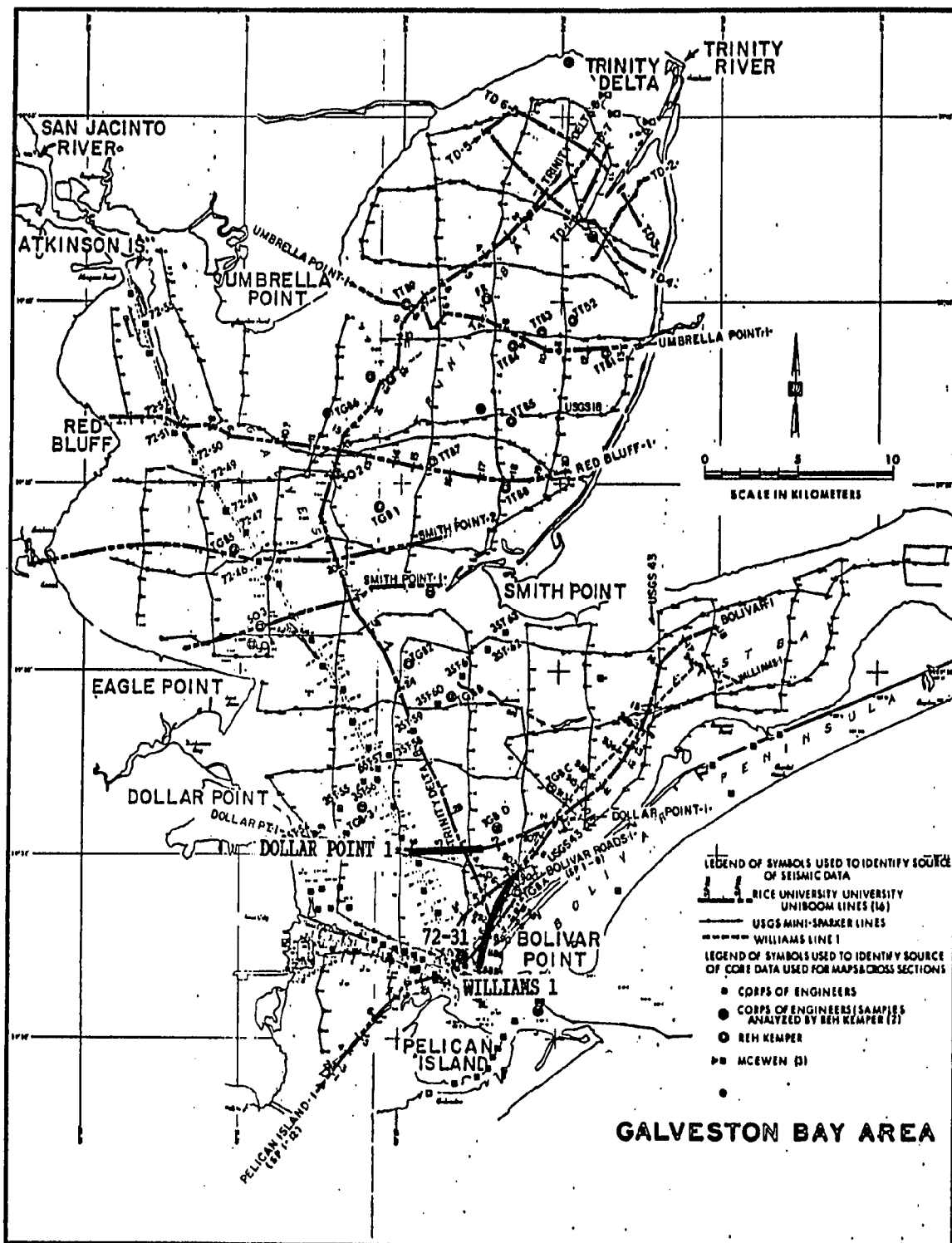


Figure 4-16. Middle estuary deposits with buried oyster reef on Dollar Point Line 1.

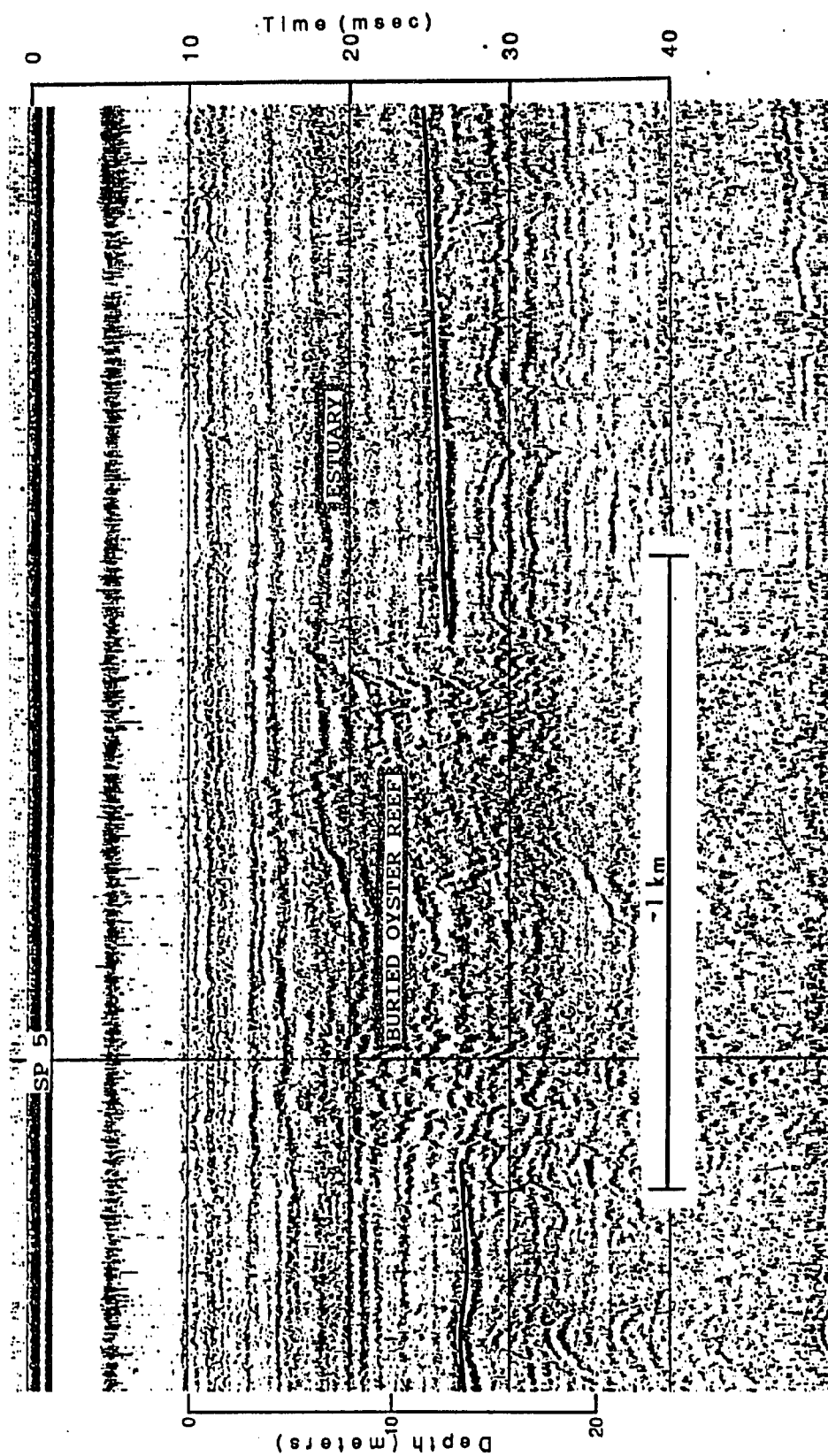
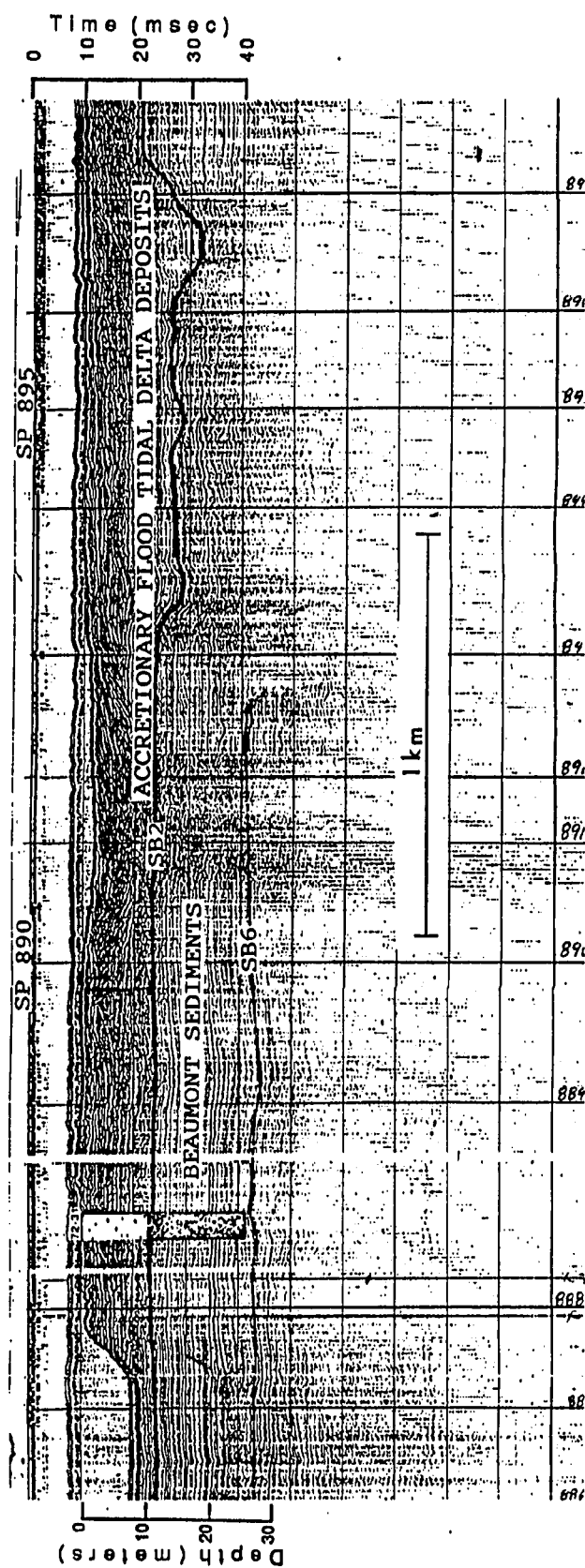


Figure 4-17. Flood tidal delta deposits overlying Beaumont sediments on Williams Line 1.



As previously discussed, the loss of seismic reflection character is very pronounced in the sediments of the incised river valley. While the loss of reflection character is useful in following the trace of the incised valley, it precludes the imaging of floodplain and deltaic sediments within the valley. Thus, seismic facies analysis of those deposits that occur within the deepest part of the valley was not possible.

Morphology of the Incised Valley

When all of the information is considered together, the complexity of the incised valley system beneath Galveston and Trinity Bays becomes apparent. Part of this complexity stems from the fact that two systems are present, that is, the fluvial system and the estuary. Also, more than one glacial cycle is represented. The cross sections presented in Figs. 4-19 through 4-23 demonstrate the variability of the river valley, as well as of the estuary, along this one relatively short reach of the Trinity/San Jacinto incised valley. The morphology of the incised valley, that is the size and shape of the river valley and the thicknesses and lateral extents of the sedimentary deposits that fill it, is demonstrated by the series of maps presented in Figs. 4-25 through 4-30.

In Figs. 4-19 through 4-23, information from core descriptions and seismic sections is combined to present

cross-sectional views of the Trinity/San Jacinto River incised valley. The data used to produce these cross sections are indicated along the tops of the sections. The Smith Point section (Fig. 4-21) was made entirely from core descriptions. The other four cross-sections were made from some combination of core information plus one or more seismic lines. Sediment core information was used on these four sections to determine the depth to and thickness of the Holocene floodplain sediments within the incised valley, as this information can not be obtained using the seismic data. Fig. 4-18 shows the positions of all of the cross sections.

The Umbrella Point section (Fig. 4-19) crosses a broad, shallow Beaumont terrace on the east side of the Trinity River valley, as seen in Fig. 4-1. Core information (Fig. 4-2) was used to identify the upper surface. On the west side of the incised valley, Deweyville terrace overlies Beaumont clay, as seen on Line TD8 (Fig. 4-8). Along this section, which is situated in the present-day upper estuary, prodelta sediments are indistinguishable from estuarine sediments.

Red Bluff Line 1 (See Figs. 4-9, 10, and 11.) crosses both the Trinity and the shallower San Jacinto incised river valleys. The configuration of the three Beaumont terraces, at shot points 10-11, 13, and 19-20, suggests a change in course for the Trinity River between Deweyville time and the present. Thus, the large Deweyville terrace (shot points

Figure 4-18. Locations of cross-sections (Figs. 4-19 through 4-23).

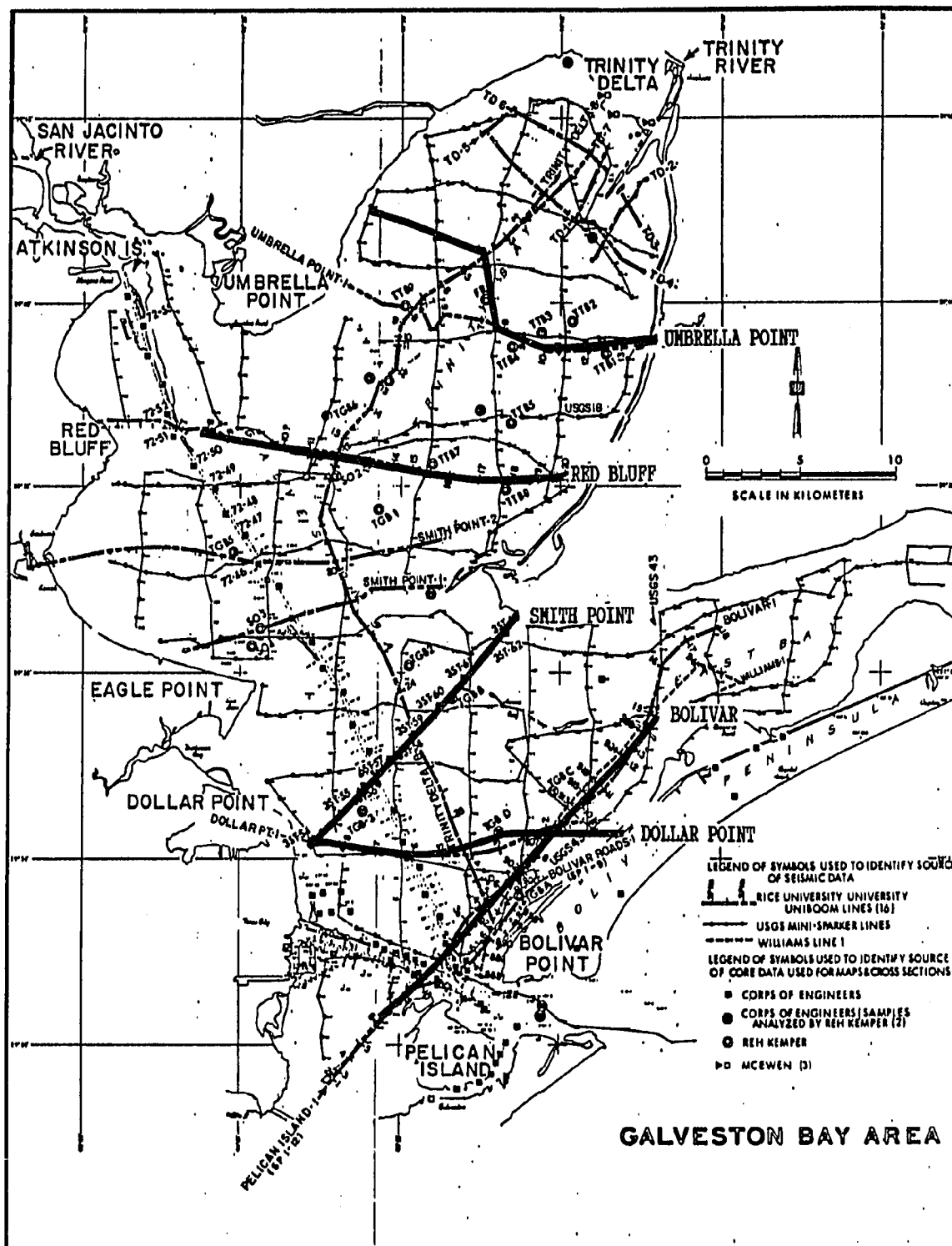
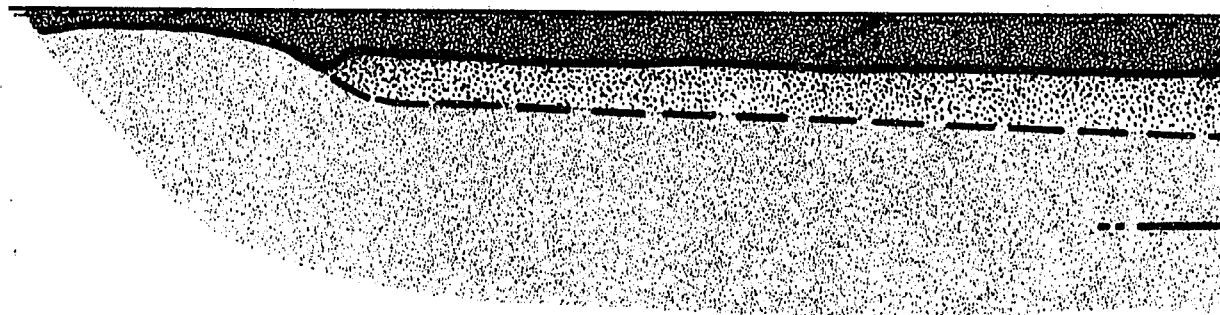


Figure 4-19. Umbrella Point cross-section. Information from Umbrella Point Line 1, shot points 7-13; cores FR and TTB-3, 2, and 1; and Trinity Delta Line 8, shot point 4.

S.P.

LI



LINE-TD8 SP4

CORE-FR

7

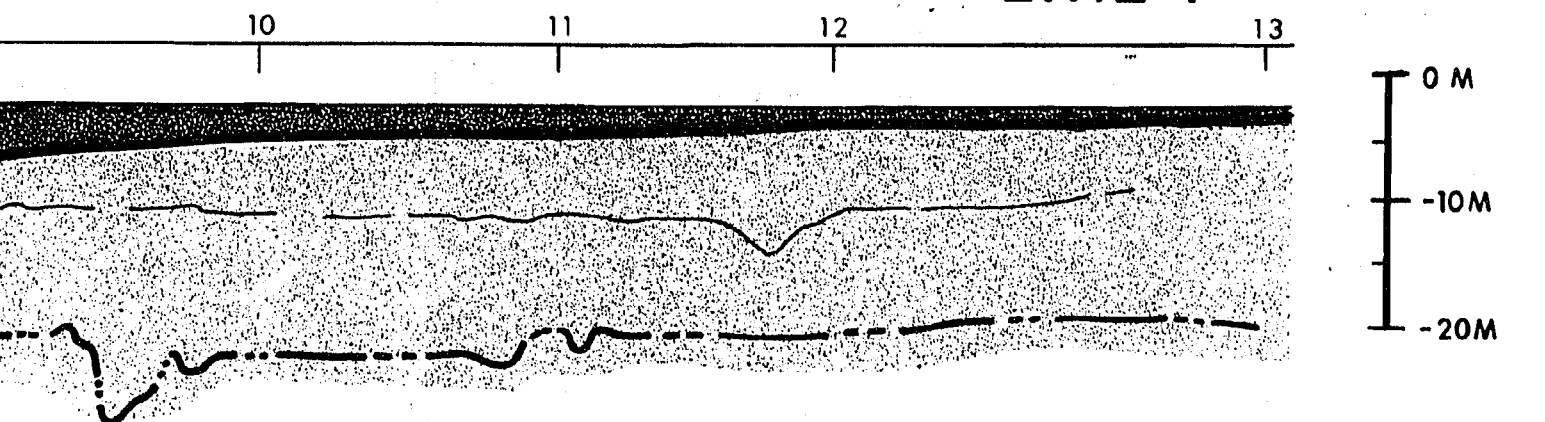
8

COYSTER
REEF

TRINITY RIVER
INCISED VALLEY

EAST →

UMBRELLA POINT LINE 1



VERTICAL
EXAGGERATION = 50 X

- WATER BOTTOM
- SEQUENCE BOUNDARY, STAGE 2
- - - SEQUENCE BOUNDARY, STAGE 5 b or d.
- - - SEQUENCE BOUNDARY, STAGE 6


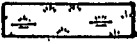



-  HOLOCENE ESTUARINE DEPOSITS
-  HOLOCENE MARSH / OVERBANK DEPOSITS
-  HOLOCENE FLUVIAL SANDS
-  STAGE 5a or c DEPOSITS, DEWEYVILLE TERRACE
-  STAGE 5e DEPOSITS, BEAUMONT TERRACE

Figure 4-20. Red Bluff cross-section. Information from Red Bluff Line 1, shot points 9-20; cores SO2, TTB-7 and 8.

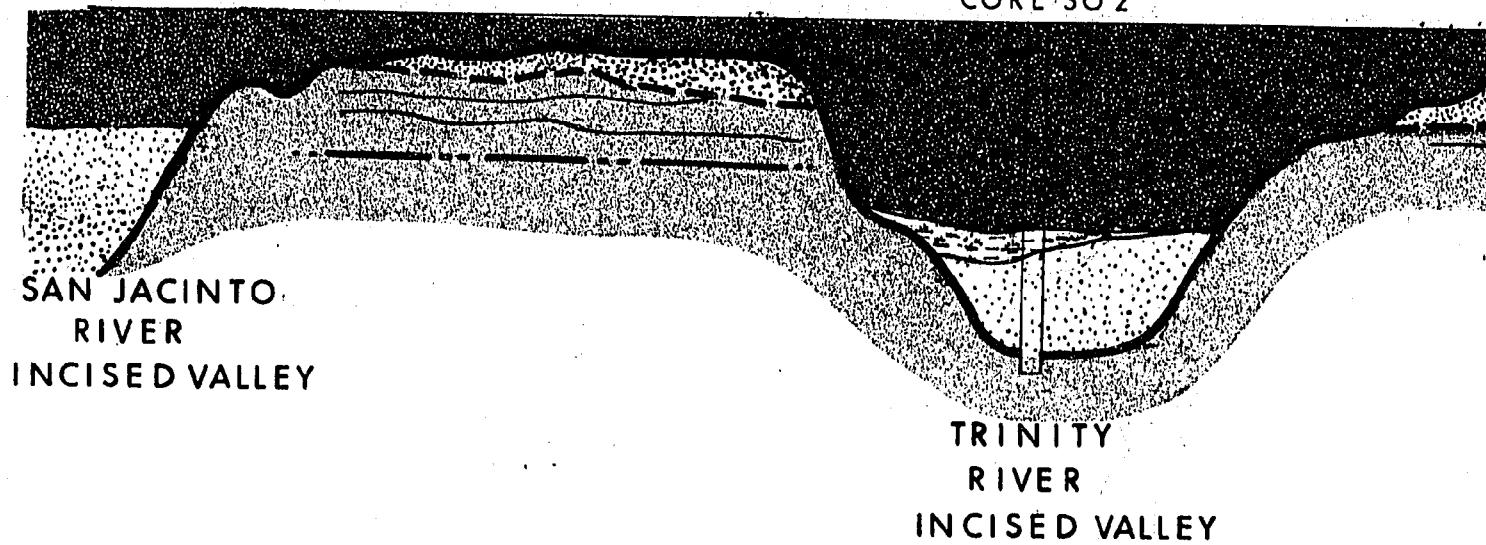
SP 9

10

11

12

CORE SO 2

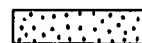
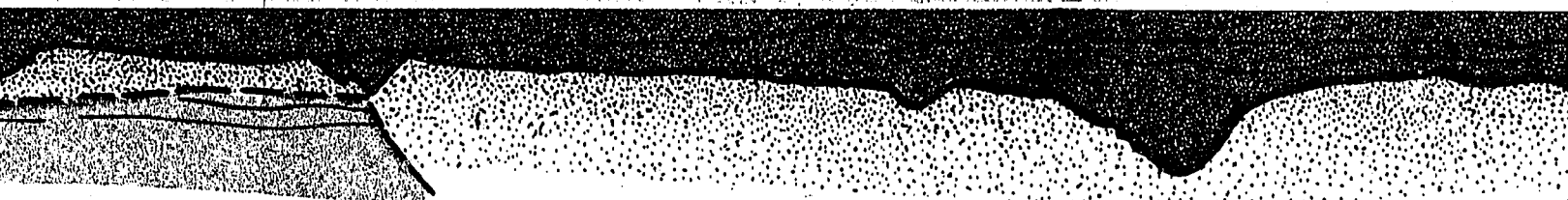


13

14

15

16



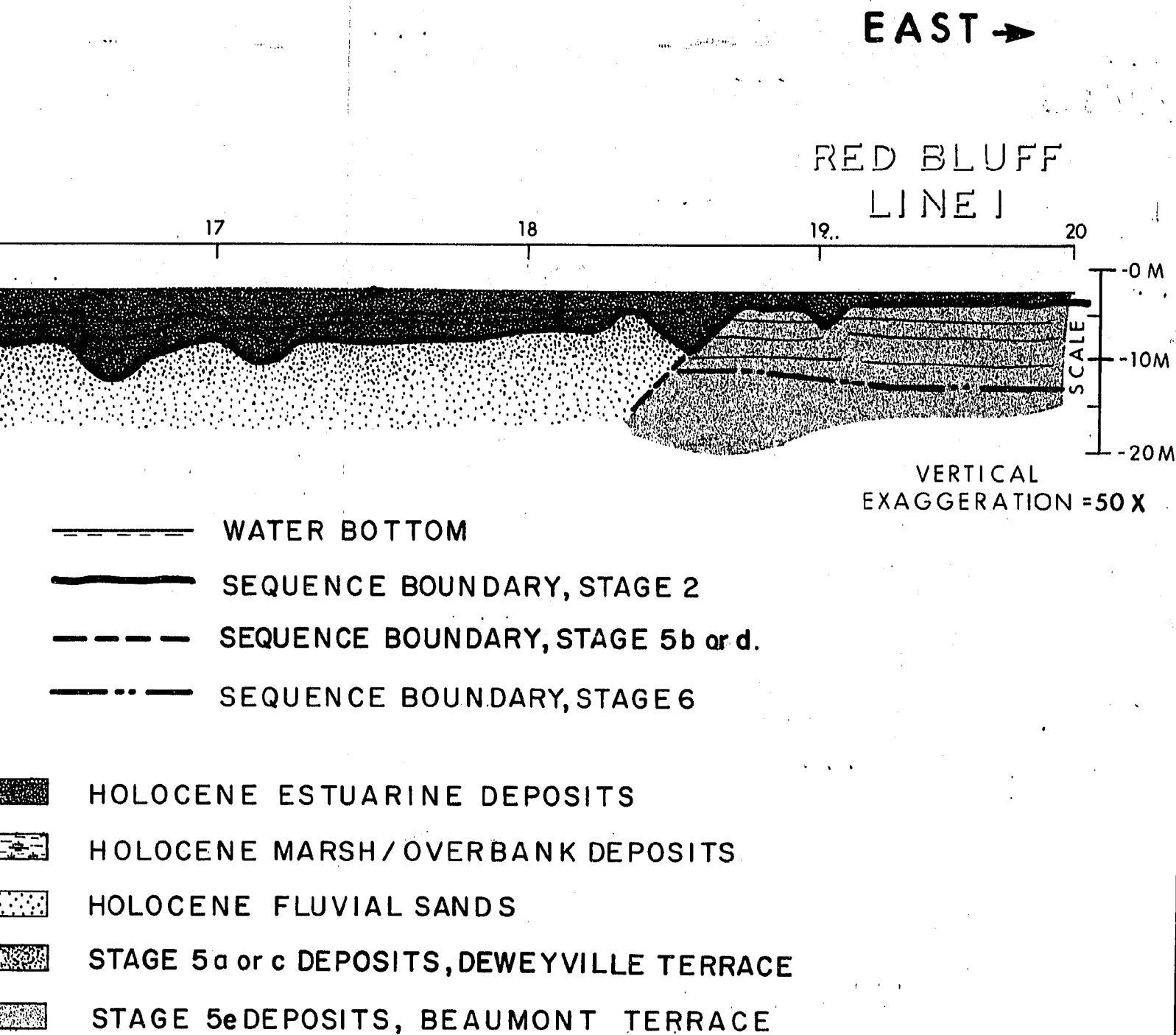
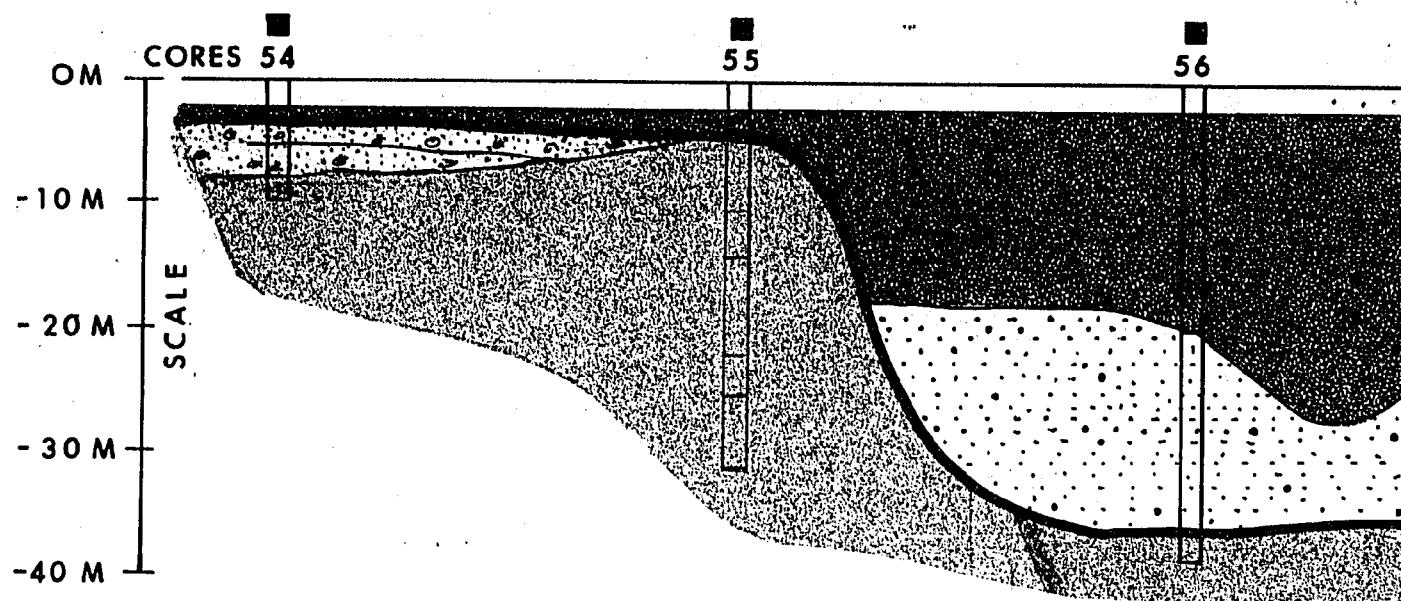
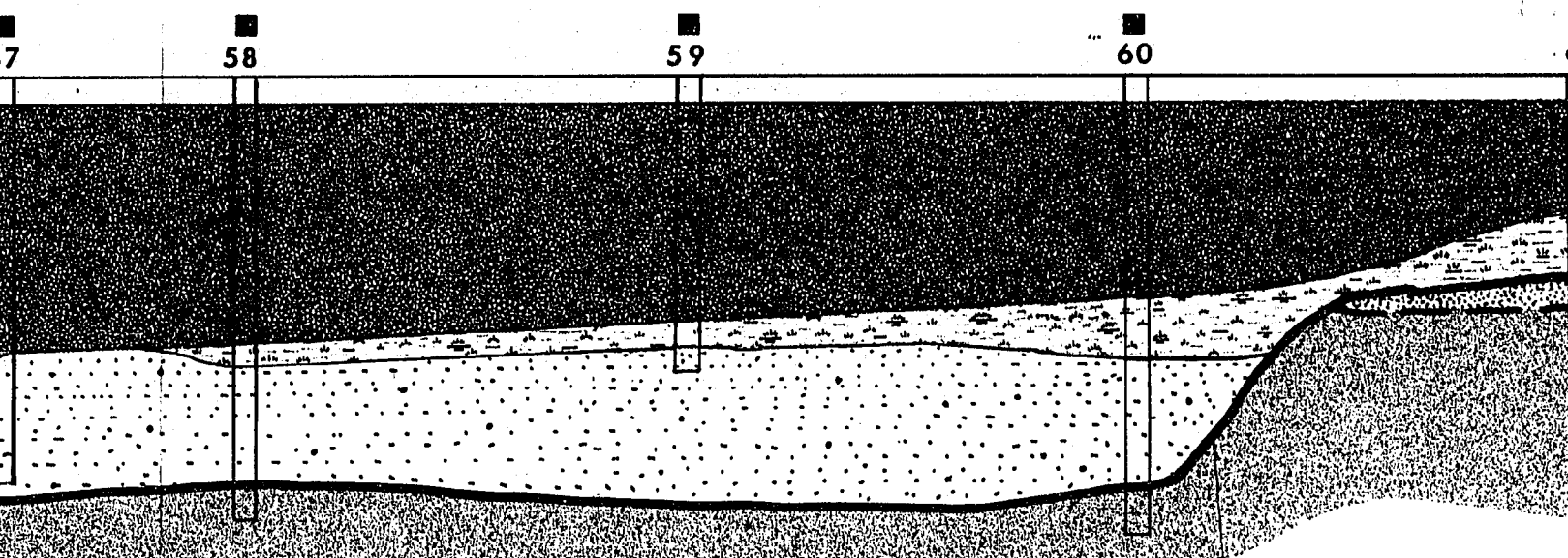


Figure 4-21. Smith Point cross-section. Information from Corps of Engineers cores 3ST-54 through 63.


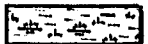
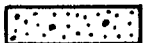


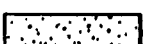
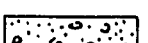
DOLLAR POINT





TRINITY RIVER INCISED VALLEY

- ===== WATER BOTTOM
- ~~~~~ SEQUENCE BOUNDARY, STAGE 2
- SEQUENCE BOUNDARY, STAGE 5 b or c.

-  HC
-  HC
-  HC
-  ST
-  ST
-  HC
-  M/L

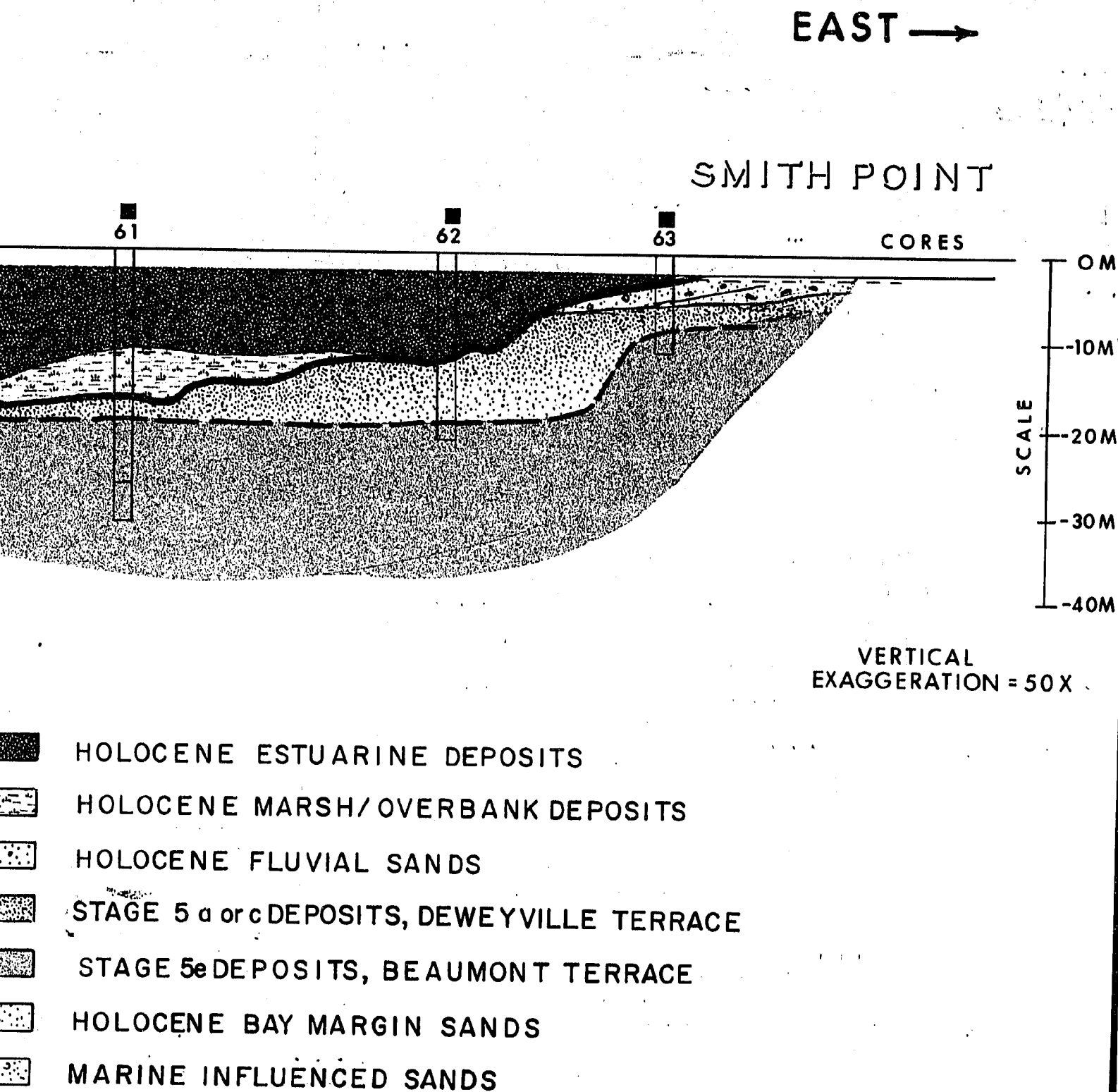


Figure 4-22. Dollar Point cross-section. Information from Dollar Point Line 1, shot points 4-9; cores TGB-D, TGB3, and 3ST-54; and Bolivar Line 1, shot point 9.

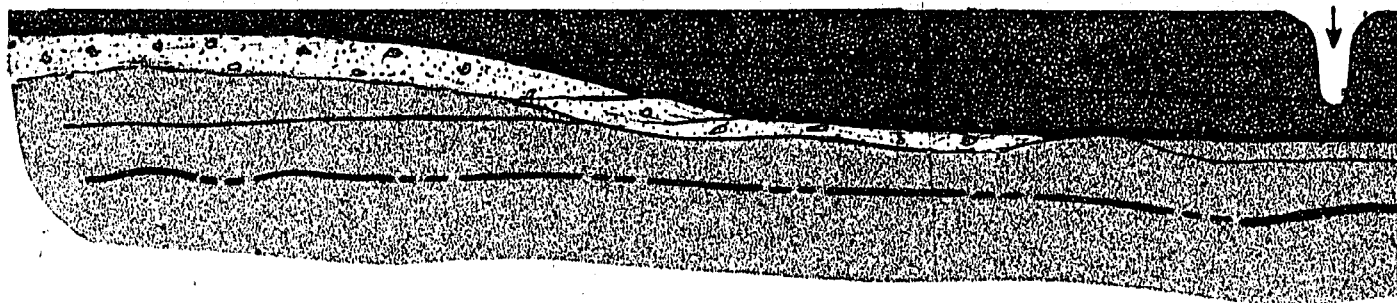
S.P.

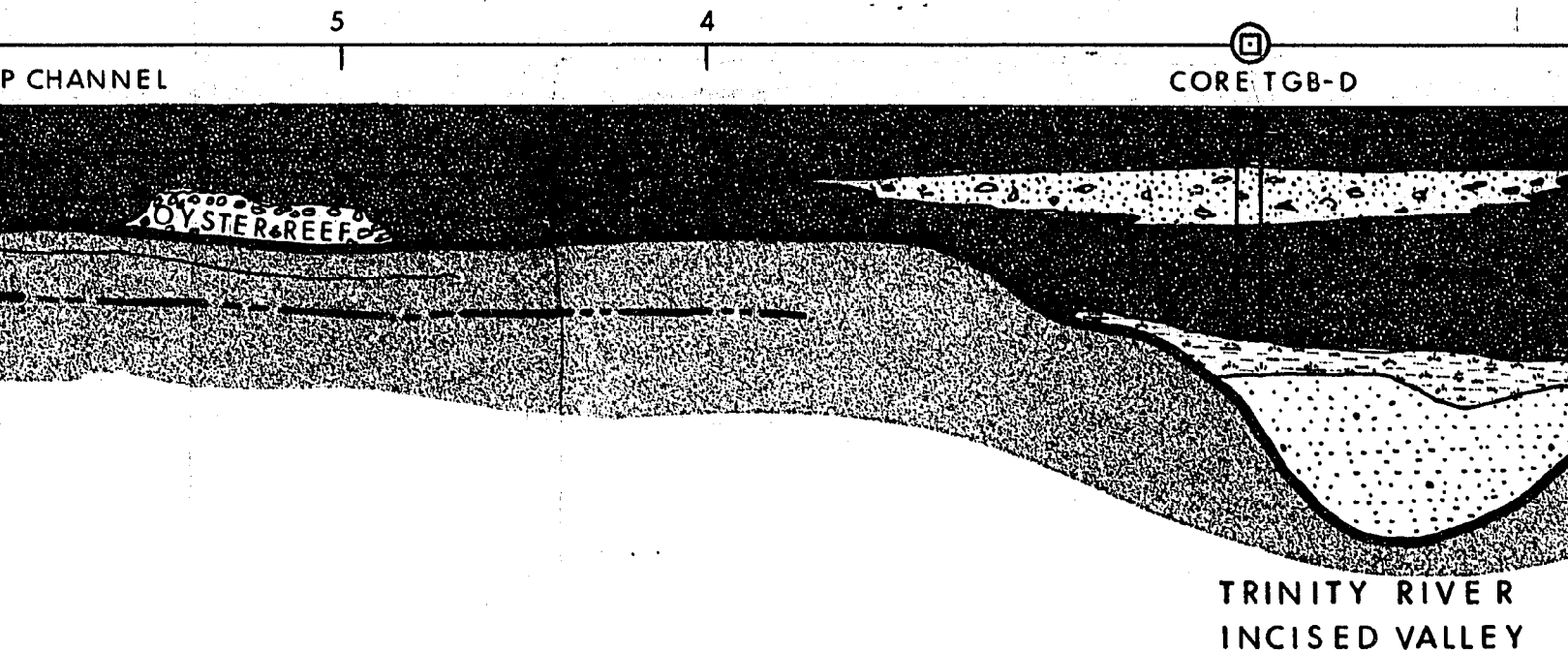
8

7

6

HOUSTON SHIP

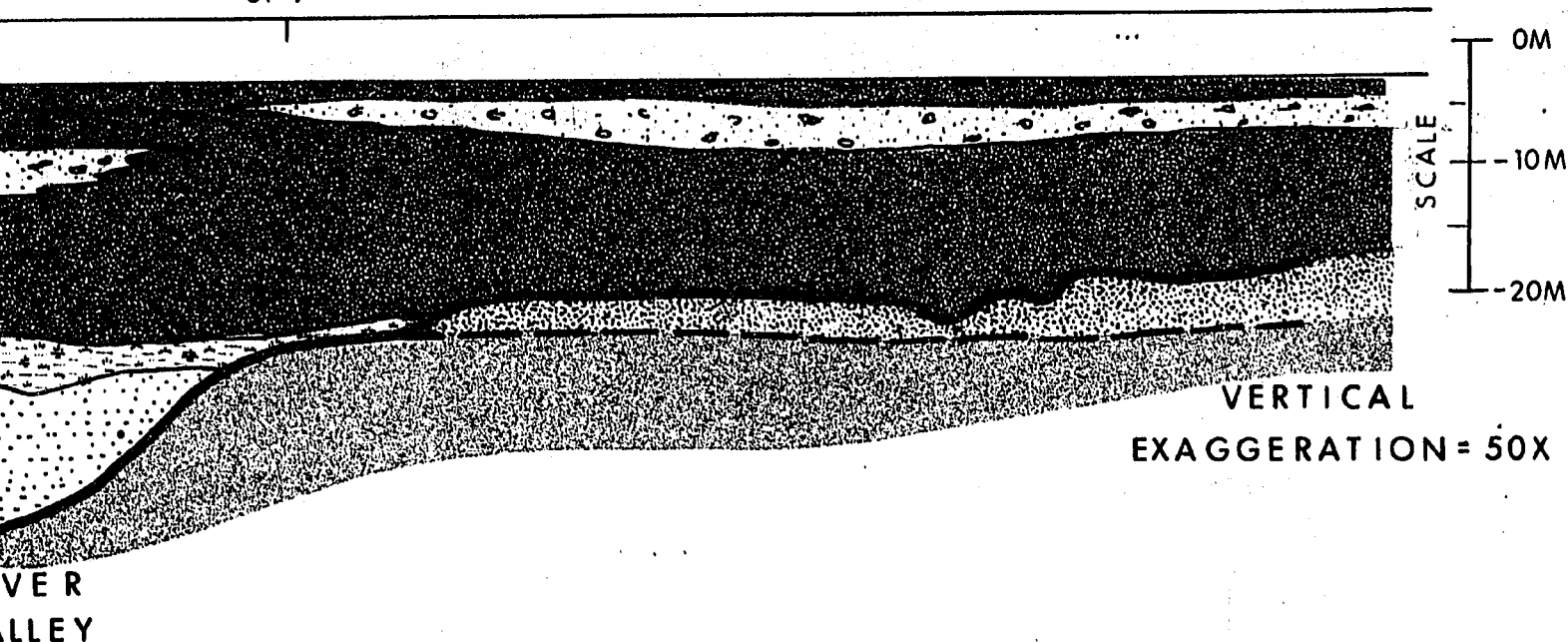




- ===== WATER BOTTOM
- SEQUENCE BOUNDARY, STAGE 2
- SEQUENCE BOUNDARY, STAGE 5b ord.
- SEQUENCE BOUNDARY, STAGE 6

- HC
- H
- HC
- ST
- ST
- M

EAST →

DOLLAR POINT
LINE 1LINE BL-1
SP 9
 HOLOCENE ESTUARINE DEPOSITS

 HOLOCENE MARSH/OVERBANK DEPOSITS

 HOLOCENE FLUVIAL SANDS

 STAGE 5 a or c DEPOSITS, DEWEYVILLE TERRACE

 STAGE 5e DEPOSITS, BEAUMONT TERRACE

 MARINE INFLUENCED SAND

Figure 4-23. Bolivar cross-section. Information from Bolivar Line 1, shot points 2-14; Pelican Island Line 1, shot points 9 and 10; and core TGB-C.

PELICAN ISLAND LINE 1

SP9

10

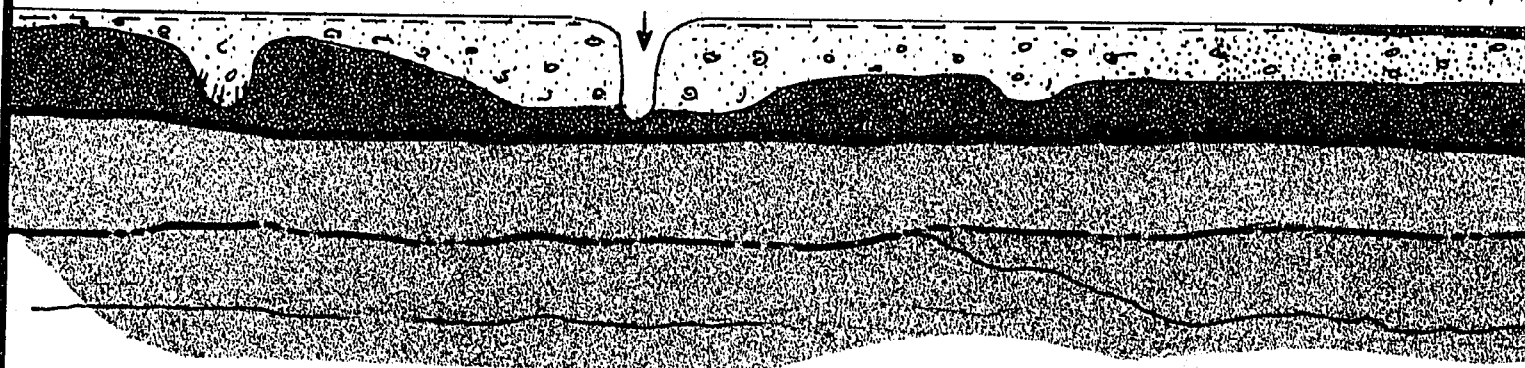
SP 2

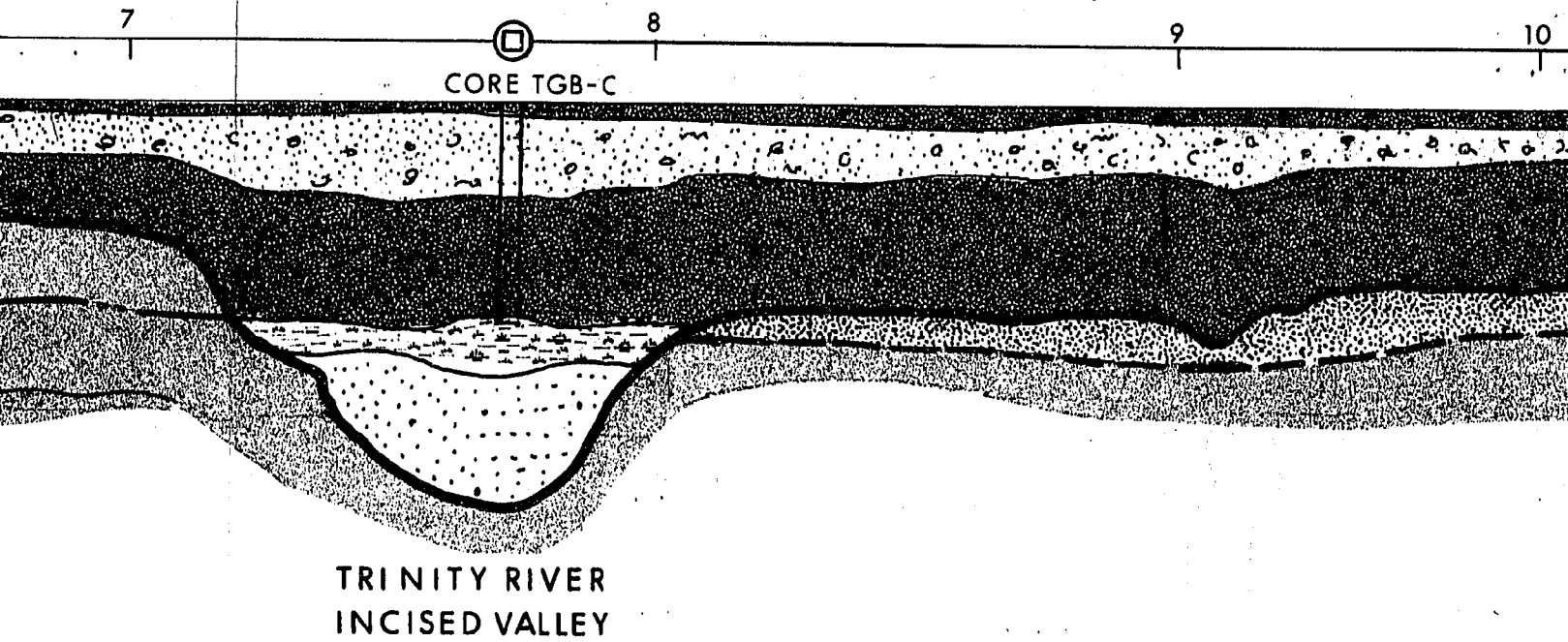
4

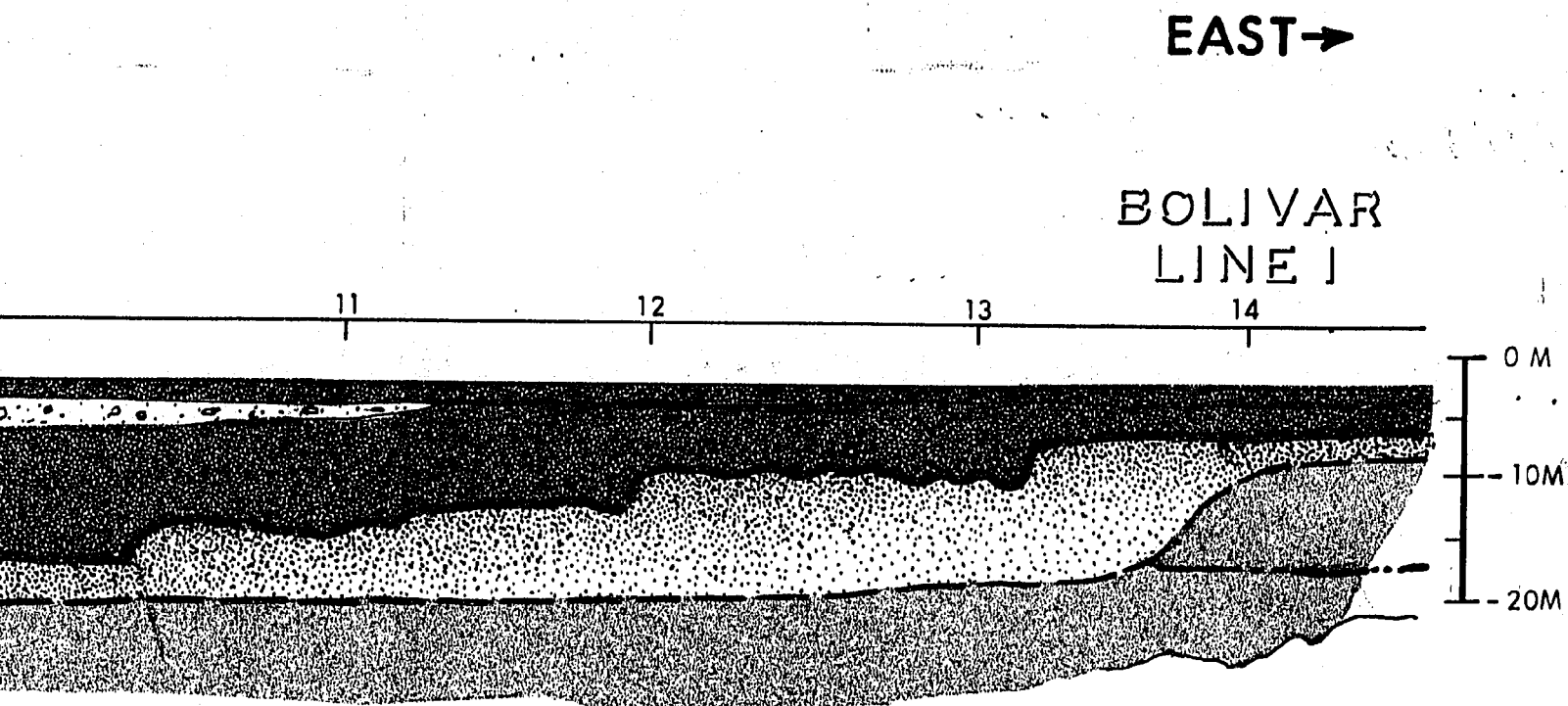
5

6

HOUSTON SHIP CHANNEL













VERTICAL
EXAGGERATION = 50X

- WATER BOTTOM
- ~~~~~ SEQUENCE BOUNDARY, STAGE 2
- - - - - SEQUENCE BOUNDARY, STAGE 5b. or d.
- . . . - SEQUENCE BOUNDARY, STAGE 6

-  HOLOCENE ESTUARINE DEPOSITS
-  HOLOCENE MARSH/OVERBANK DEPOSITS
-  HOLOCENE FLUVIAL SANDS
-  STAGE 5a or c DEPOSITS, DEWEYVILLE TERRACE
-  STAGE 5e DEPOSITS, BEAUMONT TERRACE
-  HOLOCENE TIDAL INLET

14-18) may represent a valley that was carved into the Beaumont, then filled with Deweyville sediments, and finally abandoned when the river cut the most recent incised valley (shot points 11-12) into Beaumont sediments. Note Deweyville above Beaumont at shot points 10 and 13.

Core descriptions from the Corps of Engineers were used to make the Smith Point cross section (Fig. 4-21). Though these core descriptions did not provide detailed lithologic information, this cross section demonstrates their utility for basic understanding of the valley morphology. The river is anomalously wide here, probably due, at least in part, to the position of this cross section just below the confluence of two rivers. The sands seen in Core 3ST-54 (See Figs. 4-4 and 4-5.) are probably Ingleside remnants. The upper 5m of sand in Core 3ST-63 are mixed with soft mud and are probably there as a result of bay margin erosion.

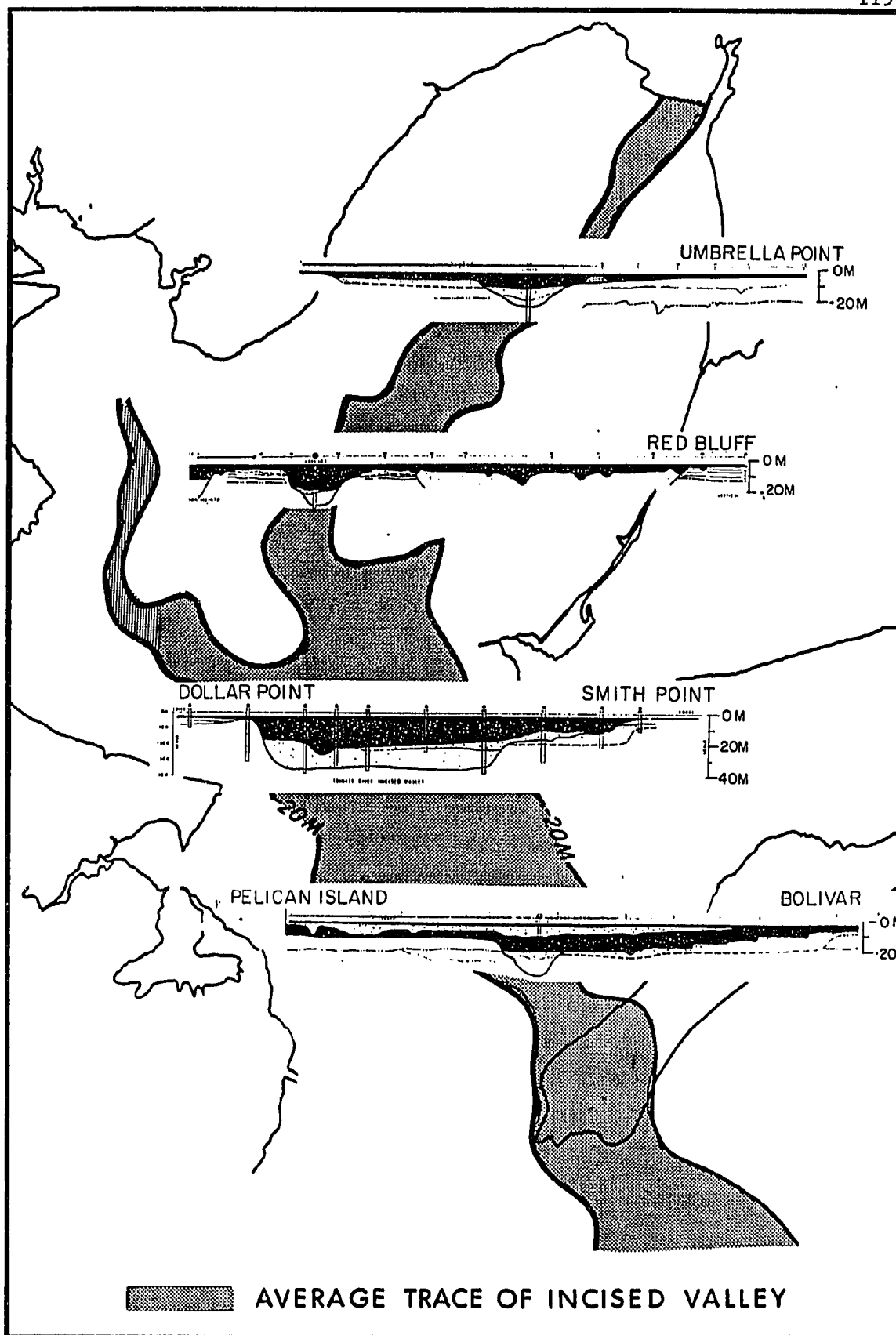
Dollar Point Line 1 (See Figs. 4-4 and 4-5) spans a much narrower stretch of the incised valley, though it crosses the valley only seven kilometers from the Smith Point section. This section (Fig. 4-22) illustrates the typical morphology of the incised valley beneath Galveston Bay. There is a broad, shallow Beaumont surface on the west side of the incised valley and Deweyville terrace overlying Beaumont, or more likely, pre-Beaumont clays, on the east side. Buried oyster reef and tidal inlet sands in the upper ten meters of this section indicate a lower estuary setting.

Bolivar Line 1 (Fig. 4-23) gives a full view of the Deweyville terraces (as seen in Fig. 4-7), the broad, shallow Beaumont terrace on the west side of the incised valley, and the flood tidal delta. Lateral accretion in sandy sediments covered by estuarine mud is visible on the seismic line, and is associated with the closing of the tidal inlet that accompanied the formation of Bolivar Peninsula.

Again, the cross sections in figures 4-19 through 4-23 illustrate the variability in the morphology of the incised valley system, and these are summarized in Fig. 4-24. Note the change from Line BL1 to Smith Point to Line RB1, a distance of only 15 km (Fig. 4-24). Variations in the width and shape of the incised river valley along this reach are random. Deweyville terrace is seen on the west side of the valley on UP1, then on the east side on RB1. The valley is wide at Smith Point; elsewhere it is very narrow.

The maps that follow in Figs. 4-25 through 4-30 add a third dimension to the characterization of the morphology of the incised valley and its fill. A 5 m contour interval is used on all of the maps. Depths on the structure contour map of the pre-flood incised valley (Fig. 4-25) are all subsea. All of the other maps are isopachs of specific depositional environments within the incised valley/estuary system.

Figure 4-24. Summary view of cross-sections across the incised valley. Cross-section locations approximate their true locations. Relationship of each cross-section to the trace of the incised valley/Holocene floodplain is emphasized.



The structure contour map on the pre-flood surface (SB2) of the buried Trinity/San Jacinto River valley (Fig. 4-25) depicts broad, flat terraces on either side of a deep valley. As has been previously discussed, the difference between the deep valley and the terraces is clearly discernable, both on the seismic data and in the sediment core descriptions. The undulating upper surfaces of the terrace deposits descend toward the center of the valley at discrete intervals. West Bay is probably a former offshore area, while East Bay appears to have been an interfluvial area (F. Siringan, personal communication).

The incised Trinity River valley can be traced from the head of Trinity Bay to Galveston Bay, where it converges with the incised San Jacinto River valley. It then continues through Galveston Bay and across the tip of Bolivar Peninsula. The valley has been mapped offshore by Thomas and Anderson (1989) and Thomas (1990). Confidence in the trace of the deep valley across Trinity and Galveston Bays is high because of the abundance of data and the ease with which it can be identified.

Fig. 4-26 depicts the distribution of the terrace deposits. Deweyville deposits are seen on both sides of the incised valley in Trinity Bay, but are present mostly on the east side of the deep valley in Galveston Bay. Beaumont terraces were identified along both sides of the incised valley in Trinity and Galveston Bays. In Galveston Bay, the

Figure 4-25. Structure contour map on Sequence Boundary 2, detailing the shape of the incised Trinity/San Jacinto River valley. Contour interval is 5m. All depths are subsea.

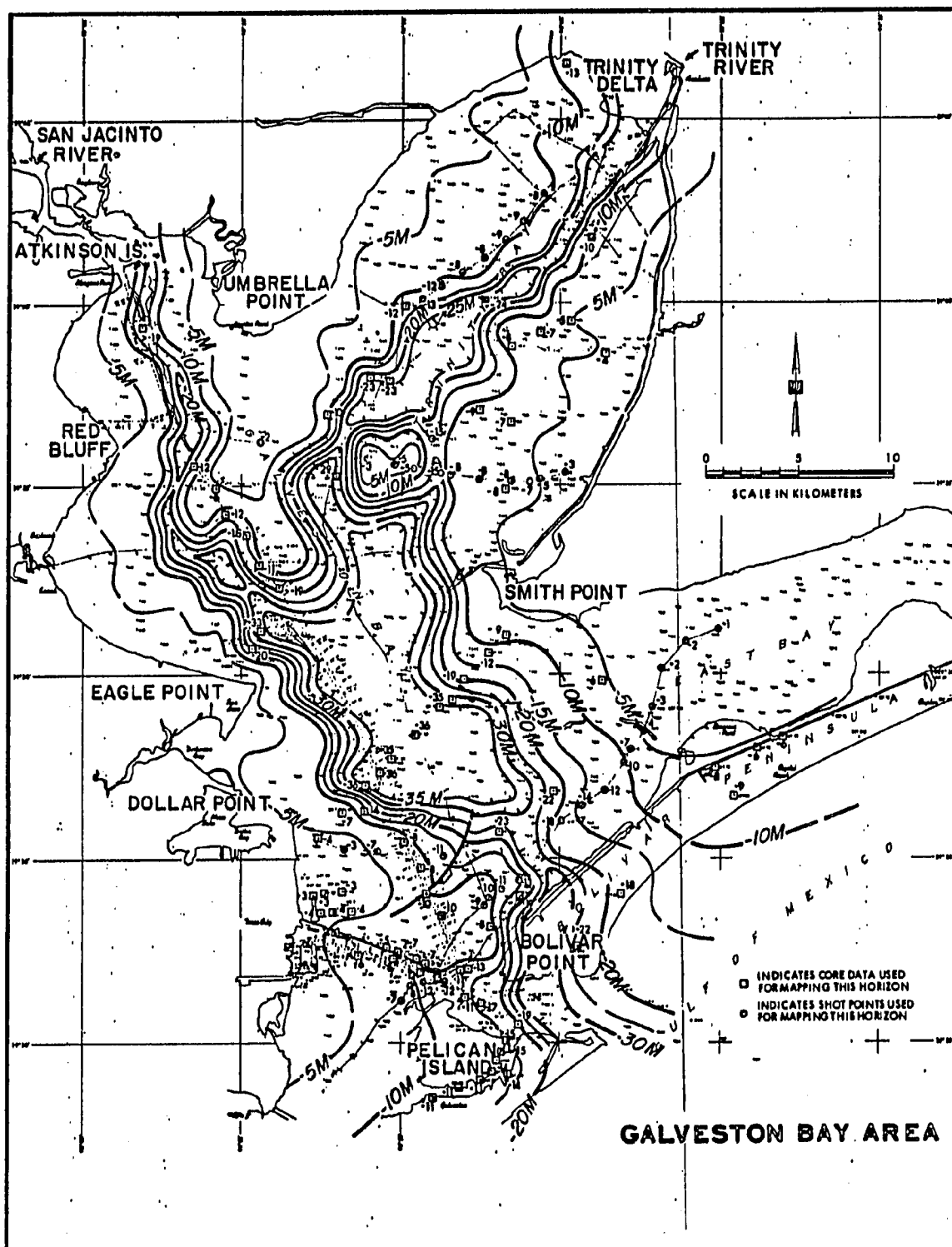
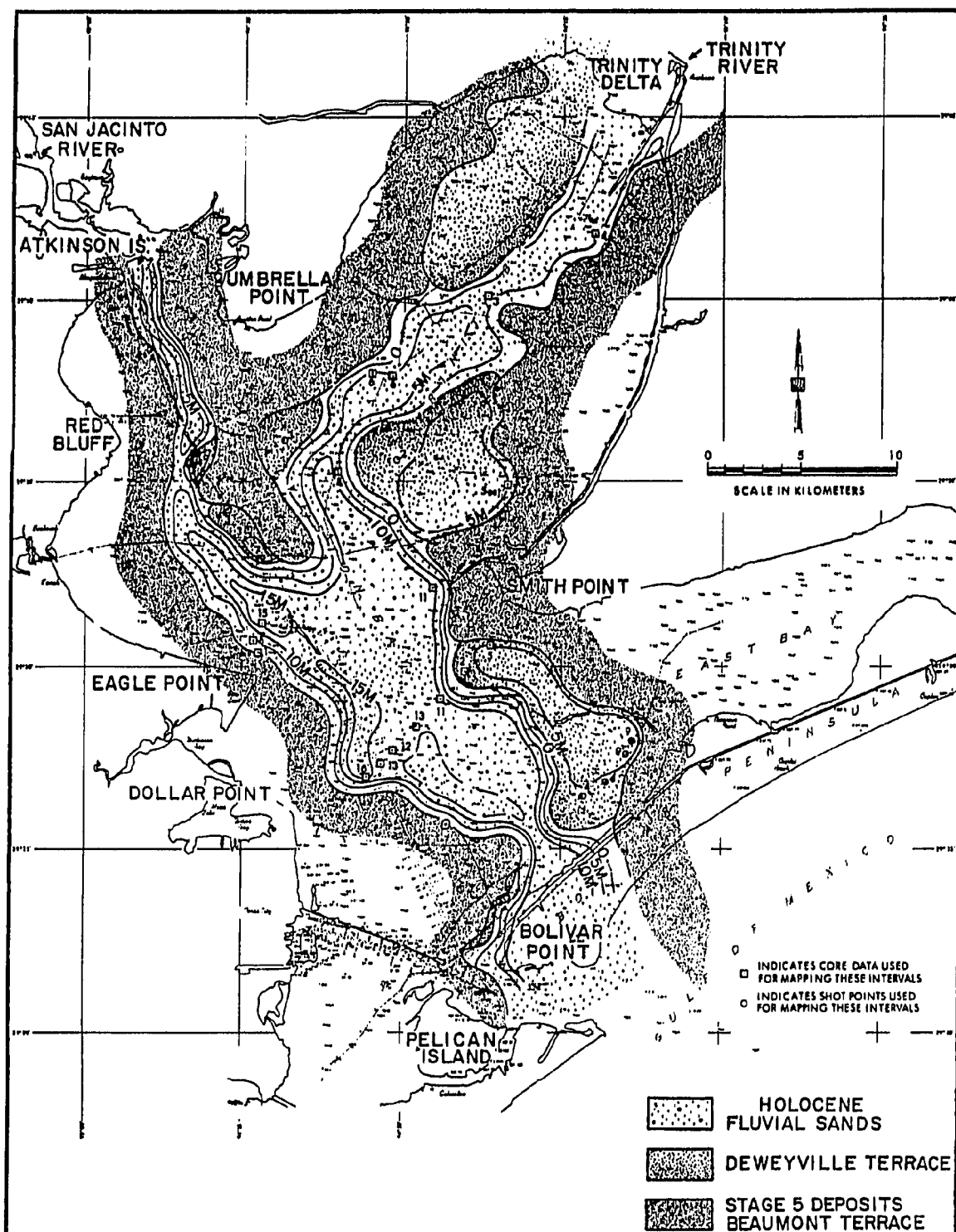


Figure 4-26. Distribution of terrace deposits. Also, isopach thicknesses of Deweyville and Holocene sands. Contour interval is 5m. Deweyville and Holocene sands are considered separately.



west side of the incised valley is very steep. An erosional surface cuts through the Beaumont, forming a broad, shallow terrace that can be seen along the western bay margin and extending outward from Dollar Point almost to Bolivar Peninsula.

Confidence in the identification and distribution of terraces is high in areas with ample seismic data and core information, such as the eastern side of Trinity Bay, where they can be plainly seen on Lines RB1 (Figs. 4-9 and 4-11), USGS 18, and USGS 20. On the west side of Trinity Bay, the terraces can be plainly seen on Lines TD8 (Fig. 4-8) and RB1. Determination of the exact lateral extent of those terraces is precluded by the quality of the other seismic lines and the lack of core data. In Galveston Bay, the erosional surface on the west side of the deep valley can be seen on many seismic lines, and there are many core descriptions which corroborate the existence of a Beaumont surface as mapped. The Williams line shows some probable Deweyville remnants between shot points 899 and 902 and between 893 and 897. On the east side, Deweyville terraces can be clearly seen on Line BL1 (Fig. 4-7), the Williams line, and on USGS Line 43, and there are sandy deposits in core 3ST-62 tentatively identified as Deweyville terrace. The extent of Deweyville deposits between core 3ST-62 and the seismic lines, all located several kilometers to the southeast of that core, is inferred.

The isopach map of fluvial sands (Fig. 4-27) shows that sand is distributed rather uniformly throughout the incised valley and that it has a maximum thickness of 16 m. This is deceptive, however, as inspection of the isopach map depicted in Fig. 4-26 reveals. Holocene fluvial sediments occupy a relatively deep valley of variable, though mostly narrow width, that is somewhat sinuous. Sand thickness averages 5-10 m, and is higher (up to 16 m) in the deeper parts of the river valley. The thickness of Deweyville terrace sands is 3-5 m on average, ranging up to 9 m thick in one location behind Bolivar Peninsula. The distribution of Deweyville sands within the incised valley is patchy.

From an exploration standpoint, locating these sand bodies within the incised valley would be difficult. Deweyville terraces are completely absent along some stretches of the incised valley. The Holocene sands, though mostly thicker than the terrace deposits, are confined to a narrow belt within the valley. The two types of sand bodies occur at different depth ranges and are separated laterally. For these reasons, the risk involved in exploring an incised valley system would approximate that of exploring an ancient fluvial system.

The distribution of marsh deposits within the incised valley is seen in Fig. 4-28. Marsh deposits are generally less than 5 m thick and were found overlying Deweyville and Holocene fluvial sediments. They are significant because

Figure 4-27. Isopach of fluvial sands. Contour interval is 5m. Deweyville and Holocene sand thicknesses are considered together.

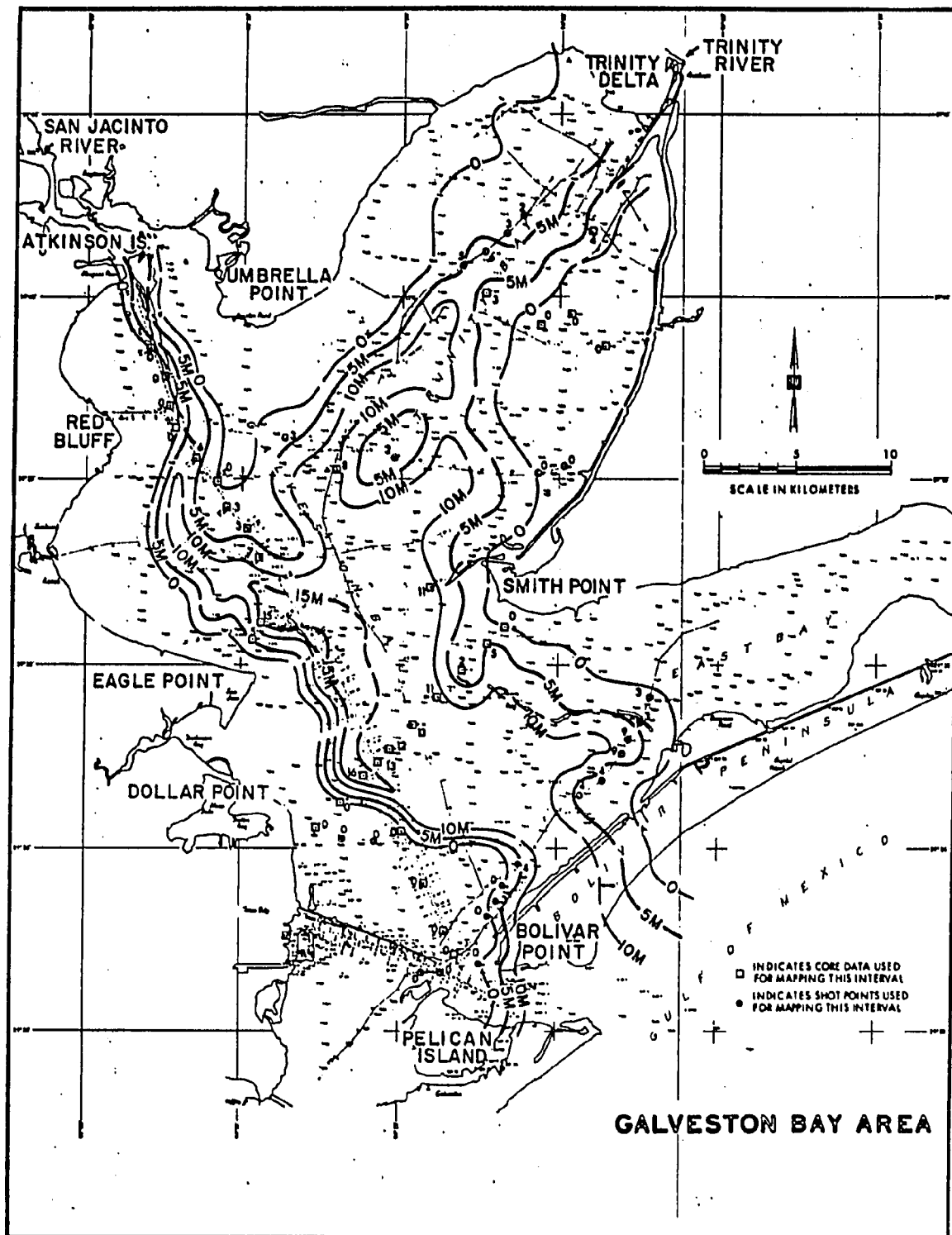
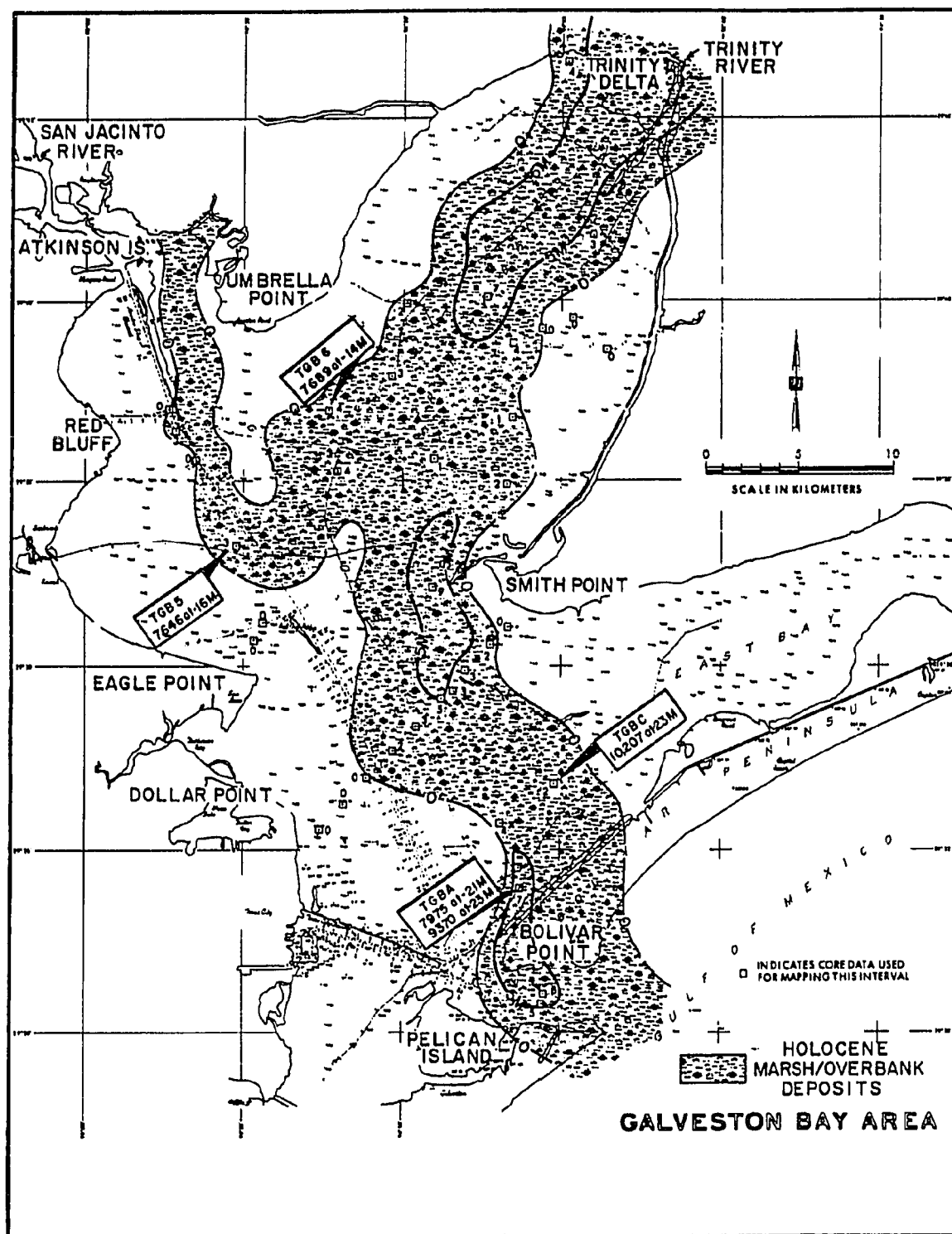


Figure 4-28. Distribution of marsh deposits with isopach thicknesses. Contour interval is 5m.



their presence indicates the location of the bayline, the flooding surface that separates fluvial from paralic sediments (Posamentier et al, 1988). Radiocarbon dates obtained from peats found within the marsh deposits can be used to date the flooding of the fluvial system and the formation of the estuary. Future work will concentrate on constraining the timing of flooding events and will rely on this map.

The isopach map in Fig. 4-29 is of the entire estuarine sequence. Rehkemper's (1969) division of the estuarine sediments into upper transgressive and regressive, middle, and lower estuary facies could not be established on the seismic data. Notice that the incised valley has substantially more estuarine mud in it than fluvial sand. This indicates a low rate of sediment supply for the Trinity River in relation to the rate of sea level rise in the Holocene.

The isopach of the bay head delta (Fig. 4-30) is based on core information. A thin ribbon of sand hugs the bay margin along the subaerially exposed Trinity delta. Sediment flow into Trinity Bay occurs through the dredged Trinity Channel (McEwen, 1963), forming the finger of sand seen in the eastern portion of Trinity Bay. No distinct delta front environment with associated foreset beds can be seen on the seismic data in the vicinity of the modern Trinity delta.

Figure 4-29. Isopach of estuarine sediments. Contour interval is 5m.

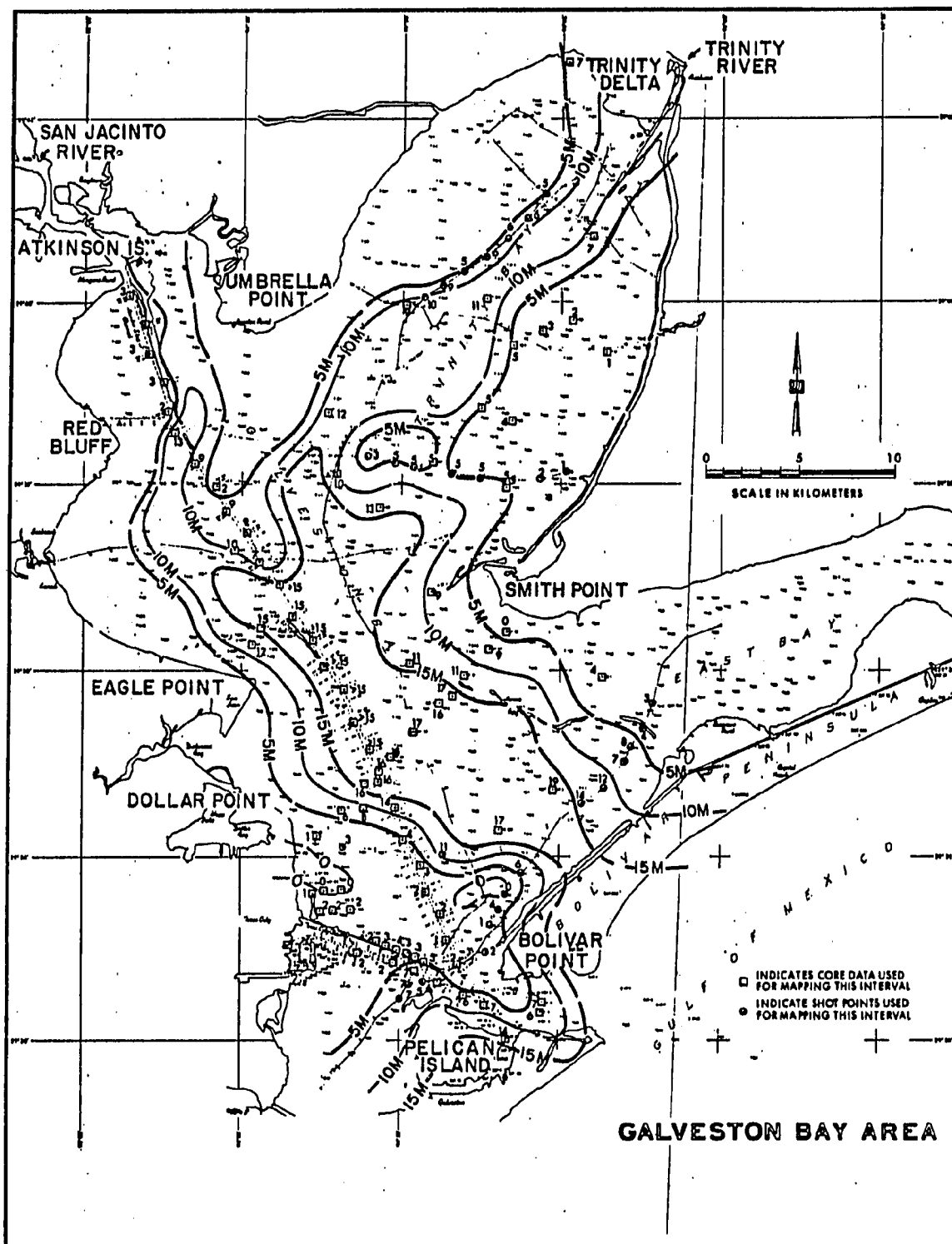
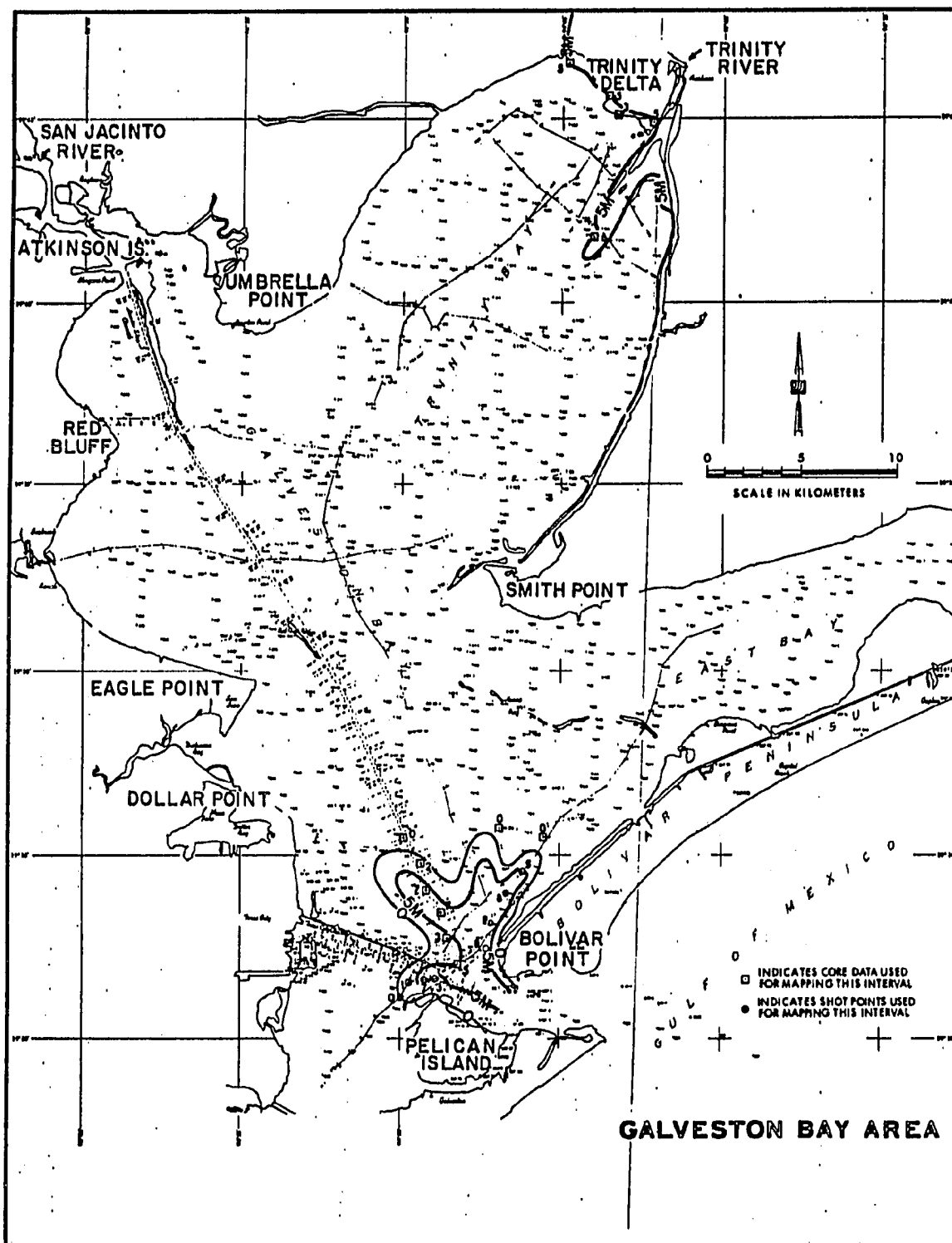


Figure 4-30. Isopach of bayhead delta and flood tidal delta. Contour interval is 5m.



Tidal inlet deposits consist of sandy mud and muddy sand with a mixture of marine and estuarine fauna found in abundance (Rehkemper, 1969). The bedforms of the flood tidal delta near Bolivar Point can be clearly seen on the uniboom data. The isopach of the flood tidal delta near Bolivar Point (Fig. 4-30) shows only those sandy sediments being deposited today by tidal action. Those sandy deposits associated with the formation of Bolivar Peninsula that are now covered with mud, and those covered by the man-made portion of Pelican Island, have not been included in this map.

It is hoped that the preceeding maps and cross sections provide a well-defined model for an incised valley/estuary. Such a model should facilitate the recognition of incised valleys, and the depositional environments within them. The sedimentary sequence and its distribution, thus described, also aids in understanding the evolution of the valley and the estuary.

Understanding the morphology of an incised valley as a whole aids in the interpretation of environments within it. As an example, point bar and tidal inlet deposits are both sandy and characterized by lateral accretion. It can be difficult to distinguish between the two environments on seismic data. Core information would clarify this, but lacking such information, one could determine the

depositional environment if one knew the shoreline location and the depth and lateral dimensions of the incised valley.

CHAPTER 5: RESULTS OF SEISMIC STUDIES: RESPONSE OF THE GALVESTON TRINITY BAY INCISED VALLEY TO CHANGES IN SEA LEVEL

The deposits in the Trinity/San Jacinto incised valley provide important sea level information. A river adjusts its gradient to changes in sea level by aggradation or incision (Mackin, 1948). Regarding the estuary, the sedimentary sequence and the vertical stacking of environments details the response of the system to the Holocene rise in sea level. Sea level information is sought to satisfy the following three objectives: 1) to understand how the sea level cycles of the last 120 k yrs are reflected in the incised valley sediments, and 2) to obtain evidence for rapid versus slow sea level rise in the last ten thousand years, and 3) to examine how the estuary responded to rapid sea level rises, if indeed such events occurred.

SEA LEVEL SIGNALS IN THE PRE-FLOOD VALLEY

In studying the sediments of the pre-flood incised valley, one observes the response of the fluvial system to fluctuations in sea level which have occurred since 120 ka. Terrace deposits within the incised valley are related to

transgressive and high stand deposition, while river incision accompanied falling sea level. The relationship of Trinity/San Jacinto River incised valley sediments to sea level cycles was established in this study by sequence stratigraphy. Consideration of the dimensions of river incision and aggradation, as well as information concerning former coastlines, allows some correlations to be made between these fluvial deposits and the late Quaternary sea level cycles as seen in Fig. 2-5. Dating of sediments is needed for precise knowledge of the stratigraphy of these sediments.

In the vicinity of Galveston and Trinity Bays, the Beaumont formation consists primarily of highstand near-shore marine and deltaic deposits. The post-Beaumont incision in the Trinity and San Jacinto Rivers left Beaumont deposits behind as strath terraces. Deweyville aggradational floodplain deposits represent transgressive and high stand deposition. These deposits were left behind as constructional terraces by subsequent lowering of sea level, and they are bound by Sequence Boundary 2. The two terrace formations are distinguished on the basis of sediments, relative positions within the valley, and surface morphology.

The time of Deweyville deposition can not be determined from the data available for this thesis. However, some points about the Deweyville terraces and the sea level

fluctuations that produced them can be made. Significant incision followed Deweyville deposition, separating this depositional event from the Holocene sea level rise. Thus, Deweyville is not, as some investigators have suggested (Aten, 1983 and Pearson et al, 1988), a parasequence within the Holocene rise in sea level. Rather, it is deposition associated with a higher order sea level cycle that occurred between Stage 5e deposition and Stage 2 incision (Thomas, 1990). This is corroborated by the seismic data used in this study. Evidence from other sources has also been discussed in previous sections of this thesis.

Fig. 5-1 summarizes the history of the Trinity/San Jacinto incised river valley in as much detail as is discernable from available data. For more detail, dates of fluvial sediments would be necessary.

Deweyville meanderbelt deposits appear to have filled the incised river valley to overflowing in many places (Figs. 4-20 and 4-23). Yet, it has been noted that sea level evidently did not rise to the present-day level at that time. This implies exceptionally high sediment supply during Deweyville time.

Response of a river to changes in base level is complex, and river incision is not always continuous, nor is it driven solely by eustasy (Blum, 1990). When threshold values of sediment load and aggradation are met, a river may respond by cutting down, leaving behind discrete terraces

Figure 5-1. Proposed depositional history of the Trinity/San Jacinto River Valley.

- 1) 120 ka. Incision of the river after the substage 5e highstand.
- 2) Sea level rose, and the river aggraded during Deweyville deposition, substage 5a or 5c.
- 3) Re-incision of the river after Deweyville highstand. At Bolivar, the Trinity River remained within the same floodplain, cutting down through Deweyville deposits. At Red Bluff, the river had changed course and cut a new valley through Beaumont deposits. This left a relatively shallow valley, filled with Deweyville fluvial sands, immediately to the east.
- 4) 18-20 ka, stage 2. Maximum depth of the Trinity River valley beneath Galveston Bay was approximately 30m below present sea level. As sea level began to rise again, the Holocene floodplain aggraded and was subsequently flooded. Flooding in this portion of the Trinity River began 8-10 ka.

AT RED BLUFF

AT BOLIVAR

1) POST SANGAMON INCISION



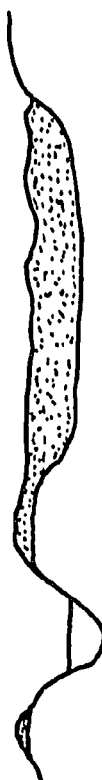
2) DEWEYVILLE HIGH STAND



3) POST DEWEYVILLE INCISION



4) 8-10 K YR B.P., IMMEDIATELY PRIOR TO FLOODING



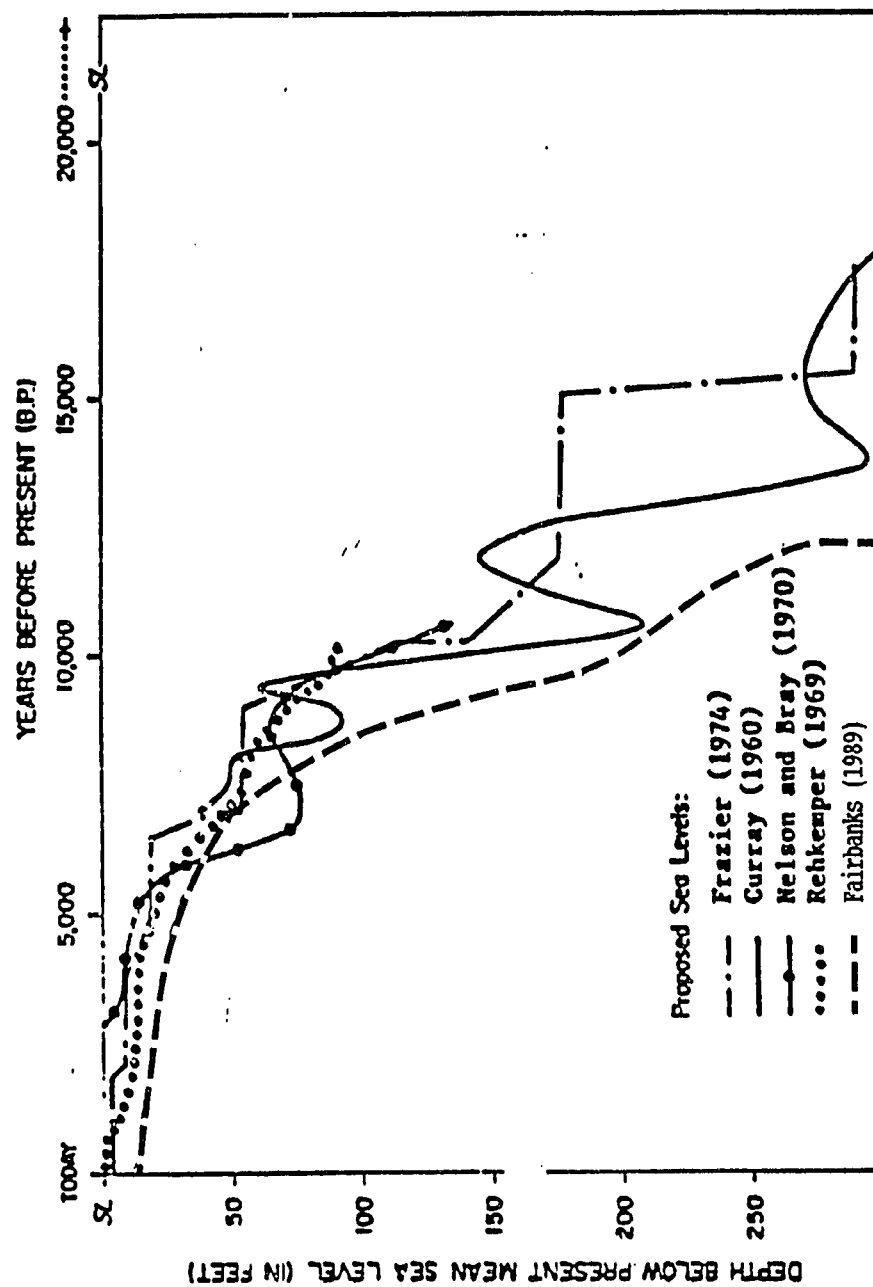
(Schumm, 1979). Thus, one cannot read into the shape and number of terrace deposits a detailed account of sea level falling with a particular number of still stands.

RESPONSE OF THE INCISED VALLEY TO THE HOLOCENE RISE IN SEA LEVEL

The sedimentary sequence within the incised valley contains information concerning the Holocene rise in sea level. Gulf Coast sea level curves show fluctuations that may correspond to rapid rises and still stands contained within the overall Holocene rise (Thomas and Anderson, 1989). Rehkemper's (1969) sea level curve was based on careful study of the incised valley sediments beneath Galveston and Trinity Bays and radio carbon dates that he obtained for many of his sediment samples. Information from Rehkemper's study, and from the seismic interpretation presented in Chapter 4 of this thesis, were used to understand the Holocene flooding of the incised valley which produced the modern Galveston/Trinity Bay estuary.

The sea level curves in Fig. 5-2 represent various interpretations of the Holocene sea level rise of the last 18-20 k yrs. Curray's (1960) curve is based on shell dates taken from offshore sand banks which he assumed were relict barrier islands. He used those fluctuations in sea level that had coinciding physiographic and lithologic evidence in generating his curve. The shape of Rehkemper's

Figure 5-2. Holocene sea level curves from the Gulf Coast (Curry, 1960; Rehkemper, 1969; Nelson and Bray, 1970; and Frazier, 1974) and the Caribbean (Fairbanks, 1989).



(1969) sea level curve is supported by evidence contained in his sediment cores. He honored, on average, all of the peat dates and used other information, such as abrupt changes in depositional environments, to indicate changes in the rate of sea level rise. Nelson and Bray (1970) honored all of their peat dates except one that they considered to be anomalously old for its depth. Dates for Frazier's (1974) sea level curve are based on peats from Vermillion Bay and on shells from offshore bars all over the Texas and Louisiana continental shelf. Frazier used all of the peat dates, and those shell dates of surf-zone pelecypods that could be supported by the dated shells of other near-shore fauna. Fairbanks (1989) curve is a 17,000 yr curve based on the dating of Barbados corals (*A. Palmata*).

It has been suggested that the rapid sea level rises shown in these Holocene sea level curves represent an over-interpretation of the data (Shepard, 1963; Kraft, 1971). Wilkinson and Byrne (1977), for instance, favor a smooth transgression based on their study of incised valley sediments in Lavaca Bay. However, evidence of former shorelines on the Louisiana continental shelf, mapped by Suter et al (1987), supports a discontinuous rate of rise of sea level, as does the evidence found in Rehkemper's (1969) data and Thomas's (1990) results.

The incised valley-fill deposits in Galveston and Trinity Bays consist chiefly of soft shelly estuarine muds. These are underlain by fluvial sands and, in some places, stiff overbank muds and peaty marsh deposits that represent flooding of the valley. The estuarine muds may be capped, depending on their position within the estuary, by bayhead delta or flood tidal delta deposits. This valley-fill sequence represents primarily transgressive sedimentation, as the environments step landward moving down through the section. Subsequent regression is evidenced in Trinity Bay by the progradation of the Trinity Delta over the estuary. This regression can also be detected in the column of estuarine sediments where deposits of the upper estuary are found overlying those of the middle estuary.

Flooding dates are combined with the shape of the flooding surface in Fig. 5-3, so that the flooding of the estuary can be understood. The structure contour map is based on seismic data and core information. Radiocarbon dates are from Rehkemper's (1969) study and are from peats and estuarine shells (See Table 3-1). The important date for initial flooding of the estuary is around 8 ka. Prior to that time, the marsh deposits represent either upstream fluvial marsh or the beginnings of a flooded valley/ upper estuary.

The significant discernable events from Rehkemper's (1969) sea level data were combined with the flooding

Figure 5-3. Structure contour map on top of flooding surface. Contour interval is 5m. All depths are subsea. Flooding dates from Rehkemper (1969) are also listed in Table 3-1. Radiocarbon dates are from peats, except where indicated on the map to be from other sources.

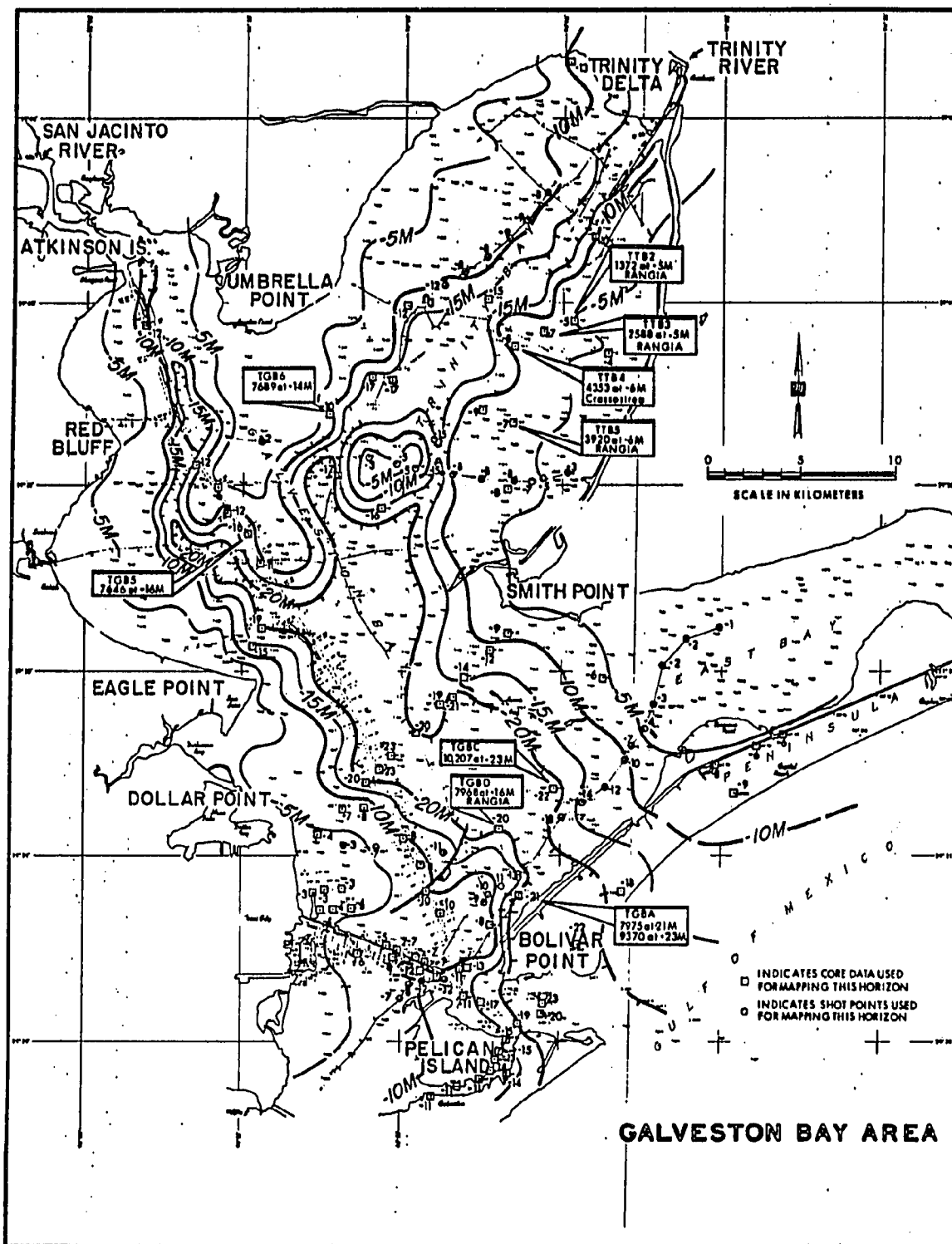


Figure 5-4. Summary of response of Galveston and Trinity Bay estuary to Holocene rise in sea level.

1) 9-10 ka. Floodplain or possible beginning of upper estuary. Based on:

TGB-C	10,207 yr. B.P.	23m	peat
TGB-A	9370 yr. B.P.	23m	peat

2) 7-8 ka. Estuary established. Based on:

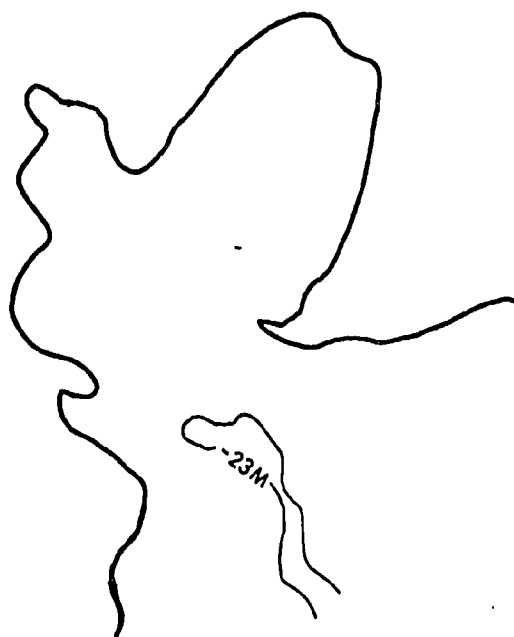
TGB-A	7975 yr. B.P.	22m	peat
TGB-D	7968 yr. B.P.	16m	<i>Rangia</i>
TGB5	7646 yr. B.P.	16m	peat
TGB6	7689 yr. B.P.	14m	peat

3) 4 ka. Maximum flooding, beginning of highstand conditions. Based on:

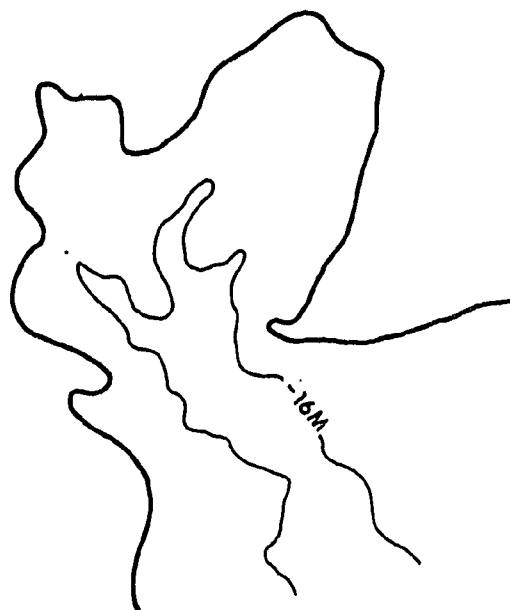
TTB4	4353 yr. B.P.	6m	<i>Crassostrea</i>
TTB5	3920 yr. B.P.	6m	<i>Rangia</i>
TGB2	3690 yr. B.P.	7m	T.O.C.

4) 2.5 ka. Highstand conditions established. Based on:

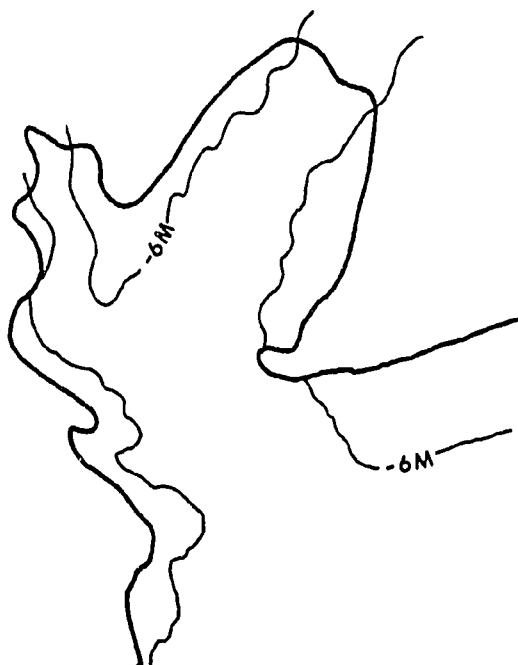
TTB2	1372 yr. B.P.	5m	<i>Rangia</i>
TTB3	2588 yr. B.P.	5m	<i>Rangia</i>



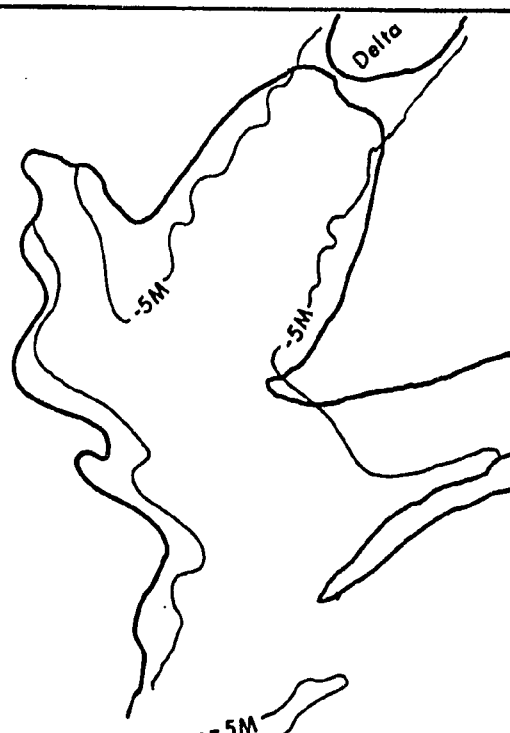
a) 9-10 K yr B.P.
Flooding or possible beginning
of upper estuary.



b) 7-8 K yr B.P.
Estuary established.



c) 4 K yr B.P.
Maximum flooding.



d) 2.5 K yr B.P.
Highstand conditions.

surface map to produce a scenario for the evolution of the estuary (Fig. 5-4). The beginning of flooding in the river valley may have occurred as early as 10-9 ka (Fig. 5-4a). By 8-7 ka (Fig. 5-4b), the estuary was established. It seems that the sea level rise was rapid, based on the evidence in core TGB-D, where middle estuarine deposits directly overlies peats. Flooding above the confluence of the Trinity and San Jacinto Rivers at approximately this time is indicated in cores TGB 5 and 6.

Following establishment of the estuary, the rate of rise of sea level evidently slowed until approximately 4ka. Three dates were obtained at depths of approximately 6m subsea along the boundary between middle bay and regressive upper bay sediments. This represents a flooding surface within the estuarine sediments (Fig. 5-4c) that is probably the maximum flooding surface. As Fig. 5-4d indicates, highstand conditions were established by 2.5 ka. The 1m rise in sea level by that time could represent another flooding event, but it may be the result of subsidence. This is unclear from the available data. Galveston Island, Bolivar Peninsula, and the Trinity Delta all formed during highstand conditions, which were established since the time of maximum flooding.

In summary, sea level signals are decipherable in these fluvial and estuarine sediments. By studying the valley-fill sediments and fauna in Trinity and Galveston Bays,

information was obtained concerning the rate of sea level rise and the position of flooding surfaces within the estuarine sediments. The interpretation in Fig. 5-4 depends on Rehkemper's insights into the sedimentary history of the estuary. It does not vary significantly from his interpretation, except in the additional 4 ka flooding surface postulated to represent rapid flooding and the beginning of the present high stand in sea level. This varies from his interpretation of flooding at 7-8 ka, then a relatively slow rise yielding to still stand at approximately 5 ka.

A cross-sectional view of the incised valley beneath Galveston Bay at Bolivar Peninsula (Fig. 4-18 for location) is presented in Fig. 5-5. This figure summarizes the response of the entire fluvial-estuarine system to sea level changes and puts it within the framework of sequence stratigraphy. The sequence boundaries and highstand Beaumont and Deweyville terrace deposits have been discussed at length. Fluvial sediments above Sequence Boundary 2 are the upstream deposits equivalent to the lowstand prograding complex. The boundary between fluvial and marsh sediments is time-transgressive and dated at approximately 9-10 ka. Marsh and estuary environments within the incised valley are backstepping deposits of the transgressive systems tract. The boundary between marsh and estuary is a flooding

Figure 5-5. Summary of fluvial-estuarine response to sea level changes. Emphasis is on depositional units and surfaces as they relate to sequence stratigraphy. (Bolivar cross-section. Information from Bolivar Line 1, shot points 2-14; Pelican Island Line 1, shot points 9 and 10; and core TGB-C. See Fig. 4-18 for location.)

PELICAN ISLAND LINE 1

SP 9

10

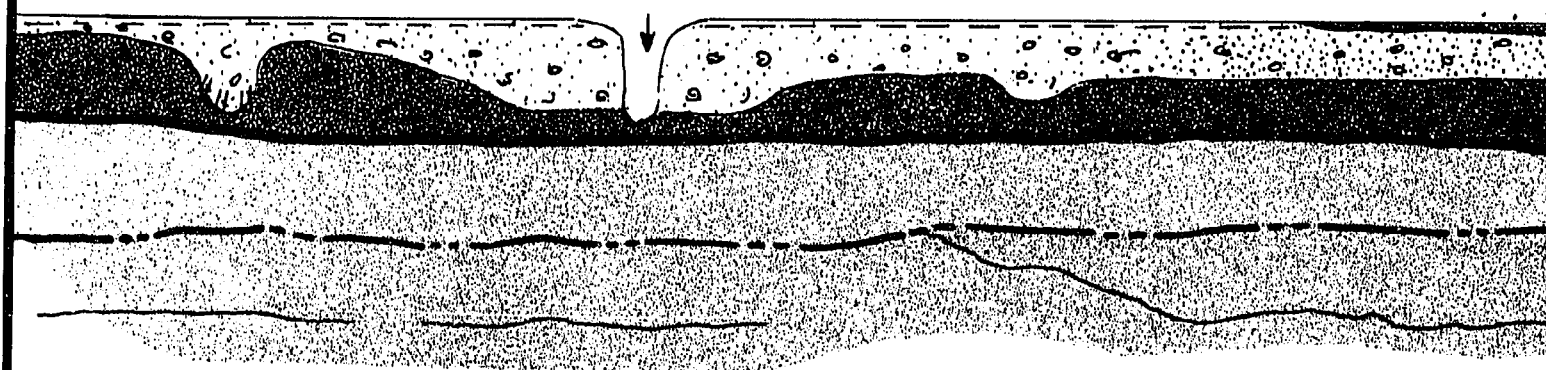
SP 2

4

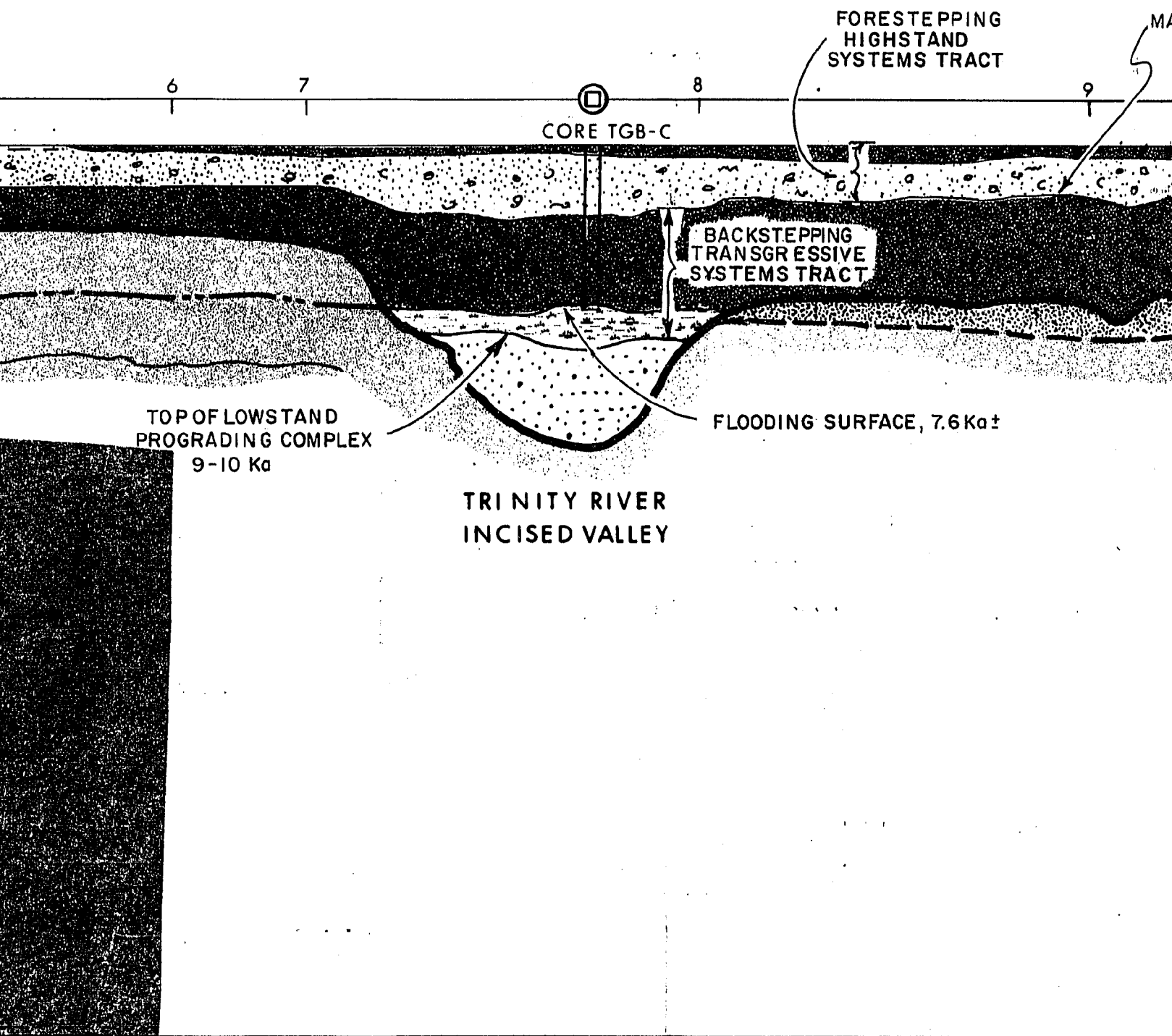
5

6

HOUSTON SHIP CHANNEL



TOP OF LO
PROGRADIN
9-10



ESTEPING
HSTAND
EMS TRACT

MAXIMUM FLOODING SURFACE
4 Ka \pm

9

10





11

12

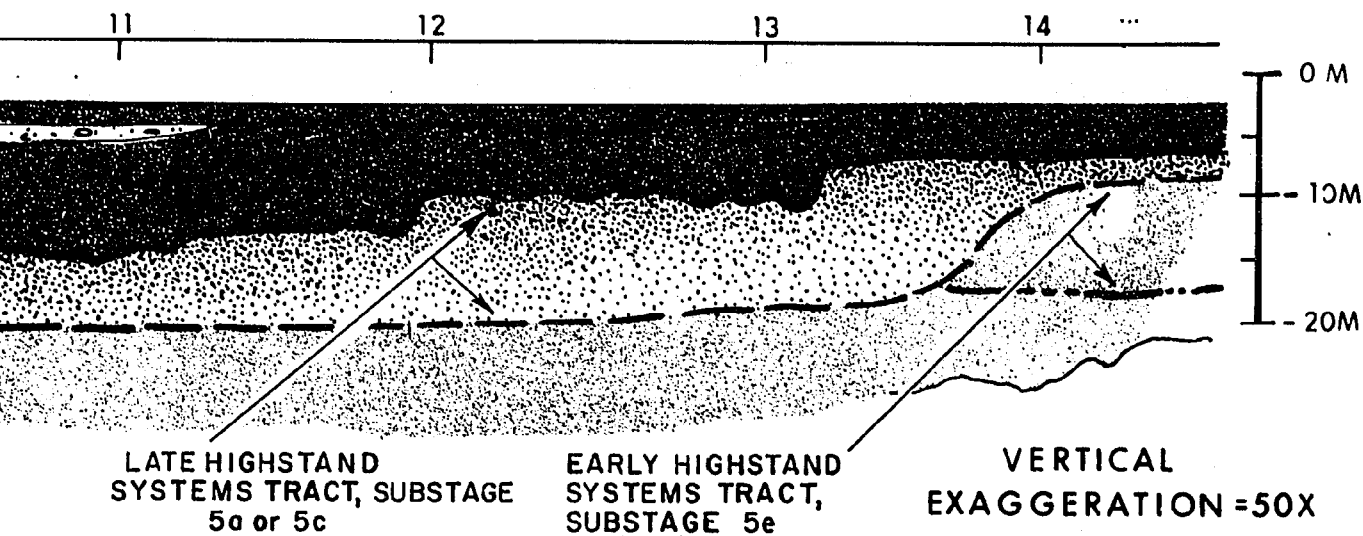
ACE, 7.6 Ka \pm

LATE HIGHSTAND
SYSTEMS TRACT, SUBSTAGE
5a or 5c







EARLY HIGH
SYSTEMS
SUBSTAGE

- WATER BOTTOM
-  HOLOCENE ESTUARINE DEPOSITS
- TIME TRANSGRESSIVE FACIES BOUNDARY
-  HOLOCENE TIDAL INLET DEPOSITS
- MAXIMUM FLOODING SURFACE (TIME BOUNDARY), 4 Ka
-  HOLOCENE ESTUARINE DEPOSITS
- FLOODING SURFACE, 7.6 Ka
-  HOLOCENE MARSH/OVERBANK DEPOSITS
- TIME TRANSGRESSIVE BOUNDARY, 9-10 Ka

EAST →

BOLIVAR
LINE I

BOTTOM
 NE ESTUARINE DEPOSITS
 RANSGRESSIVE
 BOUNDARY
 NE TIDAL INLET DEPOSITS
 UM FLOODING SURFACE
 (BOUNDARY), 4Ka
 NE ESTUARINE DEPOSITS
 IG SURFACE, 7.6 Ka
 NE MARSH/OVERBANK DEPOSITS
 RANSGRESSIVE BOUNDARY, 9-10 Ka

-  HOLOCENE FLUVIAL SANDS
-  SEQUENCE BOUNDARY, STAGE 2 (TIME BOUNDARY)
-  DEWEYVILLE TERRACE (FLUVIAL) STAGE 5 a or c
-  SEQUENCE BOUNDARY STAGE 5 b or d
-  BEAUMONT TERRACE, STAGE 5e & OLDER
-  SEQUENCE BOUNDARY, STAGE 6

surface (time boundary) dated at approximately 8 ka. Above the maximum flooding surface, dated at approximately 4 ka, tidal inlet sands and overlying estuarine clays are forestepping deposits of the highstand systems tract.

Does the Galveston/Trinity Bay estuary represent the typical response of an incised valley to sea level rise? Some answers to this question can be found by comparing it to other incised valley systems along the Texas coast, as sediment supply and river morphology contribute to the response of an incised valley to sea level fluctuations.

Sediment supply greatly influences the content of incised valley fill. Many of the Texas rivers, the Lavaca, Guadalupe, San Antonio and Nueces Rivers, for example, end in estuaries similar to Galveston and Trinity Bays (Fig. 2-1). These rivers all have a sediment supply rate that is lower than that of the Trinity River. The three largest rivers in Texas, which also have the highest rates of sediment supply, the Brazos, Rio Grande and the Colorado, are not associated with estuaries. Presumably, these three rivers had a high enough sedimentation rate to keep up with the rate of sea level rise. Thus, the incised valley fill of these rivers is probably much sandier than that of the Trinity/San Jacinto River.

The shape of each estuary reflects the morphology of the river that was flooded. Galveston and Trinity Bays have

a double lobed appearance because two rivers came together to form this estuary. They are rounded because they were formed by the flooding of a meandering river belt on the relatively gentle shelf gradient of the upper Texas coast. Again, similar rivers produced similar looking estuaries. Notice Matagorda, Lavaca, and Corpus Christi Bays, Fig. 2-1. In contrast, Baffin Bay (same fig.) has a more elongate shape and is the result of flooding smaller, flashy streams on the steeper south Texas shelf gradient.

CHAPTER 6 CONCLUSIONS

1. This study demonstrates the utility of using high resolution seismic data to recognize incised valleys and to identify depositional environments and determine their distribution.
2. Depositional environments within the incised valley system have distinct characteristics on the seismic data. It was possible in this study to distinguish between Beaumont and Deweyville terraces, the modern floodplain, estuarine and flood tidal delta deposits.
3. Trinity River incised valley morphology is more complex than previously realized. This reflects the complexity of late Quaternary sea level fluctuations.
4. Fluvial deposits beneath Trinity Bay bound by Sequence Boundary 6 indicate that fluvial systems have been present in the area for a long time.
5. In Trinity Bay, deposits overlying Sequence Boundary 6 are terminated by a ravinement surface. This supports a higher-than-present sea level for substage 5e.

6. Deweyville terraces represent high stand deposits which were left behind by subsequent lowering of sea level. Timing for this was substage 5a or 5c.

7. The Trinity River incised valley beneath Galveston and Trinity Bays is 20-35m deep along the deepest part and is 2-9 km wide along this reach of the valley. It has 5-15m of sand in the deepest part, averaging approximately 10m. Up to 5m of sand are distributed along the sides of the valley as terrace deposits.

8. The flooding event which established the Galveston Bay estuary occurred 7-8ka, and maximum flooding occurred approximately 4 ka. These were possibly rapid flooding events.

9. Beneath Galveston Bay, the incised valley is filled with 5-15m of fine-grained marsh and estuarine sediments. This amount of transgressive estuarine fill, together with the fact that the Trinity River is still confined to its incised valley, reflects the relatively low sediment supply rate of the Trinity River with respect to the rate of sea level rise in the Holocene. One could expect sandier incised valley-fill sediments in a larger river.

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