

ANNUAL REPORT

East Texas and Western Louisiana Coastal Erosion Study

Year 4

**Robert A. Morton, William A. White,
James C. Gibeaut, Roberto Gutierrez, and Jeffrey G. Paine
Assisted by Radu Boghici and Kami Norlin**

**Prepared for the U.S. Department of Interior
U.S. Geological Survey**

Cooperative Agreement No. 14-08-0001-A0912

**Bureau of Economic Geology
Noel Tyler, Director
The University of Texas at Austin
Austin, Texas 78713-8924**

October 1995



BUREAU OF ECONOMIC GEOLOGY

THE UNIVERSITY OF TEXAS AT AUSTIN

*University Station, Box X • Austin, Texas 78713-8924 • (512) 471-1534 or 471-7721 • FAX 471-0140
10100 Burnet Road, Bldg. 130 • Austin, Texas 78758-4497*

October 24, 1995

Mr. Jack Kindinger
U. S. Geological Survey
600- 4th Street South
St. Petersburg, FL 33701

Reference: Cooperative Agreement No. 14-08-0001-A0912

Dear Mr. Kindinger:

Enclosed are two copies of the Annual Report for the referenced agreement for the period of September 16, 1994, through September 15, 1995.

Sincerely,

A handwritten signature in black ink that reads "Bob Morton".

Robert A. Morton
Senior Research Scientist

RAM:amm
Enclosures

cc: N. Samuels
D. Ratcliff

ANNUAL REPORT

East Texas and Western Louisiana Coastal Erosion Study

Year 4

**Robert A. Morton, William A. White,
James C. Gibeaut, Roberto Gutierrez, and Jeffrey G. Paine
Assisted by Radu Boghici and Kami Norlin**

**Prepared for the U.S. Department of Interior
U.S. Geological Survey**

Cooperative Agreement No. 14-08-0001-A0912

**Bureau of Economic Geology
Noel Tyler, Director
The University of Texas at Austin
Austin, Texas 78713-8924**

October 1995

CONTENTS

| | |
|--|---|
| Report Organization | 1 |
| Work Element 1: Coastal Erosion Analysis | 1 |
| Work Element 2: Regional Geologic Framework..... | 2 |
| Work Element 3: Coastal Processes..... | 4 |
| Work Element 4: Prediction of Future Coastal Response..... | 5 |
| Work Element 5: Sand Resources Investigations | 6 |
| Work Element 6: Technology Transfer | 6 |

Addenda (attached)

1. Wetland Losses Related to Fault Movement and Hydrocarbon Production,
Southeastern Texas Coast
2. Index of Human Impact on Dunes and Vegetation
3. Beach and Dune Profiles, Galveston County
4. Foraminifera Analysis
5. Radiocarbon Analysis Report
6. "Deweyville" Terraces and Deposits of the Texas Gulf Coastal Plain
7. Descriptions of Vibracores, Sabine Lake
8. Site Dependency of Shallow Seismic Data Quality in Saturated,
Unconsolidated Coastal Sediments
9. Pre-project Profiles and Sediment Textures, Beach Nourishment Project
10. Shoreline Shape and Projection Program (SSAP): Objectives, Techniques,
and Initial Results
11. Descriptions of Vibracores, Sabine Bank and Heald Bank
12. Particle Size Analyses, Heald Bank and Sabine Bank Samples

Report Organization

The following report summarizes the major accomplishments achieved by the Bureau of Economic Geology during the fourth year study (FY 94-95) of coastal erosion and wetlands loss along the southeastern Texas coast. The report covers activities between September 1, 1994, and August 31, 1995. Major accomplishments are reported for each work element and task identified in the 5-year work plan of the cooperative agreement. Documents summarizing the major accomplishments and containing the important data sets and scientific conclusions are included as Addenda 1-12.

Work Element 1: Coastal Erosion Analysis

The coastal erosion work element is intended to (1) establish a computerized database of historical shoreline positions (1882-1982), (2) update the database using the most recent shoreline information (1990's), (3) analyze historical trends of shoreline movement in the context of the regional geologic framework and human modifications, (4) synthesize the physical and habitat characteristics of different shoreline types, (5) establish a network of field monitoring sites for surveying coastal changes, and (6) prepare documents of shoreline change suitable for coastal planning and resource management.

We continued examining relationships between wetland loss and accelerated relative sea-level rise resulting from human-induced subsidence and faulting along the southeastern Texas coast. Wetland loss in the vicinity of major oil and gas fields was analyzed. Marshes that have been converted to open water along active faults were identified and mapped to determine the extent of losses. Synthesis of data on wetland losses along the southeastern Texas coast shows that more than 11,700 ha of vegetated wetlands have been replaced by shallow subaqueous flats and open water. Salt, brackish, and fresh marshes and fluvial woodlands have been affected. Major losses have occurred in fluvial-deltaic areas along the Neches and Trinity rivers. Although many processes or activities may contribute to wetland loss, human-induced subsidence resulting from production of hydrocarbons and associated formation water is a major process affecting wetlands along the southeastern Texas coast. A paper on this analysis was completed for submission to the Journal of Coastal Research. The title of the paper by W. A. White and R. A. Morton is "Wetland Losses Related to Fault Movement and Hydrocarbon Production, Southeastern Texas Coast" (Addendum 1).

Task 2: Geomorphic Characterization. During year 4, the geomorphic characteristics of Gulf beaches and dunes in Galveston County were classified in cooperation with the Texas General

Land Office. This work was jointly sponsored by the Texas Natural Resources Inventory Program, which is an effort to develop extensive databases of natural resources using a geographic information system (ARC/INFO). An ordinal ranking of dunes was prepared and a ranking of human impacts on foredunes was developed (**Addendum 2**). Beach profiles were surveyed at 32 sites including the 8 sites that have been surveyed annually on Galveston Island and Follets Island (**Addendum 3**).

SIGNIFICANT RESULTS. We prepared a report that summarizes and illustrates significant wetland losses associated with oil and gas production. The report concludes that most of these losses are caused by faults that were activated as a result of large-volume production of subsurface fluids (oil, gas, and formation water). Our GPS surveys and field observations were used by the Texas General Land Office to help establish the dune protection line in Galveston County.

Work Element 2: Regional Geologic Framework

Work element 2 investigated the geologic origin and evolution of the principal subenvironments that are present along the southeastern Texas coast. This is being accomplished by establishing a chronostratigraphic framework for the coastal systems and reconstructing the evolution of coastal environments during the post-glacial rising phase and highstand in sea level. This work element will also provide data on the physical characteristics and natural habitats of the various shoreline types in the context of shoreline stability.

Task 1: Stratigraphic Analysis. The study area encompasses a diverse assemblage of depositional environments ranging from non-marine fluvial systems and transitional coastal systems to the marine continental shelf. During year four, we used vibracores, faunal assemblages, isotopic dates, and seismic surveys to investigate the late Quaternary and Holocene stratigraphy of several of these environments.

Subtask 1: Data Inventory and Compilation. Dr. Martin Lagoe, micropaleontologist with the Department of Geological Sciences, The University of Texas at Austin, and Laura Stewart, graduate student, have completed the analyses of foraminifera from onshore cores CE-2, CE-4, CE-6, and CE-7 to help with the interpretation of depositional environments represented by homogeneous muds. Species identification and abundance were plotted against depth to establish changes in paleosalinity of coastal waters and the types of geological setting represented by the examined samples. Plots of foraminifera abundance and preliminary interpretations are presented

in **Addendum 4**. Preliminary results indicate the interfluvial sediments are mostly barren of forams. It is uncertain whether the absence of forams is related to the original depositional environment or diagenetic reactions since deposition. Agglutinated species are also largely absent from other samples and the reason for this is unknown. Recent discussions with Dr. Eric Collins (Dave Scott post-doctoral researcher at Dalhousie Univ.) indicate that drying of the cores may have resulted in loss of the forams. An experiment for taking cores from the modern environments is planned to address this question of original deposition versus preservation of forams.

Eighteen samples from 11 coastal plain and Sabine Lake cores were obtained for radiocarbon analyses. Materials sampled are whole valves and shell fragments (*Rangia*, *Crassostrea*, *Mulinia*, *Anadara*), peat, wood, and organic clay. The samples represent a wide range of environments including oyster reef, bayhead delta, shoreface, beach ridge, transgressive marsh, fluvial sand, and floodbasin swamp. Analyses conducted by The University of Texas at Austin Radiocarbon Lab are presented in **Addendum 5**.

Long topographic profiles were prepared for the Sabine, Neches and Trinity rivers showing the elevations and gradients of the Beaumont surface, Deweyville terraces, and modern floodplain. Differences in gradient are a function of the structural elements over which the streams flow as they enter the basin. A paper on the Deweyville Terraces (co-authored with Mike Blum) was accepted for publication in the 1995 Gulf Coast Association of Geological Societies Transactions. A preprint of the paper is attached as **Addendum 6**.

Subtask 2: Field Studies. During year 4, we prepared, photographed and described 8 cores in the entrenched valley fill of the Neches River, and 4 vibracores from the coastal wetland interfluvial between the Sabine and Trinity River systems (McFaddin National Wildlife Refuge). The vibracore descriptions are presented in **Addendum 7**.

Also during year 4 we conducted experimental onshore seismic tests at interfluvial (High Island), chenier plain (Sabine Pass) and incised valley (Neches River) sites using different sound sources (soil probe drop hammer, hammer and plate) and compressional wave geophones. Detailed meter-spacing of geophones allowed processing of data to detect noise (surf at High Island site and road traffic at other two sites) and filter the data so that the geological reflections could be evaluated. Preliminary results are encouraging and indicate that the methods warrant additional work. A summary report of the experiments entitled "Site Dependency of Shallow Seismic Data Quality in Saturated, Unconsolidated Coastal Sediments" is presented in **Addendum 8**.

SIGNIFICANT RESULTS. We now have enough seismic profiles, deep and shallow cores, foram data, and ^{14}C ages to begin a systematic stratigraphic analysis of the Sabine Lake–Sabine Bank region. Preliminary interpretations of depositional environments were made on the basis of detailed descriptions and stratigraphic cross sections prepared for the interfluvial, chenier plain, and incised valley areas. A wood sample from the top of the fluvial sands (Deweyville) in the Neches entrenched valley near Sabine Pass yielded an age of about 8970 B.P. A peat sample just above the fluvial sand dated at 8770 BP indicates the time that the lower alluvial valley of the Sabine/Neches system was flooded. Apparently the wood was from a tree growing on the abandoned surface of the Deweyville and its age is not indicative of the time of Deweyville deposition.

Work Element 3: Coastal Processes

Understanding coastal processes is the key to understanding coastal erosion and predicting future coastal changes. Therefore, this work element involves numerous tasks that attempt to quantify basin energy, sediment motion, and the forcing functions that drive the coastal system. Objectives of this work element are to evaluate the magnitudes and rates of the relative rise in sea level during geological and historical time, to provide a basis for assessing wave and current energy as well as sediment transport, to assess climatic and meteorological influences on coastal processes, to evaluate the impacts of storms on shoreline stability and instantaneous erosion potential, and to begin quantifying the coastal sediment budget.

Task 2: Sediment Transport. In May 1995, another high-precision kinematic GPS survey was conducted at Galveston Island State Park to improve data collection techniques and to document actual beach changes. Preliminary results of the post-processed data indicate substantial changes in beach width and elevation. Sand was transferred from the forebeach to the backbeach probably as a result of beach cleaning operations routinely conducted after accumulations of Sargassum wash ashore.

Task 3: Sediment Budget. This task is evaluating the primary sediment sources (updrift erosion and fluvial sediment supply) and the principal sinks (beach accretion, onshore washover, dune construction, and offshore deposition). Some additional sediment losses occur at tidal inlets and some unknown quantity is trapped in the deep-draft navigation channels. Material periodically dredged from the ship channels deserves further evaluation as a potential source of beach nourishment material.

During the fourth year of study, we completed analysis of beach and offshore surveys along the northeastern end of Galveston Island encompassing the beach nourishment project in front of the seawall. These profiles were merged with additional offshore surveys conducted by T. L. James Co., the dredging contractor for the beach nourishment project. Combined beach and nearshore profiles at 22 sites are included in **Addendum 9**. We also interpreted the textural data for 70 sediment samples collected along the profiles and in the borrow site as part of their beach nourishment project. The beach and offshore profiling, which is a collaborative effort between the USGS study and the City of Galveston study, will provide baseline data before the dredging and pumping operations.

During year 4 we obtained the wave refraction model RCPWAVE provided by the U.S. Army Corps of Engineers' Coastal Engineering Research Center. Results from the model will be compared to large-scale (5 km) geomorphic features of the southeast Texas shoreline from East Matagorda Bay to Sabine Pass. Also we constructed a rectilinear bathymetric grid covering the study area, which is 300 km long and extends 100 km offshore to depths of 30 m. Grid cells measure 500 m alongshore and 125 m normal to shore forming a grid with 600 by 800 cells. Digital bathymetric data used to construct the grid were obtained from Mark Hanson of the U.S. Geological Survey in St. Petersburg, Florida. We used a combination of bathymetric data from surveys dating from the 1930's to the 1970's. Care was taken to use the latest available data for a particular area. Preliminary plots of the compiled bathymetry were printed to check for missing data and for quality control.

SIGNIFICANT RESULTS. Preliminary wave refraction analyses were conducted for the study area from Sabine Pass to Sargent Beach using a coarse grid. Results show constructive wave interference that is controlled by bathymetry and correlates well with the average long-term erosion rates on adjacent beaches.

Work Element 4: Prediction of Future Coastal Response

Task 1: Mathematical Analysis of Rates of Change. In year 4 development continued on the Shoreline Shape and Projection Program (SSAP) that will aid in determining future shoreline positions. The program will project future shoreline positions based on established methods that compute shoreline rates-of-change and a new method that involves comparing the shape of the projected shoreline with the expected shape. SSAP is being developed in FORTRAN for the Windows operating environment and is designed to easily accept historical shoreline data from a Geographic Information System (GIS) and to return projected shorelines to the GIS.

Work on SSAP in year 4 involved checking the algorithms that compute shoreline rates-of-change. Rate-of-change calculations from the literature and Bureau publications were compared with calculations from SSAP. Results from a computer program provided by Mike Fenster of the University of Virginia (UVA) were also compared. All comparisons have been favorable even though there were some slight differences with the UVA program and results published by Fenster et al., 1993, in the Journal of Coastal Research. The cause of these differences has been traced to variations in the methods of calculations and errors in the literature. A report providing detailed explanations of the methodology and test results is presented in **Addendum 10**.

SIGNIFICANT RESULTS. The program variables were documented to assist in subsequent program trouble shooting, additions, and upgrades. Variable names, types, uses, and occurrences have been traced through the program's subroutines and presented in a table.

Work Element 5: Sand Resources Investigations

This work is being conducted in cooperation with the Minerals Management Service as part of the sand assessment project. Textural analyses were completed for selected samples from 25 vibracores collected from Sabine Bank and Heald Bank. Core profiles for each of the 25 cores were prepared from visual descriptions and the sediment textures.

SIGNIFICANT RESULTS. We completed describing the 25 cores collected from the Sabine Bank-Heald Bank region and completed textural analyses for selected samples from the vibracores. Vibracore descriptions are presented in **Addendum 11** and sediment textures are presented in **Addendum 12**.

Work Element 6: Technology Transfer

The technology transfer work element provides for timely reporting of project results and makes the interpretations and conclusions available to users as needed. It also establishes a repository to preserve raw data and materials that would be a significant source of information for future studies.

SIGNIFICANT RESULTS. In year 4, four papers were presented at international conferences. A paper by R. A. Morton entitled "Global impact of mining and urbanization on earth surface processes and geomorphology in the coastal zone" was presented at the International Union of Geological Sciences Workshop that was held in Madrid, Spain. Results of the wetland-loss study were presented at the Society of Wetland Scientists annual meeting, held

in Portland, Oregon, May 30–June 3, 1994. An abstract entitled “Marsh Loss in the Galveston Bay System, Texas,” by W. A. White and R. A. Morton was published in the conference proceedings. Two papers were presented at the SEPM meeting in St. Petersburg, Fla. One paper by R. A. Morton and W. A. White was entitled “Evolution of incised coastal plain rivers, southeast Texas coast,” the other by J. C. Gibeaut, J. A. Kyser, R. Gutierrez, and R. A. Morton was entitled “High-accuracy bathymetric surveys for coastal research.”

Plans were initiated to hold an invited symposium on coastal research at the 1996 South-Central Section Meeting of the Geological Society of America. The meeting, which will be held in Austin, Texas, will highlight the USGS-BEG-LSU coastal cooperative research program.

Electronic files (ARC/INFO) containing all the shoreline positions for the southeastern Texas coast were transferred to the Minerals Management Service at the request of Melanie Stright, preservation officer. We also transferred ARC/INFO electronic files of shorelines of Galveston Island to a graduate student at TAMU College Station, and shorelines of South Padre Island to TAMU Corpus Christi, Conrad Blucher Institute.

Reprints of BEG articles documenting large-scale sedimentological and morphological changes in coastal environments related to hurricanes were sent to Chris Barton of the USGS in St. Petersburg.

**Addendum 1. Wetland Losses Related to Fault Movement and
Hydrocarbon Production, Southeastern Texas Coast**

**Wetland Losses Related to Fault Movement and Hydrocarbon Production,
Southeastern Texas Coast**

William A. White and Robert A. Morton

Bureau of Economic Geology

The University of Texas at Austin

Austin, Texas 78713

ABSTRACT

Time series analyses of surface fault activity and nearby hydrocarbon production from the southeastern Texas coast show a high correlation among volume of produced fluids, timing of fault activation, rates of subsidence, and rates of wetland loss. Greater subsidence on the downthrown sides of faults contributes to more frequent flooding and generally wetter conditions, which are commonly reflected by changes in plant communities (e.g., Spartina patens to Spartina alterniflora) or progressive transformation of emergent vegetation to open water. Since the 1930s and 1950's, approximately 5,000 hectares of marsh habitat has been lost as a result of subsidence associated with faulting. Marshes have expanded locally along faults where hydrophytic vegetation has spread into former upland areas.

Fault traces are linear to curvilinear and are visible because elevation differences across faults alter soil hydrology and vegetation. Fault lengths range from 1 to 13.4 km and average 3.8 km. Seventy-five percent of the faults visible on recent aerial photographs are not visible on photographs taken in the 1930s indicating relatively recent fault movement. At least 80% of the surface faults correlate with extrapolated subsurface faults; the correlation increases to more than

90% when certain assumptions are made to compensate for mismatches in direction of displacement. Coastal wetlands loss in Texas associated with hydrocarbon extraction will likely increase where production in mature fields is prolonged without fluid reinjection.

INTRODUCTION

Along the northwestern Gulf of Mexico, significant oil and gas reserves coincide with the Nation's most extensive and productive coastal wetlands. Direct wetland losses caused by excavation of drilling sites, construction of canals, and installation of pipelines by the petroleum industry are easily observed and have been documented as a primary environmental impact (TURNER and CAHOON, 1988). Less obvious but equally destructive are wetland losses associated with subsidence and faulting induced by oil and gas production. This study extends the work of WHITE and TREMBLAY (1995) by examining in more detail changes in wetlands along faults and the histories of fault movement and fluid production.

Hundreds of faults offset Quaternary sediments and intersect the land surface along the southeast Texas Gulf Coast (VERBEEK, 1979). There is evidence that many faults have become active during the past few decades as a result of the withdrawal of water, oil and gas (VAN SICLEN, 1967; GUSTAVSON and KREITLER, 1976; VERBEEK and CLANTON, 1981). Wetland losses along surface faults have been documented (WHITE *et al.*, 1985; MORTON and PAINE, 1990; WHITE and TREMBLAY, 1995; WHITE and MORTON, 1995), but the extent, timing, and probable causes of the fault activity have not been fully investigated. In this study, 40 faults that intersect coastal wetlands on the upper Texas coast were identified, mapped, and examined using aerial photographs (Figure 1). Primary objectives of this investigation were to document the locations and lengths of surface faults

intersecting coastal wetlands, to determine historical activity of the faults, and to examine the relationship between fault movement, underground fluid production, and wetland changes.

METHODS

Most surface faults analyzed in this paper were initially identified as part of a wetlands mapping effort of the Texas Coastal Zone (WHITE *et al.*, 1985 and 1987). Faults were identified primarily on photographs taken in 1979, from which the fault traces were optically transferred to USGS 7.5 minute topographic base maps.

Faults crossing wetlands are traceable on aerial photographs due to slightly lower elevations on the faults downthrown side creating contrasting moisture regimes and vegetation communities that highlight the fault trace (Figures 2 and 3) (CLANTON AND VERBEEK, 1981; WHITE *et al.*, 1985). Sequential aerial photographs were used to determine when a fault first became visible and traceable at the land surface and to examine the subsequent progressive changes in vegetation and moisture conditions along the fault. The principal imagery examined to define fault traces and changes along the trace were aerial photographs taken in 1930, 1956, 1979, and 1989-1993. In selected areas, these photographs were supplemented with 1940s, early 1950s, and 1960s vintage photographs. The trace of each fault was classified as: (0) not visible, (1) faintly visible, or (2) distinctly visible. Faults that were distinctly visible and traceable on more recent photographs, but only partly traceable on older photographs were assigned two visibility classes, such as 0 to 1.

The distinctiveness of a fault trace can be influenced by soil moisture at the time the photographs were taken (VERBEEK and CLANTON, 1981). In general, we concluded that variations in moisture conditions during wetter periods should produce fault-normal variations in soils and vegetation that persist, making the

faults visible on photographs even during drier periods. For example, faults traceable on 1930 photographs, which were taken during a period of higher than normal rainfall, were equally traceable on 1956 photographs, which were taken during a drought.

The link between surface faults and subsurface faults has been reported by many researchers (WEAVER and SHEETS, 1962; VAN SICLEN, 1967; REID, 1973; KREITLER, 1978; VERBEEK, 1979; VERBEEK and CLANTON, 1981). In this study, surface and subsurface faults were correlated by extrapolating subsurface faults shown on structure maps (from GEOMAP Co. and other sources) to the surface generally at angles between 45 and 80° (QUARLES, 1953; BRUCE, 1973; REID, 1973; GUSTAVSON and KREITLER, 1978).

Locations of surface faults and directions of throw were compared to the locations of oil and gas fields to determine the geographic relationship of the faults to the fields. A distance of 5,000 m was used as an estimate of geographic proximity between surface faults and producing fields. Faults may be activated greater distances than this from some fields if production from multiple fields causes regional depressurization and subsidence (EWING, 1985; GERMIAT and SHARP, 1990).

FAULT DISTRIBUTION, MOVEMENT, AND RELATION TO SUBSURFACE FAULTS

Distribution

Forty faults intersecting wetlands were identified and mapped between Sabine Lake and Matagorda Bay (Figure 1). Faults are scattered throughout this region and affect wetlands that have developed on Pleistocene deltaic and thin Holocene marsh deposits on the mainland, and Holocene barrier and flood-tidal delta deposits on the

islands and peninsulas (FISHER et al. 1972). Four parallel faults forming a graben, which is defined at the surface by wetter conditions and lower marshes, were mapped on the inland margin of East Bay (Figure 1). VERBEEK and CLANTON (1981) mapped 5 faults in this area, one of which was identified in shallow high-resolution seismic reflection profiles. Inland from Follets Island, there are 9 faults, most of which have a NE strike. Several of these faults appear to be associated with the salt dome Hoskins Mound. In general, faults are linear to curvilinear, and their traceable lengths range from 1 to 13.4 km (Table 1).

Fault Movement

Most of the faults (about 75%) exhibited recent surface expression during the last 6 decades, with the majority appearing since the 1950s. Of the 40 faults mapped on recent aerial photographs, only 10 (25%), were visible on photographs taken in the 1930s (Table 1). By the early- to mid-1950s, 26, or approximately 65%, were identifiable on aerial photographs. Many of the faults identified on 1930s and 1950s photographs, however, were only faintly traceable and would not have been easily recognized without prior knowledge of the fault locations. By 1979, all but one of the 40 faults could be located and traced on aerial photographs. Distinctiveness of fault traces was due primarily to extensive replacement of emergent vegetation by open water along the downthrown side.

Surface and Subsurface Faults

Geological structures in the Gulf Coast Basin that influence near-surface coastal plain sediments formed as a result of gravity-driven tectonism involving tensional stresses and sediment mobilization. The dominant features are large

expansion faults (growth faults), salt diapirs, and withdrawal basins. Late Cenozoic structural history of the region includes several stages of faulting and reactivation of older faults caused by episodic movement of salt and deep-water shale as well as shifting sites of diapirism. The regionally extensive expansion faults in the subsurface are aligned northeast-southwest, which is parallel to the present day coast.

Subsurface faults are high-angle normal faults that have increased throw with depth, and an angle that commonly steepens toward the earth's surface (VAN SICLEN, 1967; BRUCE, 1973, KREITLER, 1977; SHEETS, 1979; VERBEEK and CLANTON, 1981). Subsurface faults were extrapolated to the surface at angles generally ranging from about 45° to 80°. Most faults in this study had a best fit at angles of between 60° and 70° (Table 1).

Sixty percent of the mapped faults can be correlated with extrapolated faults shown on subsurface structure maps. The correlation of surface faults with subsurface faults increases to 80% if only those faults with adequate subsurface control for fault identification are considered. Sixteen surface faults have an excellent to good correlation with subsurface faults in terms of location, orientation, and direction of vertical displacement, and 8 exhibit at least some properties that correlate with subsurface faults. Four of the faults have reverse throws relative to nearby subsurface faults. Considering these as correlative brings the total out of the 30 with adequate subsurface control to 28, or 93% that can be correlated with subsurface faults .

Surface faults can have an apparent reverse throw relative to their subsurface equivalent for several reasons. First, the direction of movement along a fault at the surface can be locally opposite to the throw of the major fault plane at depth because of a rotational component associated with fault movement. This phenomenon commonly occurs along normal faults associated with salt domes and shale ridges in the Gulf Coast Basin (MARTIN JACKSON, 1995, Personnel Communication).

Second, movement at the surface across a fault can be in a reverse direction to the original displacement along the fault (BELL, 1991).

The relationship between subsurface and surface faults is exemplified on Bolivar Peninsula near the Caplen field, where two subsurface faults that intersect Lower Miocene strata at about 1,800 m have an excellent correlation with surface faults at extrapolated angles of approximately 65° (EWING, 1985).

CHANGES IN EMERGENT VEGETATION ACROSS FAULTS

Field observations and marsh transects indicate that vegetation communities change across faults as a result of elevation differences on the upthrown and downthrown sides. For example, along a topographic transect across a fault inland from Follets Island (Figure 1), plant communities on the upthrown side, which is about 25 cm higher than the downthrown side, change from an irregularly-flooded high marsh of Spartina spartinae and Spartina patens, to a more frequently-flooded low marsh of Spartina alterniflora, Distichlis spicata, and Salicornia sp. (Figure 4). Soils also vary from the upthrown to downthrown sides reflecting a change in the frequency of flooding and plant species composition (Table 2). Similar changes occur across faults in back-island salt marshes on Bolivar Peninsula. Field observations in May 1991 indicated that vegetation communities on the topographically higher upthrown sides of faults contained more Spartina patens and Distichlis spicata than the downthrown sides, which supported larger stands of Spartina alterniflora and patchy areas of Scirpus maritimus, Distichlis spicata, and Spartina patens.

Differences in plant communities across faults appear to be related to a successional change in vegetation as subsidence and associated relative sea-level rise increase the depth, frequency, and duration of flooding on the downthrown sides of

faults. Because Spartina alterniflora can withstand more frequent flooding than Spartina patens and Distichlis spicata (ADAMS, 1963; CHABRECK, 1972; WEBB and DODD, 1978; GLEASON and ZIEMAN, 1981; MENDELSSOHN and MCKEE, 1988a; NAIDOO et al. 1992), a gradual replacement of these higher marsh species by Spartina alterniflora is expected. In a salt marsh in North Carolina, ADAMS (1963) attributed the replacement of portions of a maritime forest (Juniperus virginiana) by Spartina alterniflora to a relative rise in sea level. If fault-related subsidence and relative sea-level rise continue at rates that surpass rates of marsh sedimentation, eventually water depths and frequency of inundation will exceed even that which Spartina alterniflora can tolerate (MENDELSSOHN and MCKEE, 1988b) and all emergent vegetation will be replaced by open water.

These types of successional changes are occurring on the downthrown sides of faults crossing Bolivar Peninsula. Aerial photographs taken in the 1930s do not reveal the faults. Vegetation appears to be primarily that of a topographically high irregularly-flooded marsh characterized by Spartina patens and Distichlis spicata. By the 1950s, the faults are visible, and formerly high marshes on the faults downthrown sides had become partly replaced by low regularly-flooded Spartina alterniflora marsh, and open water. By 1979, there was additional local replacement of high marsh by low marsh, but the most significant and widespread change was that from marsh to open water.

Succession and loss of emergent vegetation in this area are attributed more to inundation than to increases in salinity. Estuarine salinities in East Bay, for example, average approximately 10-15 ppt (MARTINEZ 1973, 1974, 1975), which is within the tolerance range of salinities for most of the above listed species (PENFOUND AND HATHAWAY, 1938; CHABRECK, 1972; MENDELSSOHN and MCKEE, 1988a). Salinity may play a roll in the succession, however, as Spartina

patens is less tolerant of increasing salinities than Spartina alterniflora (PEZESHKI et al. 1987; MENDELSSOHN and MCKEE, 1988a; NAIDOO et al. 1992).

The progressive historical changes toward more extensive flooding, permanent inundation, and loss of wetlands on the downthrown sides of faults (Figure 5) is an indication of active fault movement. Approximately 5,000 hectares of emergent vegetation have been converted to open water as a result of fault-related subsidence from the 1930s and 1950s to the 1970s. About 70% of the loss has occurred in the Neches River Valley in association with two faults that cross the valley (Figure 6). Additional wetland losses totaling almost 900 hectares have occurred along faults in salt marshes on Bolivar Peninsula and in brackish marshes to the northeast (WHITE and TREMBLAY, 1995).

In some areas, differential subsidence along faults has resulted in an expansion of marshes rather than a loss of marshes. Marsh expansion is due to more frequent inundation and the spread of hydrophytes into areas previously characterized by prairie grasses. An example of this type of change occurred along an active fault that crosses Gordy Marsh near the eastern shore of Trinity Bay (Figure 7). This fault could not be clearly discerned on aerial photographs taken in 1930 nor in the 1950s, but by 1963, the fault had a distinct trace because of wetter conditions on the downthrown southeast side. By 1970 and 1979, the fault was even more distinct and wetlands, as interpreted on aerial photographs, had expanded. From the 1950s to 1989, marsh area increased by 275 hectares on the downthrown side of the fault (WHITE et al. 1993).

A scenario of vegetation succession similar to the irregularly to regularly flooded marshes can be envisioned for the prairie to marsh conversion as the frequency of flooding increases on the downthrown sides of faults. Prairie grasses near Gordy Marsh are dominated by Spartina spartinae, with other scattered species including Schizachyrium scoparium, Paspalum lividum, Setaria geniculata (CROUT

1976; HARCOMBE and NEAVILLE, 1977). Marshes are characterized by Spartina patens, Spartina spartinae, Distichlis spicata, Scirpus maritimus, Phragmites australis, and locally Spartina alterniflora, among other species (CROUT 1976; HARCOMBE and NEAVILLE, 1977; BENTON et al. 1979; and WHITE et al. 1985). As the area of prairie grasslands became more frequently inundated, there was a corresponding change in vegetation types from prairie species to marsh species. Vegetation and soil types are similar to those shown in Table 2.

SURFACE FAULTS AND OIL AND GAS PRODUCTION

Subsidence associated with the withdrawal of underground fluids such as ground water, oil, and gas, has been reported in many parts of the world (BELL, 1988) including the Gulf Coast Basin (GABRYSCH, 1969; POLAND and DAVIS, 1972; MARTIN and SERDENGECTI, 1984). Some early examples of subsidence and faulting associated with oil and gas production are the Goose Creek field in the Houston area, and the Saxet field in the Corpus Christi area (PRATT and JOHNSON, 1926; GUSTAVSON and KEITLER, 1976; HILLENBRAND, 1985). There is evidence that production from at least 18 oil and gas fields located on the Texas coastal plain has caused subsidence, some of which occurred along active faults (KREITLER, 1977; VERBEEK and CLANTON, 1981; EWING, 1985; KREITLER et al., 1988; HOLZER, 1990; WHITE and TREMBLAY, 1995).

Despite the widespread recognition of this phenomenon, the potential for significant wetland losses as a result of moderate to deep hydrocarbon production has generally been disregarded because in many old sedimentary basins, the magnitude of compaction strain associated with hydrocarbon production was small (GEERTSMA, 1973). This is not the case in relatively young sedimentary basins

where large volumes of hydrocarbons and formation water are produced at moderate depths.

According to summaries presented in CHILINGARIAN *et al.* (1995), induced subsidence depends primarily on production depth, areal extent and thickness of reservoir, consolidation state of reservoir and overburden, heterogeneity of sediment column, and volume and rate of produced fluids. Tertiary reservoirs and overlying strata of the Gulf Coast basin where subsidence is pronounced are typically shallow to moderately deep, moderately thick (multiple pay zones) and areally extensive, unconsolidated, interbedded sandstones and mudstones with high in-situ porosities (MORTON and GALLOWAY, 1991). These sediments are highly compressible and subject to compaction as a result of fluid withdrawal.

Oil and gas reservoirs of the Gulf Coast are compartmentalized by sealing faults that create permeability boundaries and limit lateral flow of fluids. Because the reservoirs are confined by faults that prevent drainage from adjacent strata, large-volume fluid production results in greatly reduced pore pressures and increased shear stresses. In the absence of direct subsurface measurements, cumulative fluid production is a leading indicator of reduced pore pressures and increased shear stresses within the reservoir.

Previous studies in the Gulf Coast Basin demonstrate that land surface subsidence commonly occurs several kilometers away from producing wells rather than directly above the producing formation (GUSTAVSON and KREITLER, 1976; EWING, 1985; MORTON and PAINE, 1990). The locus of subsidence and wetland loss is controlled by the coupling between reservoir compaction and slip along the faults. The induced subsidence and wetland losses are concentrated along faults that become active when sufficiently large volumes of fluid (oil, gas, formation water) are removed from the subsurface. Fluid extraction causes a decline in pore pressure within the rocks and alters the state of stress near the faults. Thus, both the pattern

of hydrocarbon production and the three-dimensional geometries of faults need to be considered in predicting the location and magnitude of wetland losses.

Geographic Association between Surface Faults and Oil and Gas Fields

In this study, 29 (about 70%) of the surface faults are within 5,000 m of an oil and gas field and have an orientation and direction of throw that suggests an association with the field. Only 21 fields (53%), however, have both a close geographic association with faults and production history (for example, year of discovery) that suggest that oil and gas production could be responsible for the faults initial appearance at the surface. Nevertheless, the progressive loss of wetlands along many of the faults indicates recent fault movement may be related to oil and gas production even though the faults were present before production began. In some cases fault movement may be related to regional extensional subsidence associated with large-volume regional fluid production from more distant fields.

VERBEEK and CLANTON (1981) and HOLZER and BLUNTZER (1984) concluded that differential subsidence and fault activation from hydrocarbon production in the Houston area is relatively minor compared to that associated with extensive volumes of groundwater withdrawal. Most of the faults analyzed in this study, however, are in areas that should not be significantly affected by groundwater pumpage.

Hydrocarbon Production, Fault Activity, and Associated Wetland Losses

To determine possible relationships between hydrocarbon production, and surface fault activity promoting wetland loss, we investigated production histories of three moderately large oil and gas fields that have a geographic association with

surface faults. All three fields, Port Neches, Clam Lake, and Caplen (Figure 8), are associated with deep-seated salt domes (FISHER *et al.*, 1972, 1973; MUSOLFF, 1962). Production histories of the three fields are somewhat similar in that each was discovered before 1940, production is from Miocene and Oligocene reservoirs, and cumulative oil production in each exceeds 19 million barrels. Surface faults correlate well with subsurface faults, and formerly extensive marshes have been converted to open water on the downthrown sides of the faults. Surface environments where the fields are located include the alluvial valley of a major river, an interfluvial coastal plain marsh and a barrier island (Figure 8).

Port Neches Field.

The Port Neches field is located in the Neches River valley near the head of Sabine Lake (Figure 8). Cumulative hydrocarbon production has exceeded 25 million barrels of oil and 40 billion ft³ of gas since discovery of the field in 1929 (Figure 9). If associated fields (Port Neches, North, South, and West) are included, cumulative oil production exceeds 33 million barrels, and gas production 500 billion ft³. Production in the Port Neches field is from average depths of about 1,800 m (TEXAS RAILROAD COMMISSION, 1994). Annual production records show rapid acceleration in gas production in the late 1950s, with production falling precipitously after 1959 (Figure 9). Oil production peaked in the early 1950s and gradually declined through the 1980s.

Traces of two surface faults mapped east of the Port Neches field (Figure 6) were not visible on photographs taken in the 1930s or mid 1950s, but were visible on photographs taken in the 1960s (Figure 5). Between 1956 and 1978, almost 3,500 hectares of wetlands in the Neches River valley were replaced by open water and shallow subaqueous flats (WHITE *et al.*, 1987). These extensive losses occurred

primarily on the downthrown side of the faults that border the field (Figure 5 and 6) indicating that differential subsidence over the field contributed to the loss of wetlands.

Complications arise in attributing all the wetland losses in the Neches River valley to subsidence because other processes can contribute to wetland loss. Among those processes are dredging and filling of wetlands, which can cause direct and indirect losses, and construction of upstream dams and reservoirs that can reduce the supply of fluvial sediments that nourish and maintain wetlands. The spatial and temporal relationships among oil and gas production, fault activation, and wetland loss are compelling evidence that there is a causal relationship between hydrocarbon production and differential subsidence across the mapped faults.

Clam Lake Field

The Clam Lake field, which is located in the interfluvial area between Sabine Lake and East (Galveston) Bay (Figure 8), was discovered in 1937. Since discovery, it has produced more than 21 million barrels of oil and 4 billion ft³ of gas (Figure 10) at depths ranging from 700 m to 2000 m (WILLIAMS, 1962). The field is centered on a salt dome with complex subsurface faulting including a major north-south striking fault downthrown on the west side toward the field (WILLIAMS, 1962).

Extrapolation of this fault to the surface at an angle of approximately 60° matches well with a surface fault that is traceable over a distance of about 6 km (Figure 11). The fault trace was not visible on aerial photographs in 1930 and 1956, but is distinctly visible on photographs taken in 1966 and later. The fault intersects brackish-water marshes and its visibility is accentuated because of ponded water and low marshes on the downthrown side of the fault (Figure 11). Between 1956 and

1987 approximately 275 hectares of marsh was converted to open water primarily on the downthrown side of the fault (WHITE and TREMBLAY, 1995).

Fault movement between 1956 and 1966 correlates well with annual oil production (Figure 10). Production gradually increased from 1937 to 1958, after which there was a rapid rise in production from 1958 to 1963 followed by a decline. Cumulative oil production through 1964 exceeded 10 million barrels (Figure 10). A second fault in this area was not clearly visible on 1978 photographs but is very distinct on 1989 photographs, indicating activation or accelerated movement during the past two decades.

Caplen Field

Production from the Caplen field is primarily from lower Miocene reservoirs at depths of 2,100 to 2,200 m (EWING, 1985). After its discovery in 1939, oil production reached a peak in the mid 1950s when annual production exceeded 600,000 barrels (TEXAS RAILROAD COMMISSION records). Between 1943 and 1979, annual production fluctuated between 300,000 and 600,000 barrels a year, declining at a relatively uniform rate after 1970. Gas production increased in the late 1950s and 1960s, with casinghead gas reaching a peak between 1968 and 1971, and non-associated gas reaching a peak in the early 1980s. Production of both oil and gas declined after 1980. Apparently most of the production comes from a strong water drive, and records from the Railroad Commission of Texas indicate a total fluid production, including formation water, of 30-40 million barrels to 1985 (EWING, 1985).

Two surface faults that cross the barrier island are not visible on aerial photographs taken in 1930, but portions of the faults are traceable on photographs taken in 1952. A benchmark releveled survey along Bolivar Peninsula indicates

differential subsidence across a fault in this area from 1936 to 1954 (Figure 12). By 1950, cumulative production had reached about 3.7 million barrels of oil, and 647 million ft³ of gas (Figure 13). The faults are more pronounced on photographs taken in the 1970s and 1980s, as areas of open water expanded at the expense of marshes. Approximately 600 hectares of marsh were converted to open water between the 1950s and 1989 (WHITE and TREMBLAY, 1995). This wetland loss coincides with annual gas production that peaked in the late 1960s to early 1980s. As with the Port Neches and Clam Lake Fields, the spatial and temporal relationships between oil and gas production, faulting, and marsh loss support EWING'S (1985) conclusion of a causal relationship between fluid production and fault movement. Much larger fluid volumes produced from reservoirs at High Island salt dome (Figure 1), may have caused regional depressurization and subsidence, that contributed to reactivation of several faults along the northern margin of East Bay (EWING, 1985).

CONCLUSIONS

Recent artificially induced fault movement has resulted in the loss of large wetland areas on the southeastern Texas Gulf coast. Air photo analysis of 40 faults illustrate extensive replacement of emergent vegetation by open water along many of these faults. Upland and wetland response to fault movement is a time-dependent progression toward wetter conditions and eventually permanent inundation. Successional changes in wetlands may proceed from initial dense stands of topographically high marsh characterized by species such as Spartina patens and Spartina spartinae, to low, regularly-flooded marsh dominated by Spartina alterniflora. Continued subsidence and associated relative sea-level rise forms isolated ponds and shallow subaqueous flats, and eventually larger, coalescing ponds

and open water. This expansion of open water on the downthrown sides of faults has contributed to the loss of approximately 5,000 hectares of wetland emergent vegetation since the 1930s and 1950s. Locally, however, differential subsidence along faults has resulted in an expansion of wetlands into areas previously mapped as uplands.

Land-surface subsidence and coastal wetland loss are not only caused by shallow groundwater extraction, but can also be caused by hydrocarbon production at depths of more than 2000 m. Subsidence in many areas is focused along surface faults.

Approximately 75% of the observed faults have been activated in recent decades. There is a close correlation between history of fluid production and history of fault movement. Production data from two fields indicate that fault movement was initiated during the first 10 to 20 years of production after about 5 million bbls of oil had been extracted. In a third field, large volumes of gas production appear to have triggered fault movement. Once faults are activated, wetland losses continue throughout the production period of the field. Documented wetland losses are greatest around moderately large fields that have produced more than 19 million bbls of liquids during a period of about 40 years.

Continued large-volume extraction of conventional energy resources as well as anticipated production of alternative energy resources (geopressured-geothermal fluids) and methane dissolved and entrained in formation water in the Gulf Coast region will only increase existing subsidence and wetland losses or cause inundation of areas that are currently stable unless techniques are developed to control the induced subsidence.

The long history of fluid production, subsidence, and wetland loss in the Gulf Coast region provides a basis for managing reservoirs in other coastal plain settings

throughout the world where large oil and gas fields are being produced beneath valuable wetlands.

ACKNOWLEDGMENTS

Funding for this project was provided by the U.S. Geological Survey through a cooperative study on coastal erosion and land loss along the northern Gulf Coast.

LITERATURE CITED

- ADAMS, D. A., 196. Factors influencing vascular plant zonation in North Carolina salt marshes. Ecology, 44, 445-455.
- BELL, J. W. ,1991. Elevation changes associated with subsidence in Las Vegas Valley, Nevada. In: Johnson, A. I., (ed.), Land Subsidence, Proceedings of the Fourth International Symposium on Land Subsidence, Houston, Texas. Washington, DC, IAHS Publication No. 200, 473-481.
- BELL, J. W., 1988. Subsidence associated with the abstraction of fluids. In: Bell, F. G.; Culshaw, M. G.; Cripps, J. C., and Lovell, M. A., (eds.), Engineering Geology of Underground Movements, Geological Society Engineering Geology Special Publication No. 5, 363-376.
- BENTON, JR., A. R., SNELL, W. W., and CLARK, C. A., 1979. Monitoring and Mapping of Texas Coastal Wetlands, Galveston Bay and Sabine Lake Areas, 1978 Growing Season. College Station, Texas: Texas A&M University Remote Sensing Center, Technical Report RSC-102, variable pagination.

- BRUCE, C. H., 1973. Pressured shale and related sediment deformation: mechanism for development of regional contemporaneous faults. American Association of Petroleum Geologists Bulletin, 57, 878-886.
- CHABRECK, R. H., 1972. Vegetation, water and soil characteristics of the Louisiana Coastal region. Baton Rouge, Louisiana: Louisiana Agricultural and Experiment Station Bulletin No. 664, 72p.
- CHILINGARIAN, G. V.; DONALDSON, E. C., and YEN, T. F., 1995. Subsidence due to fluid withdrawal: Developments in Petroleum Science 41, Elsevier, Amsterdam, 498p.
- CLANTON, U. S. and VERBEEK, E. R., 1981. Photographic portrait of active faults in the Houston Metropolitan area, Texas. In: ETTER, E. M. (ed.), Houston area Environmental Geology: Surface Faulting, Ground Subsidence, Hazard Liability. Houston, Texas: Houston Geological Society, 70-113.
- CRENWELGE, G. W.; CROUT, J. D.; GRIFFIN, E. L.; GOLDEN, M. L., and BAKER J. K., 1981. Soil Survey of Brazoria County, Texas. Washington, D. C.: U. S. Department of Agriculture, Soil Conservation Service, 140p.
- CROUT, J. D., 1976. Soil Survey of Chambers County, Texas: U. S. Department of Agriculture Soil Conservation Service in cooperation with Texas Agricultural Experiment Station, 53p.
- EWING, T.E., 1985. Subsidence and surface faulting in the Houston-Galveston area, Texas--related to deep fluid withdrawal?. In: DORFMAN, M.H., and MORTON, R.A. (eds.), Geopressed-Geothermal Energy: Proceedings of the 6th U.S. Gulf Coast Geopressed-Geothermal Energy Conference. New York: Pergamon Press, 289-298.
- FISHER, W.L.; MCGOWEN, J.H.; BROWN, L.F., JR., and GROAT, C.G., 1972. Environmental Geologic Atlas of the Texas Coastal Zone--Galveston-Houston

- Area. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, 91p., 9 maps.
- FISHER, W.L.; BROWN, L.F., JR.; MCGOWEN, J.H., and GROAT, C.G., 1973.
- Environmental Geologic Atlas of the Texas Coastal Zone--Beaumont-Port Arthur Area. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, 93p., 9 maps.
- GABRYSCH, R.K., 1969. Land-surface subsidence in the Houston-Galveston region, Texas. Tokyo, Japan: Proceedings, International Symposium on Land Subsidence, Publication No. 88, IAHS, 43-54.
- GABRYSCH, R.K. and COPLIN, L.S., 1990. Land-surface subsidence resulting from ground-water withdrawals in the Houston-Galveston region, Texas, through 1987. Washington, D.C.: U.S. Geological Survey Report of Investigations No. 90-01, 53p.
- GERMIAT, S. J. and SHARP, J. M., 1990. Assessment of future coastal land loss along the upper Texas Gulf Coast to the year 2050. Bulletin of the Association of Engineering Geologists, XXVII, 263-280.
- GEERTSMA, J., 1973. Land subsidence above compacting oil and gas reservoirs. Journal of Petroleum Technology, 25, 734-744.
- GLEASON, M. L. and ZIEMAN, J. C., 1981. Influence of tidal inundation on internal oxygen supply of Spartina alterniflora and Spartina patens. Estuarine, Coastal and Shelf Science, 13, 47-57.
- GUSTAVSON, T. C. and KREITLER, C. W., 1976. Geothermal resources of the Texas Gulf Coast -- environmental concerns arising from the production and disposal of geothermal waters. Austin Texas: The University of Texas at Austin, Bureau of Economic Geology Geological Circular 76-7, 35p.
- HARCOMBE, P. A., and NEAVILLE, J. E., 1977, Vegetation types of Chambers County, Texas. The Texas Journal of Science, 39, 210-234.

- HILLENBRAND, C. J., 1985. Subsidence and fault activation related to fluid extraction Saxet Field, Nueces County, Texas. Unpublished Masters Thesis. University of Houston, 144p.
- HOLZER, T. L., 1990. Land subsidence caused by withdrawal of oil and gas in the Gulf Coastal Plain -- The Houston, Texas case history (abs.). Gulf Coast Association of Geological Societies Transactions, 40, 301.
- HOLZER, T. L., and BLUNTZER, R. L., 1984. Land subsidence near oil and gas fields, Houston, Texas. Ground Water, 22, 450-459.
- KREITLER, C.W., 1978. Faulting and land subsidence from ground-water and hydrocarbon production, Houston-Galveston, Texas. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology Research Note 8, 22 p.
- KREITLER, C.W.; WHITE, W.A., and AKHTER, M.S., 1988. Land subsidence associated with hydrocarbon production, Texas Gulf Coast (abs.). American Association of Petroleum Geologists Bulletin, 72, 208.
- MARTIN, J. C. and SERDENGECTI, S., 1984. Subsidence over oil and gas fields. In: Holzer, T. L., (ed.), Geological Society of America Reviews in Engineering Geology, VI, 23-34.
- MARTINEZ, A. R., 1975. Coastal Hydrographic and Meteorological Study, Coastal Fisheries Project Report, Texas: Texas Parks and Wildlife Department, pp. 100-157.
- MARTINEZ, A. R., 1974. Coastal Hydrographic and Meteorological Study, Coastal Fisheries Project Report, Texas: Texas Parks and Wildlife Department, pp. 61-108.
- MARTINEZ, A. R., 1973. Coastal Hydrographic and Meteorological Study, Coastal Fisheries Project Report, Texas: Texas Parks and Wildlife Department, pp. 111-172.

- MENDELSSOHN, I. A. and MCKEE, K. L., 1988a. Experimental field and greenhouse verification of the influence of saltwater intrusion and submergence on marsh deterioration: mechanisms of action. In: TURNER, R. E. and CAHOON D. R., eds., Causes of Wetland Loss in the Coastal Central Gulf of Mexico, Volume II: Technical Narrative: U.S. Department of the Interior, Minerals Management Service, MMS 87-0120, pp. 145-180.
- MENDELSSOHN, I. A. and MCKEE, K. L., 1988b. Spartina alterniflora die-back in Louisiana: time-course investigation of soil waterlogging effects. Journal of Ecology, 76, 509-521.
- MORTON, R. A. and GALLOWAY, W. E., 1991. Depositional, tectonic, and eustatic controls on hydrocarbon distribution in divergent margin basins: Cenozoic Gulf of Mexico case history. In: MEYER, A. W., DAVIES, T. A., and WISE, S. W., eds., Evolution of Mesozoic and Cenozoic continental margins: Marine Geology, 102, 239-263.
- MORTON, R.A. and PAINE, J.G., 1990. Coastal land loss in Texas—an overview: Gulf Coast Association of Geological Societies Transactions, 40, 625-634.
- MUSOLFF, N. C., 1962. Caplen Field, Galveston County, Texas. In: Denham, R. L., (ed.), Typical Oil and Gas Fields of Southeast Texas. Houston, Texas: Houston Geological Society, 30-33.
- NAIDOO, G.; MCKEE, K. L.; and MENDELSSOHN, I. A., 1992, Anatomical and metabolic responses to waterlogging and salinity in Spartina alterniflora and S. Patens (Poaceae). American Journal of Botany, 79, 765-770.
- PENFOUND, W. T., and HATHAWAY, E. S., 1938, Plant communities in the marshlands of southeastern Louisiana. Ecological Monographs, 8, 1-56.
- PEZESHKI, S. R.; DELAUNE, R. D.; and PATRICK, JR., W. H., 1987, Response of Spartina patens to increasing levels of salinity in rapidly subsiding marshes of

- the Mississippi River Deltaic Plain. Estuarine, Coastal and Shelf Science, 24, 389-399.
- POLAND, J. F. and DAVIS, G. H., 1972. Land subsidence due to withdrawal of fluids, In: Man and His Physical Environment, Readings in Environmental Geology. Minneapolis, Minnesota: Burgess Publishing Co., 77-90.
- PRATT, W.E. and JOHNSON, D.W., 1926. Local subsidence of the Goose Creek oil field. Journal of Geology, 34, 577-590.
- QUARLES, M., JR., 1953. Salt-ridge hypothesis on origin of Texas Gulf Coast type faulting. American Association of Petroleum Geologists Bulletin, 37, 489-508.
- REID, W.M., 1973. Active faults in Houston, Texas. Austin, Texas: The University of Texas at Austin, Unpublished Ph.D. dissertation, 122p.
- SHEETS, M. M., 1979. Oil fields, subsidence and surface faulting in the Houston area. Houston Geological Society Guidebook for AAPG/SEPM Convention, 20p.
- TEXAS RAILROAD COMMISSION, 1994. Oil and Gas Division Annual Report, 1992, Volume 1. Austin, Texas: Railroad Commission of Texas, 440p.
- TURNER, R.E. and CAHOON, D.R., (eds.), 1988. Causes of Wetland Loss in the Coastal Central Gulf of Mexico, Volume II: Technical Narrative. New Orleans, Louisiana: U.S. Department of the Interior, Minerals Management Service, OCS Study/MMS 87-0120, 400p.
- VAN SICLEN, D., 1967. The Houston fault problem. Proceedings of the American Institute of Professional Geologists, 3rd Annual Meeting, Texas Section, Dallas, 9-31.
- VERBEEK, E.R. and CLANTON, U.S., 1981. Historically active faults in the Houston metropolitan area. Texas. In: ETTER, E. M, (ed.), Houston area Environmental Geology: Surface Faulting, Ground Subsidence, Hazard Liability. Houston, Texas: Houston Geological Society, p. 28-68.

- VERBEEK, E.R., 1979. Surface faults in the Gulf Coastal Plain between Victoria and Beaumont, Texas. Tectonophysics, 52, 373-375.
- WEAVER, P. and SHEETS, M., 1962. Active faults, subsidence and foundation problems in the Houston, Texas, area. Houston, Texas: Geology of the Gulf Coast and Central Texas. Houston Geological Society Guidebook, 254-265.
- WEBB, J. W., and DODD, J. D., 1978. Shoreline plant establishment and use of a wave-stilling device. U.S. Department of the Army Coastal Engineering Research Center Miscellaneous Report 78-1. Fort Belvoir, Virginia, 27p.
- WHITE, W.A.; TREMBLAY, T.A.; WERMUND, E.G., JR., and HANDLEY, L.R., 1993. Trends and status of wetland and aquatic habitats in the Galveston Bay system, Texas. Webster, Texas: Galveston Bay National Estuary Program, GBNEP-31, 225p.
- WHITE, W.A.; CALNAN, T.R.; MORTON, R.A.; KIMBLE, R.S.; LITTLETON, T.G.; MCGOWEN, J.H.; NANCE, H.S., and SCHMEDES, K.E., 1985. Submerged Lands of Texas, Galveston-Houston Area: Sediments, Geochemistry, Benthic Macroinvertebrates, and Associated Wetlands. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, Special publication, 145 p.
- WHITE, W.A.; CALNAN, T.R.; MORTON, R.A.; KIMBLE, R.S.; LITTLETON, T.G., MCGOWEN, J.H., and NANCE, H.S., 1987. Submerged Lands of Texas, Beaumont-Port Arthur Area: Sediments, Geochemistry, Benthic Macroinvertebrates, and Associated Wetlands. Austin, Texas: The University of Texas at Austin, Bureau Economic Geology Special Publication, 110 p.
- WHITE, W.A. and PAINE, J.G., 1992. Wetland plant communities, Galveston Bay system. Webster, Texas: Galveston Bay National Estuary Program, GBNEP-16, 124p.

WHITE, W. A. and TREMBLAY, T. A., 1995. Submergence of wetlands as a result of human-induced subsidence and faulting along the upper Texas Gulf Coast. Journal of Coastal Research, 1, 788-807.

WHITE, W. A. and MORTON, R. A., 1995. Active faults and their effect of wetlands, upper Texas Gulf Coast (abs.). Boston, Massachusetts: Society of Wetland Scientists 16th Annual Meeting, 42-43.

WILLIAMS, K. O., 1962. Clam Lake Field, Jefferson County, Texas. In: Denham, R. L., (ed.), Typical Oil and Gas Fields of Southeast Texas. Houston, Texas: Houston Geological Society, 34-37.

YERKES, R.F. and CASTLE, R.O., 1969. Surface deformation associated with oil and gas field operations in the United States. Tokyo, Japan: Proceedings, International Symposium on Land Subsidence, Publication No. 88, AIHS, 1, 55-66.

Table 1. Length, historical development and angle of extrapolation of surface faults intersecting wetlands, upper Texas Coast.

| Fault Number | Informal Fault Name | Fault Length (km) | Fault visibility 1930 Photo | Fault Visibility 1956 Photo | Fault Visibility 1979 Photo | Fault Visibility Late 1980s-1990s Photos | Approximate angle of extrapolation between surface and subsurface faults (degrees) |
|--------------|---------------------|-------------------|-----------------------------|-----------------------------|-----------------------------|--|--|
| 1 | Orange | 1.0 | | 0* | 2 | 2 | 75 |
| 2 | Neches Valley W | 5.0 | 0 | 0 | 2 | 2 | 45 |
| 3 | Neches Valley E | 5.5 | 0 | 0 | 2 | 2 | 40 |
| 4 | Texas Point E | 1.6 | 0 | 0 | 2 | 2 | |
| 5 | Texas Point C | 1.8 | 0 | 0 | 0 | 2 | |
| 6 | Texas Point W | 3.7 | 0 | 1 | 2 | 2 | |
| 7 | Blind Lake | 10.8 | 0 | 0 | 2 | 2 | |
| 8 | Clam Lake N | 6.1 | 0 | 0 | 2 | 2 | 60 |
| 9 | Clam Lake E | 7.5 | 0 | 0 | 0-1 | 2 | 90 |
| 10 | Star Lake | 3.6 | 0 | 0 | 2 | 2 | 70 |
| 11 | Mud Lake | 2.9 | 0 | 1 | 2 | 2 | 68 |
| 12 | High Island E | 3.9 | 0 | 2 | 2 | 2 | |
| 13 | High Island N | 1.1 | 0 | 0 | 2 | 2 | 45 |
| 14 | Robinson Lake E | 3.0 | 0 | 0 | 2 | 2 | 69 |
| 15 | Robinson Lake EC | 5.0 | 0 | 0-1 | 2 | 2 | 68 |
| 16 | Robinson Lake WC | 1.0 | 0 | 0-1 | 2 | 2 | 64 |
| 17 | Robinson Lake W | 4.8 | 0 | 0 | 2 | 2 | 64 |
| 18 | Bolivar Fan E-W | 13.4 | 0 | 0-2 | 2 | 2 | 65 |
| 19 | Bolivar Fan N | 2.3 | 0 | 0-1 | 2 | 2 | 65 |
| 20 | Flake | 2.4 | 2 | 2 | 2 | 2 | 80 |
| 21 | Point Bolivar | 1.8 | 2 | 2 | 2 | 2 | 80 |
| 22 | Gordy Marsh | 2.5 | 0-1 | 0-1 | 2 | 2 | 75 |
| 23 | Lost Lake | 1.5 | 0 | 2 | 2 | 2 | |
| 24 | Jones Bay | 3.1 | 0 | 2 | 2 | 2 | 38 |
| 25 | Hitchcock N | 4.0 | 2 | 0-2 | 2 | 2 | 50 |
| 26 | Hitchcock C | 4.0 | 1 | 1 | 2 | 2 | |
| 27 | Hitchcock S | 2.6 | 0 | 1 | 2 | 2 | 70 |
| 28 | Chocolate Bay N | 3.2 | 0 | 0-1 | 2 | 2 | 64 |
| 29 | Chocolate Bay C | 6.6 | 1 | 1 | 2 | 2 | 79 |
| 30 | Chocolate Bay S | 5.1 | 0-1 | 2 | 2 | 2 | 54 |
| 31 | Hoskins Mound | 1.5 | 0 | 2 | 2 | 2 | 45 |
| 32 | Mud Island N | 1.2 | 0 | 0-1 | 2 | 2 | 45 |
| 33 | Mud Island S | 2.0 | 0-1 | 1 | 2 | 2 | |
| 34 | Christmas Bay | 2.7 | 2 | 2 | 2 | 2 | |
| 35 | Salt Lake | 12.5 | 2 | 1-2 | 2 | 2 | 83 |
| 36 | Slop Bowl | 4.2 | 0 | 1 | 2 | 2 | |
| 37 | Bryan Mound | 1.8 | 0 | 0-1 | 2 | 2 | |
| 38 | Cedar Lakes | 2.0 | 0 | 0 | 1-2 | 2 | 75 |
| 39 | Dead Caney Lake | 1.8 | 0 | 0-1 | 2 | 2 | |
| 40 | Boggy Bayou | 2.2 | 0 | 0 | 0-2 | 2 | ? |

* Visibility on aerial photographs

Total length (km) 152.5 0= not visible
Average Length (km) 3.8 1= faintly visible
Mode = 1.8 2= distinctly visible

Table 2. Types and characteristics of soils located on the upthrown block and downthrown block of a fault crossing the Brazoria National Wildlife Refuge. From CRENWELGE et al. (1981).

UPTHROWN BLOCK:

Surfside Clay

Level saline soil-rarely flooded
Water table < 0.6 m during winter
Salty prairie vegetation
90% Spartina spartinae

DOWNTROWN BLOCK:

Harris Clay

Level saline marsh soil
Water table < 0.5 m
Typically 50% Spartina patens
25% Distichlis spicata
10% Paspalum vaginatum
10% Scirpus americanus

Harris-Tracosa Complex

Broad tidal marsh areas
45% Harris Clay, 40% Tracosa Mucky Clay
Water table < 0.5 M
Depressions containing water
Tracosa Soils -- Ruppia maritima in depressions
Where vegetated-- 90% Spartina alterniflora

Figure Captions

Figure 1. Distribution of surface faults intersecting wetlands on the upper Texas Coast. Thirty-six of the forty faults are shown in this figure; the remaining four are to the southwest. Coastal deposition systems modified from FISHER et al. (1972; 1973).

Figure 2. Active coastal plain fault in the Brazoria National Wildlife Refuge inland from Follets Island (Figure 1). D = downthrown side, U = upthrown side. NASA photograph taken in 1979.

Figure 3. Field view of fault shown in Figure 2. Vegetation changes from Spartina patens on the upthrown side to Spartina alterniflora on the downthrown side. The change in vegetation is a result of lower elevations and more frequent flooding on the fault's downthrown side.

Figure 4. Topographic profile across an active fault (Figure 3) showing relative elevations and plant communities that occur on each side of the fault. Lower elevations of approximately 25 cm on the downthrown side of this fault are reflected in a topographically lower marsh community. From WHITE and PAINE (1992).

Figure 5. Neches River valley fault as shown on aerial photograph taken in 1966 by the U.S. Department of Agriculture. D = downthrown side, U = upthrown side. This is the westernmost fault shown in Figure 6.

Figure 6. Changes in the distribution of wetlands between 1956 and 1978 in the Neches River valley at the head of Sabine Lake. Differential subsidence along the

faults crossing the valley have contributed to the conversion of emergent vegetation to open water. D = downthrown side, U = upthrown side. Modified from WHITE et al. (1987).

Figure 7. Simplified illustration of fault that intersects Gordy Marsh on the southern margin of Trinity Bay (Figure 1). Marshes and ponded water characterize the downthrown side (D) of the fault. From WHITE et al. (1985).

Figure 8. Locations of Port Neches, Clam Lake, and Caplen oil and gas fields. Wetland loss around these fields has exceeded 4,500 ha since 1956.

Figure 9. Cumulative production of oil and gas from the Port Neches field located in the Neches River valley. Surface faults downthrown toward the field are not visible on aerial photographs taken in the mid-1950s but are visible by the mid-1960s after cumulative gas production had reached 40 billion ft³. Production volumes are from the TEXAS RAILROAD COMMISSION.

Figure 10. Cumulative production of oil and gas from the Clam Lake field. A surface fault downthrown toward the field was not visible in 1956 but was distinctly visible in 1966 after broad areas of emergent vegetation were replaced by open water on the downthrown side of the fault. Cumulative oil production exceeded 12 million barrels in 1966. Production volumes are from the TEXAS RAILROAD COMMISSION.

Figure 11. Fault and associated marshes and water features near Clam Lake (Figure 8) in the McFaddin National Wildlife Refuge. From WHITE et al. (1987).

Figure 12. Aerial photograph and land-surface subsidence profile showing fault on Bolivar Peninsula near Caplen field (Figure 8). Land-surface subsidence profile is based on bench mark leveling surveys in 1936 and 1954 along State Highway 87. Projection to the southwest of the fault shown in the aerial photograph indicates it should cross the highway between bench marks R171 (shown in the photograph) and Q171 which is located out of the photograph to the southwest. Increased rates of subsidence at R171 indicates that it is on the downthrown side (D) of the fault and Q171 is on the upthrown side (U). Profile from CHARLES W. KREITLER, unpublished data.

Figure 13. Cumulative production of oil and gas from the Caplen field (Figure 8). Surface faults near the field were not visible in 1930 but were visible in the 1950s. Since the 1950s, there has been an expanding loss of wetland emergent vegetation on the faults downthrown sides. Production volumes are from the TEXAS RAILROAD COMMISSION.

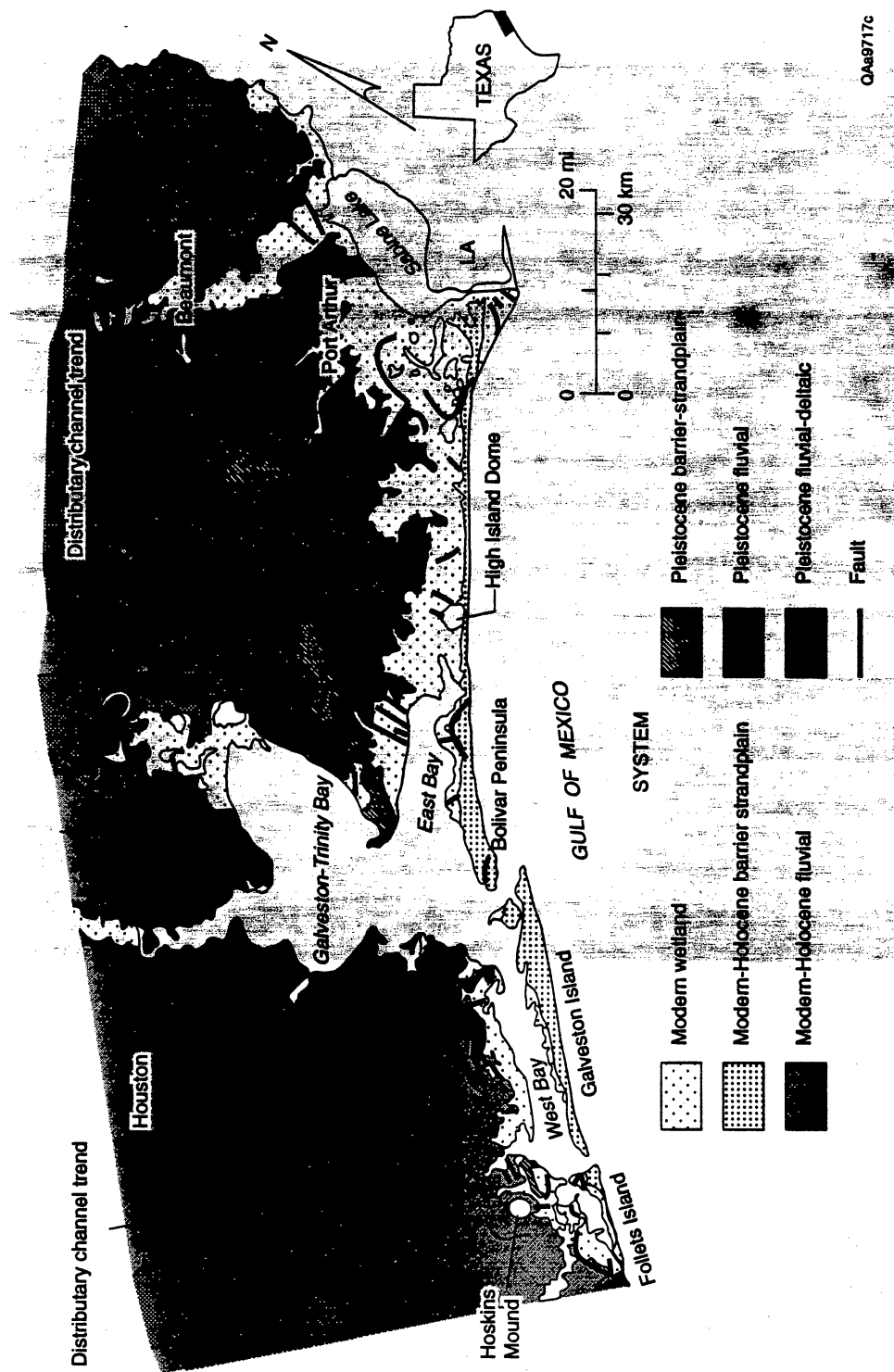
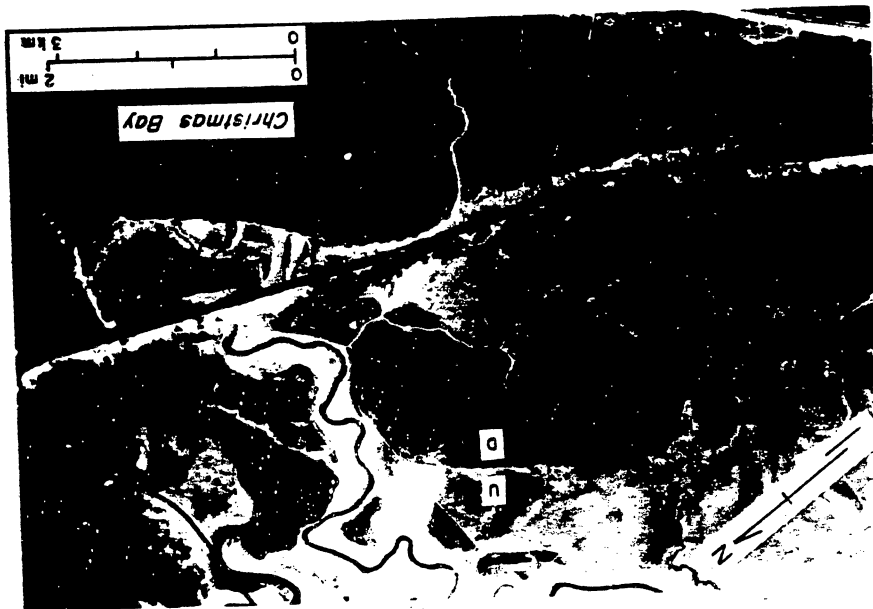


Figure 1

Figure 3



Figure 2



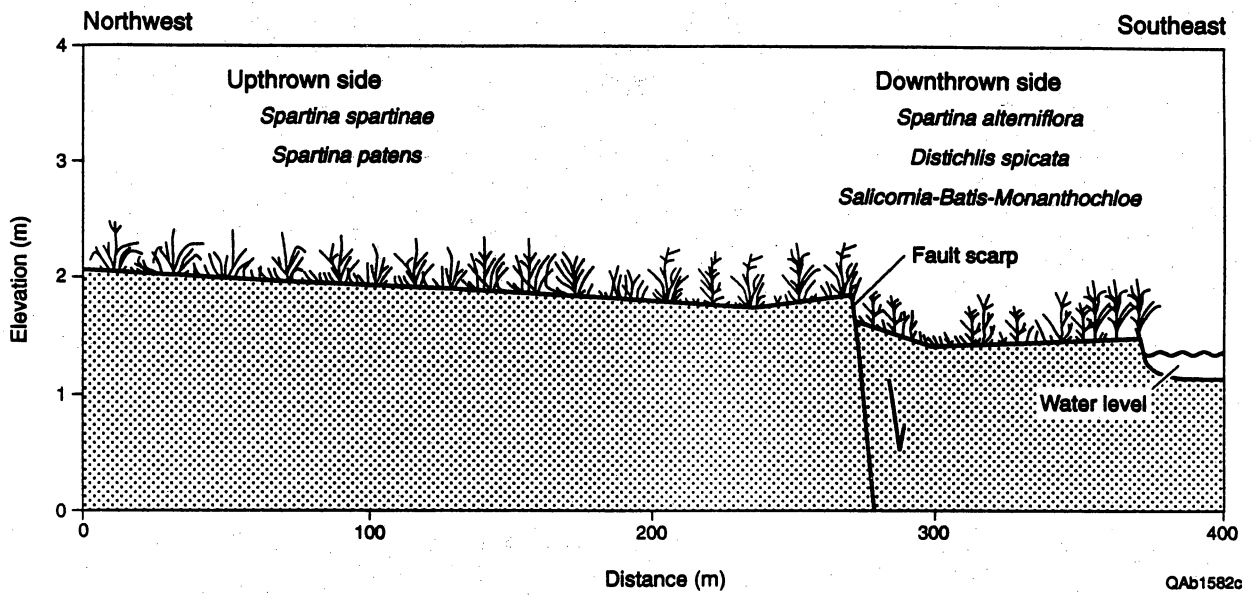


Figure 4

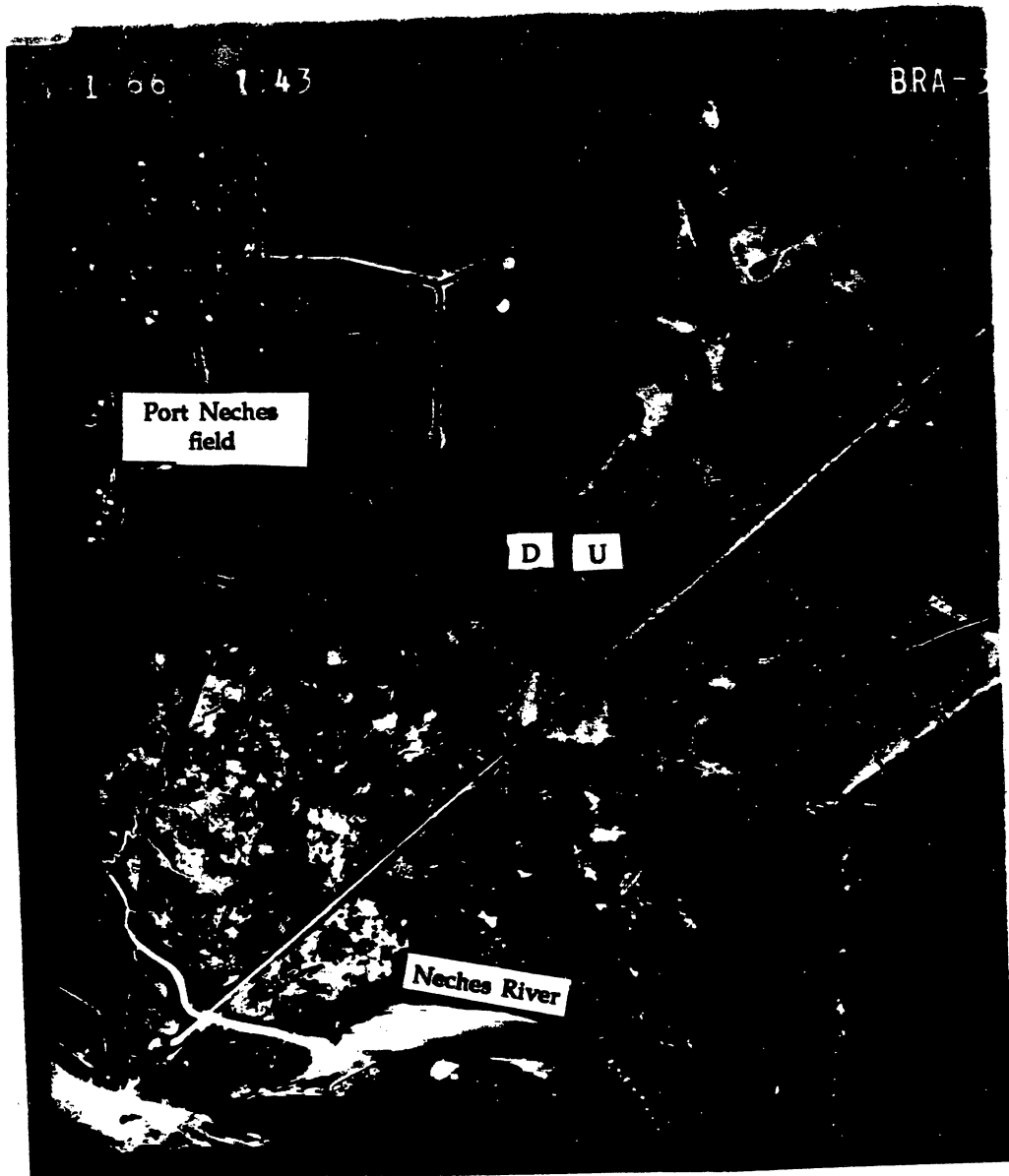
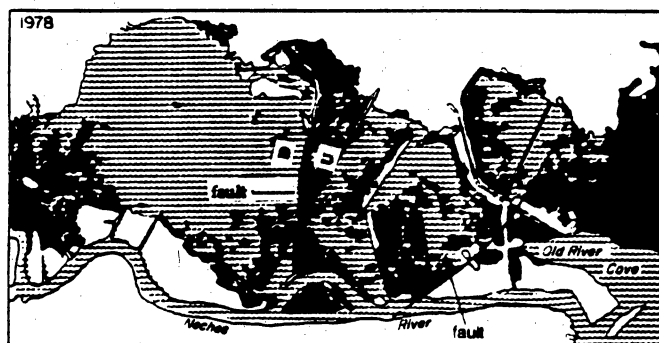
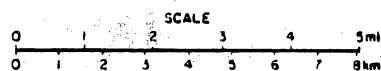
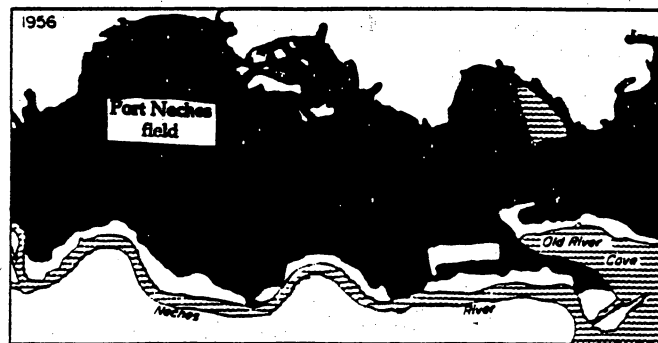


Figure 5



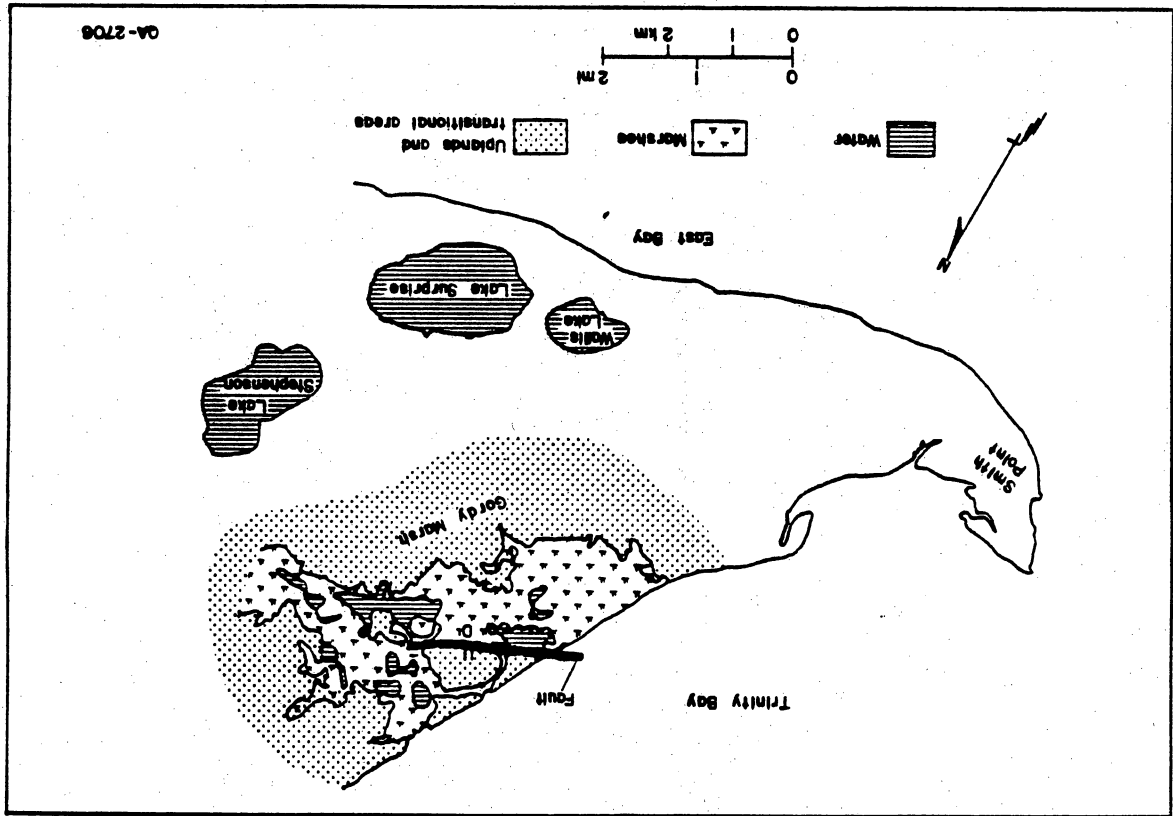
QA 3384

| Map Unit | 1956 | | 1978 | | Net Change* | |
|----------|--------|----------|--------|----------|-------------|----------|
| | Acres | Hectares | Acres | Hectares | Acres | Hectares |
| Water | 2,560 | 1,037 | 11,070 | 4,483 | +8,510 | +3,446 |
| Marsh | 15,740 | 6,375 | 6,330 | 2,564 | -9,410 | -3,811 |

* Loss of additional 900 acres (365 hectares) of marsh primarily due to spoil disposal.

Figure 6

Figure 7



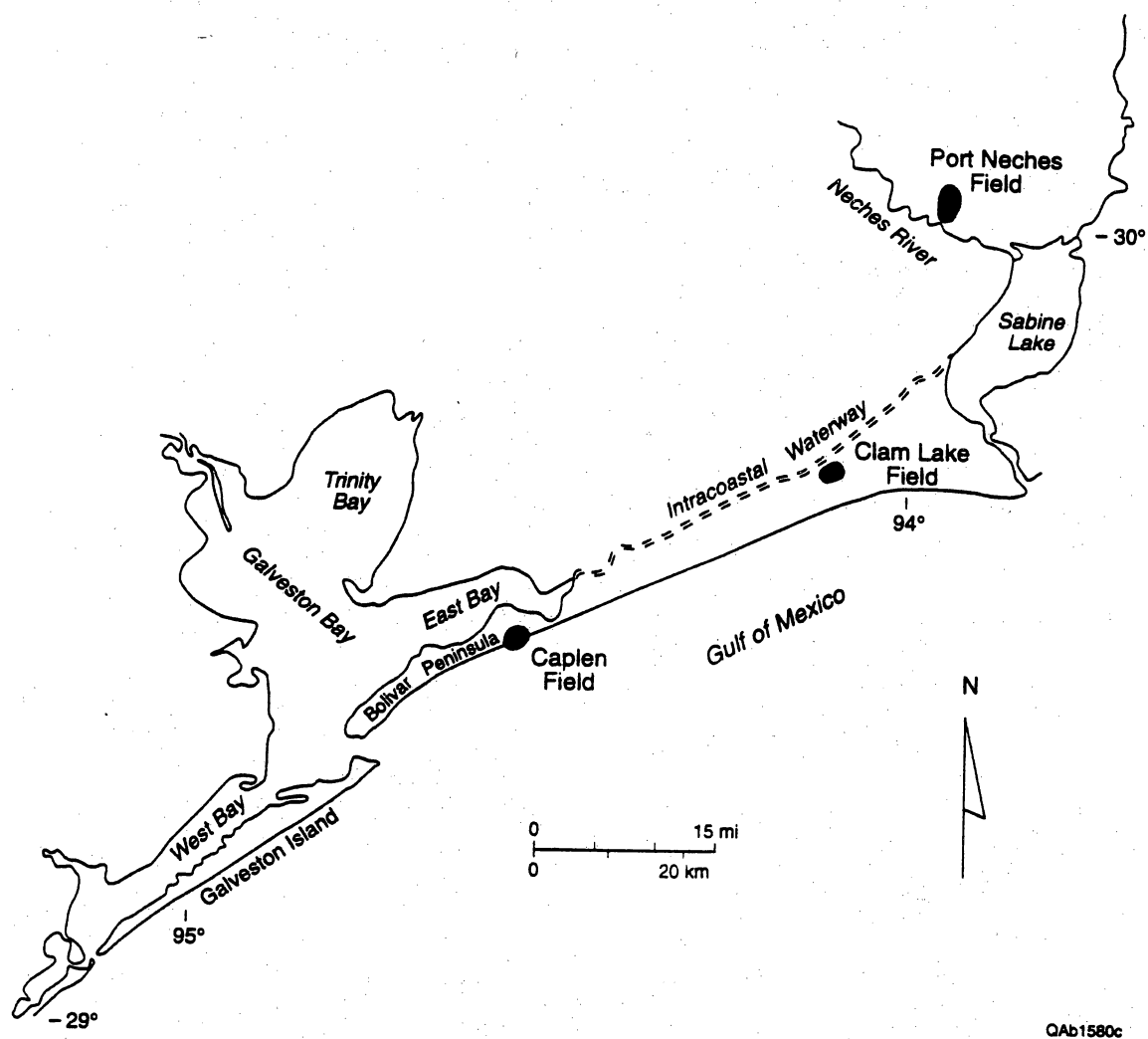


Figure 8

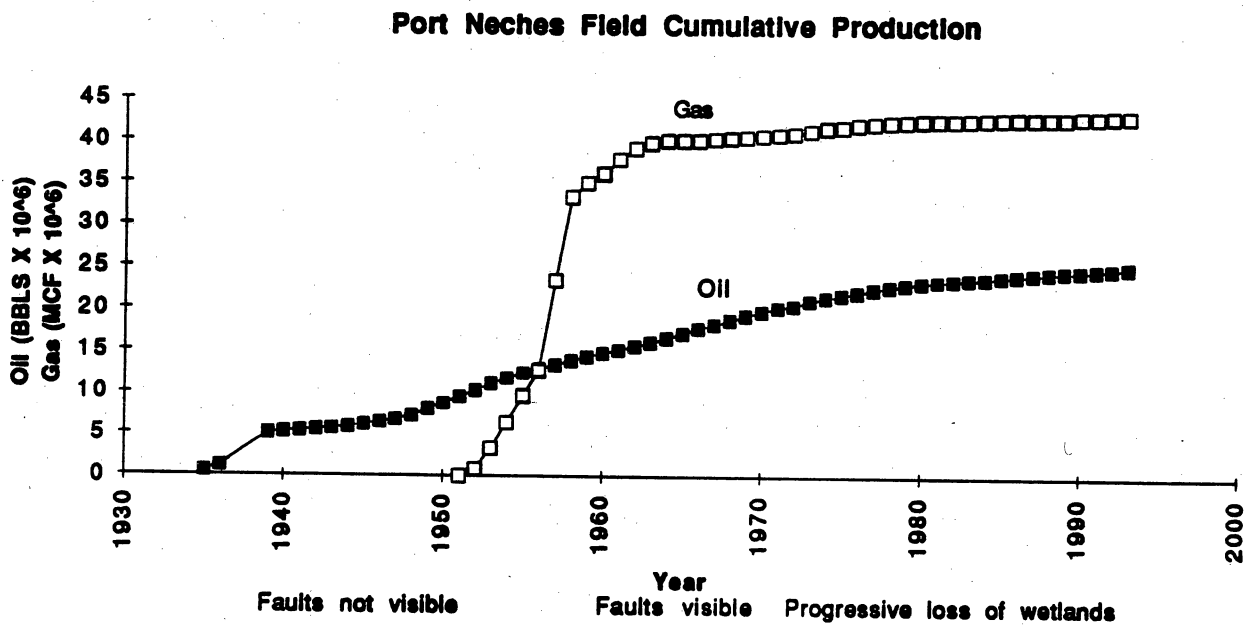


Figure 9

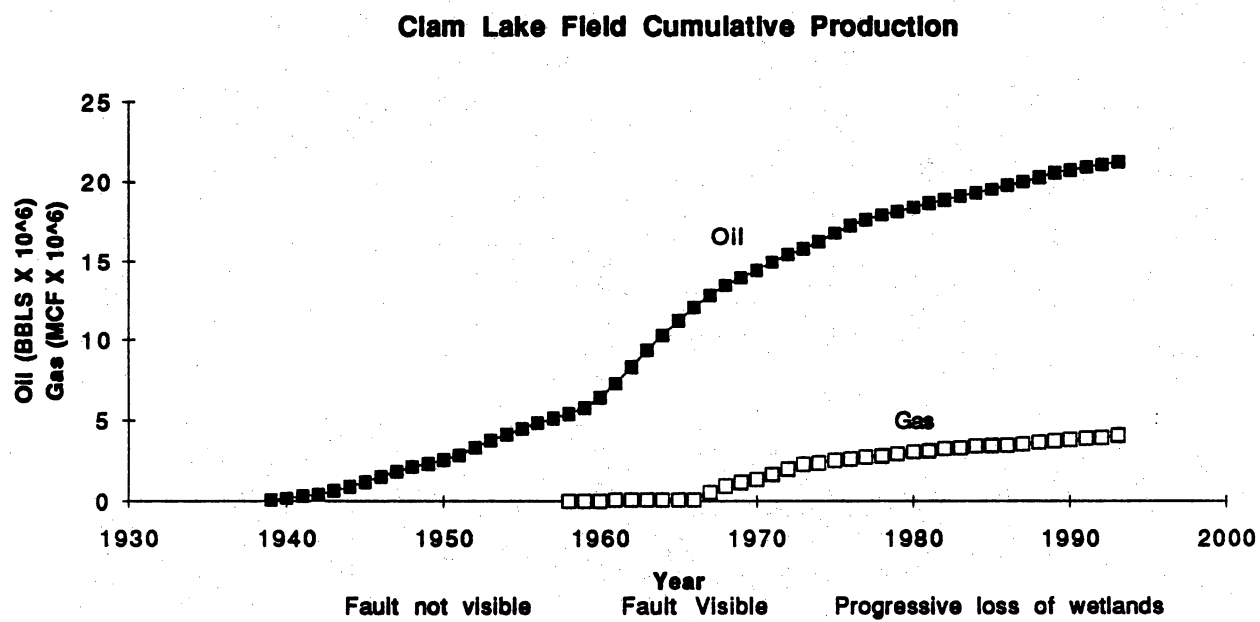


Figure 10

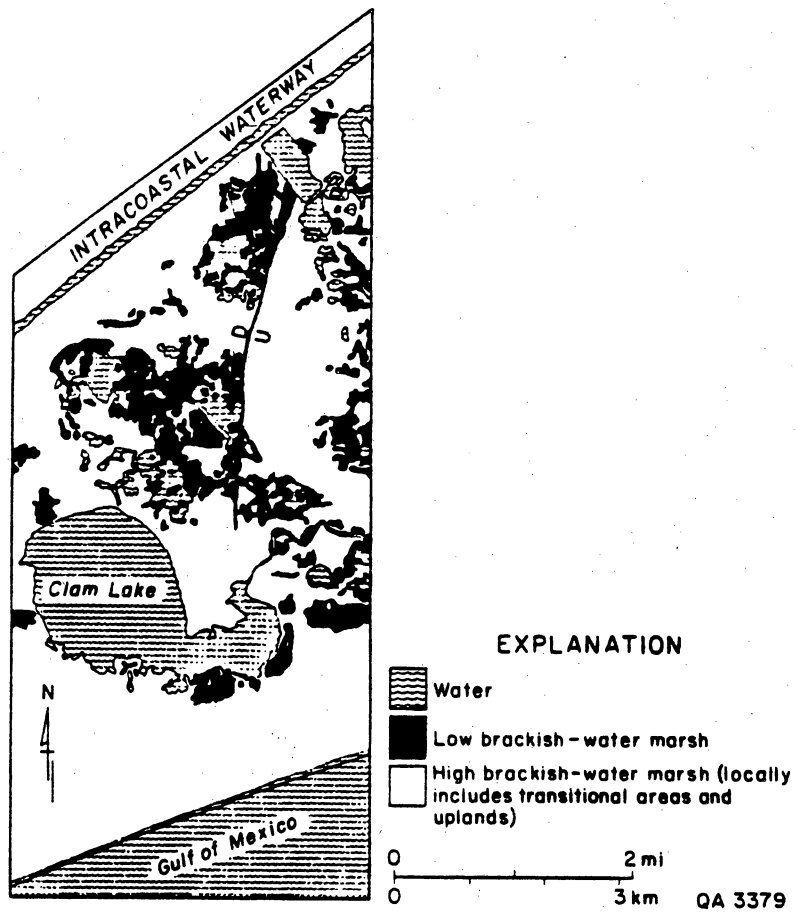
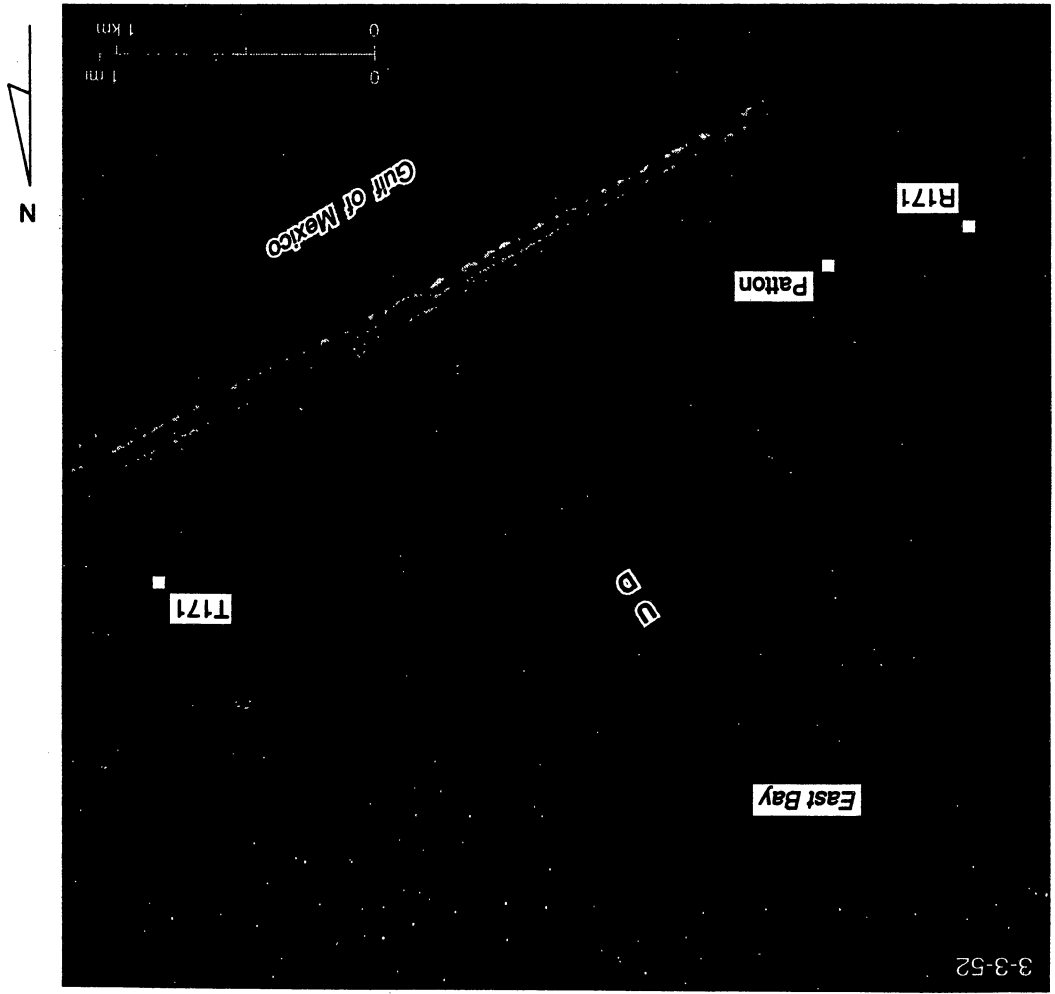
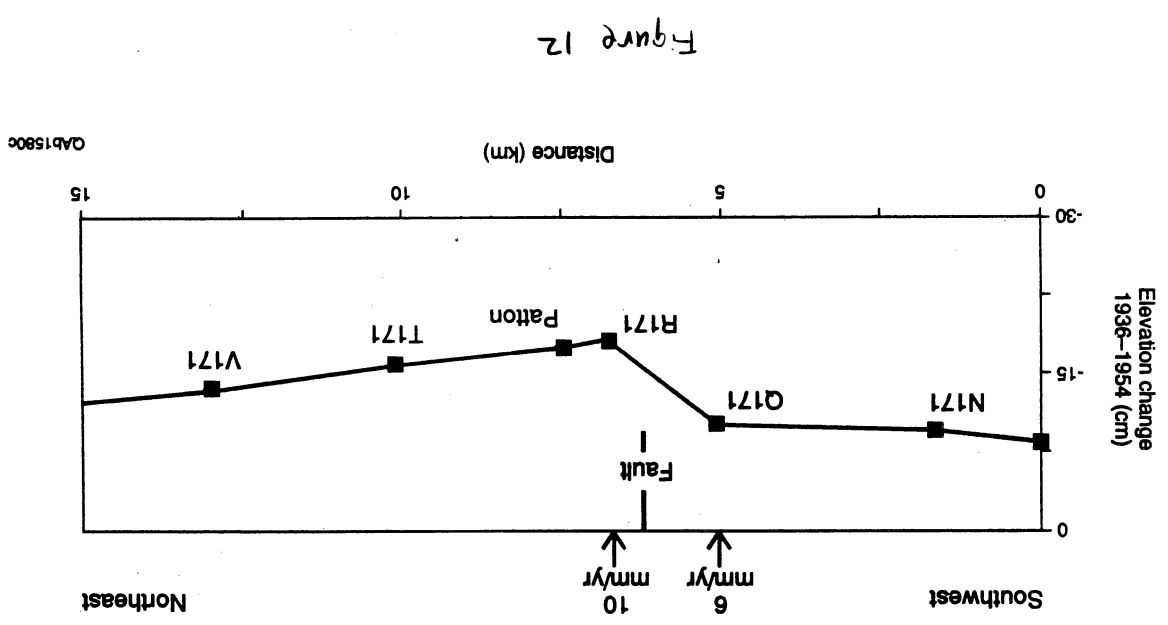


Figure 11



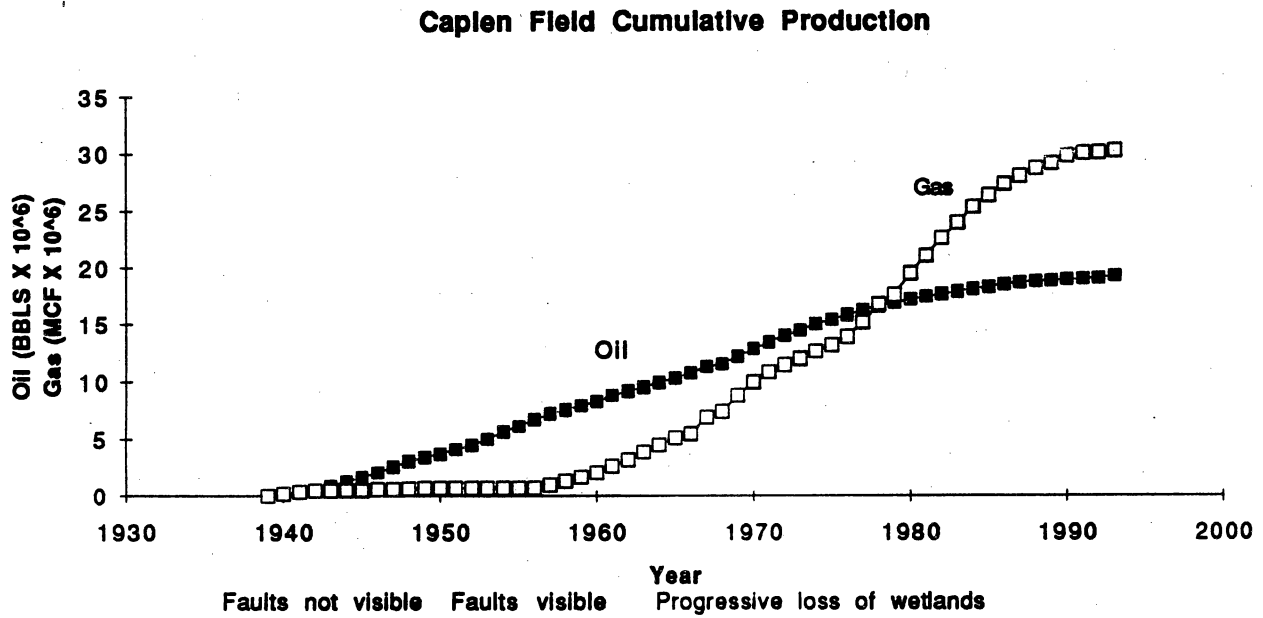


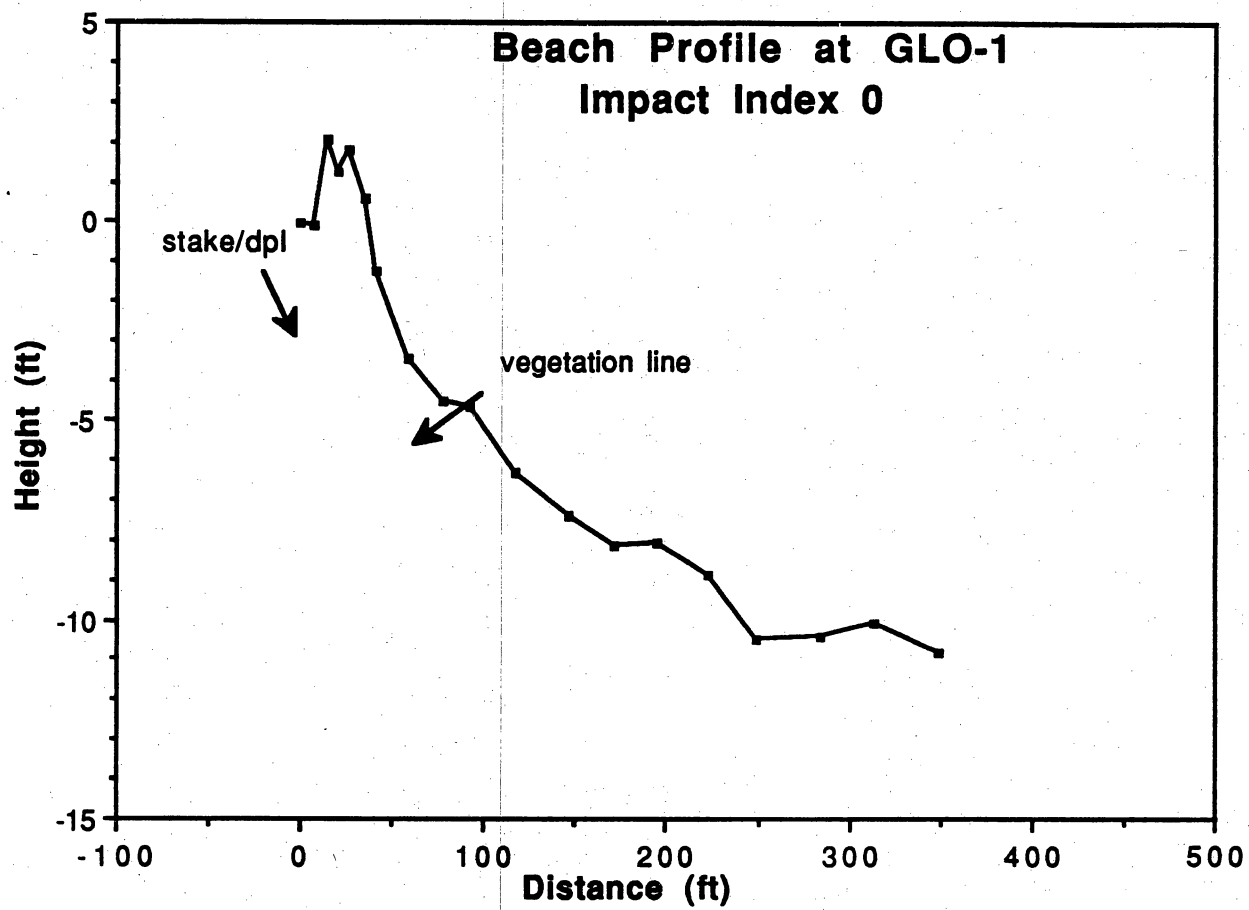
Figure 13

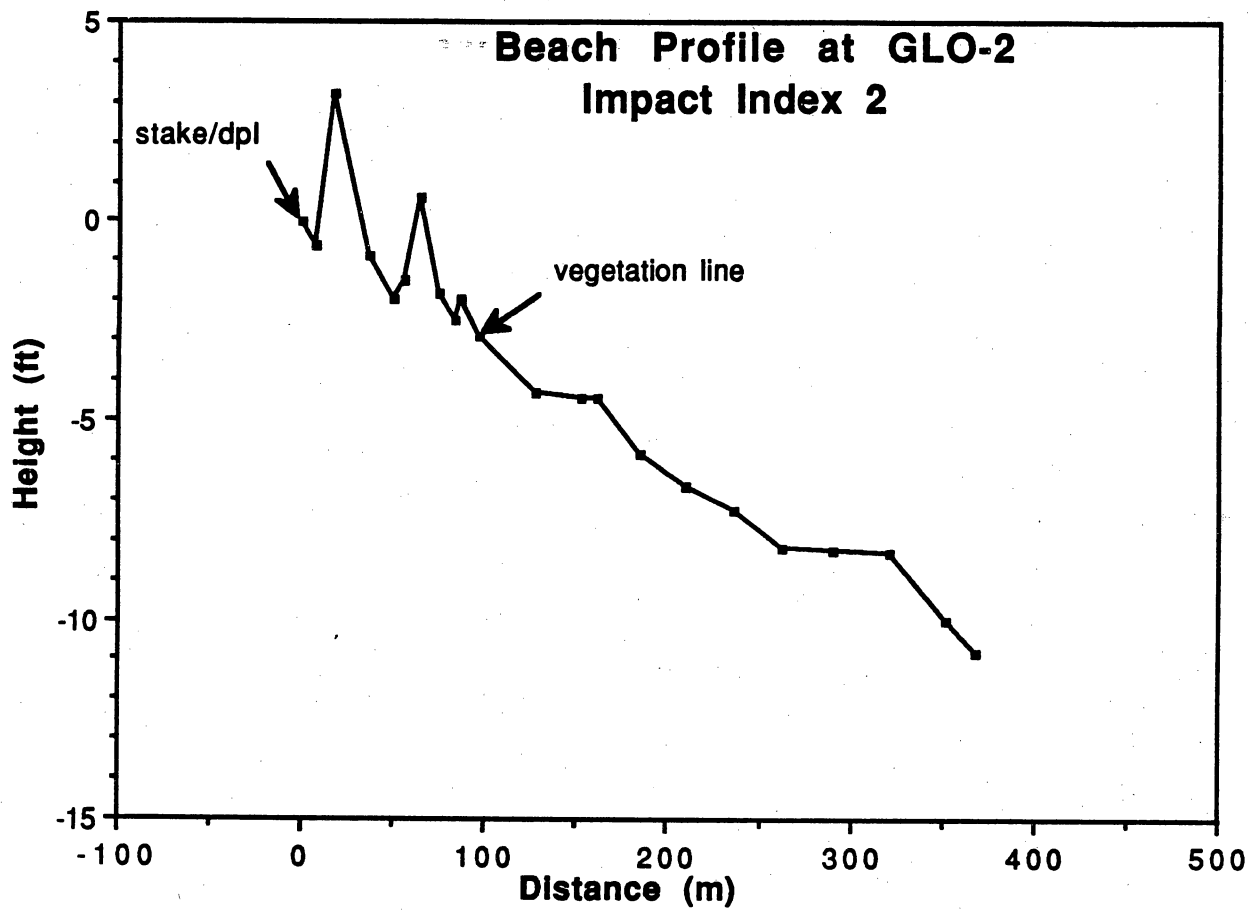
Addendum 2. Index of Human Impact on Dunes and Vegetation

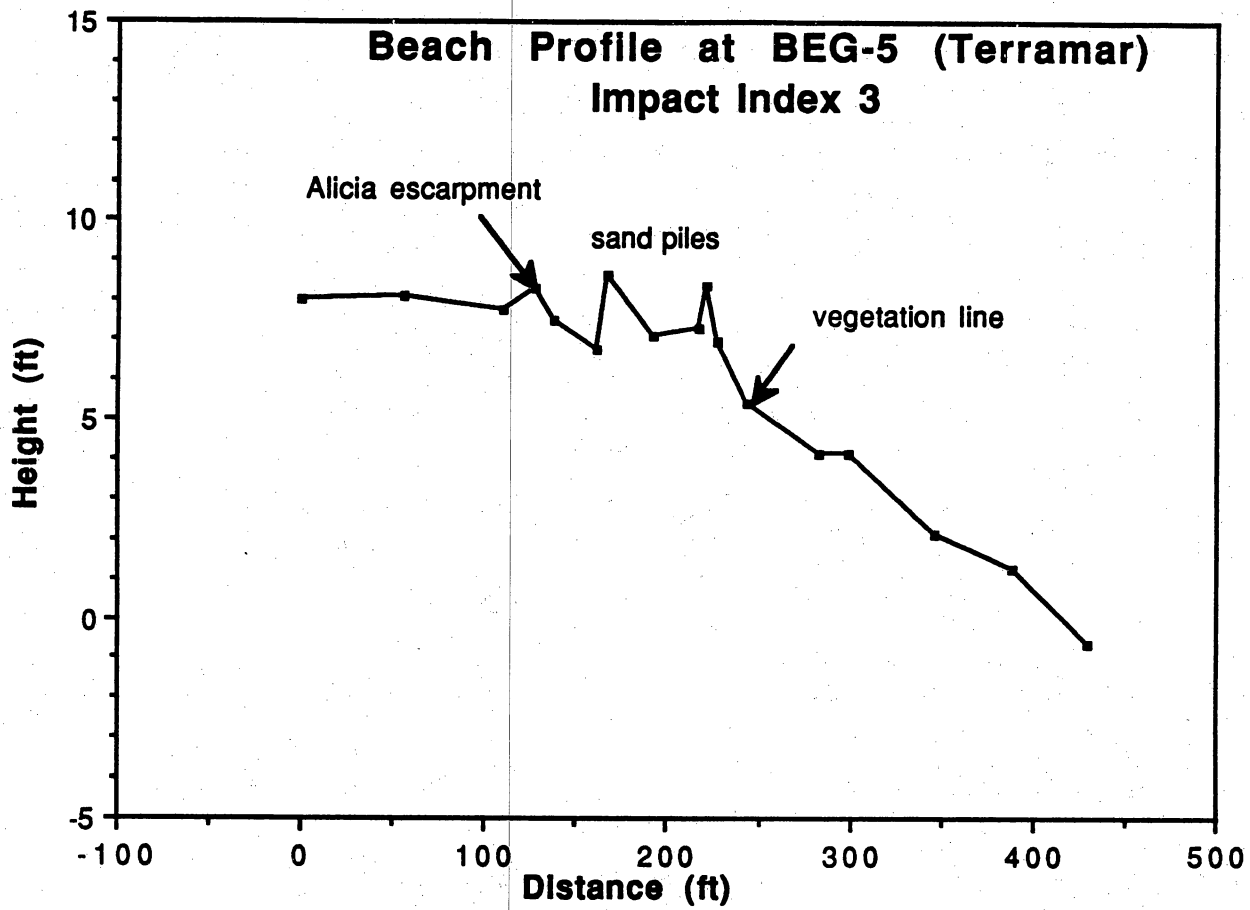
Index of Human Impact on Dunes and Vegetation

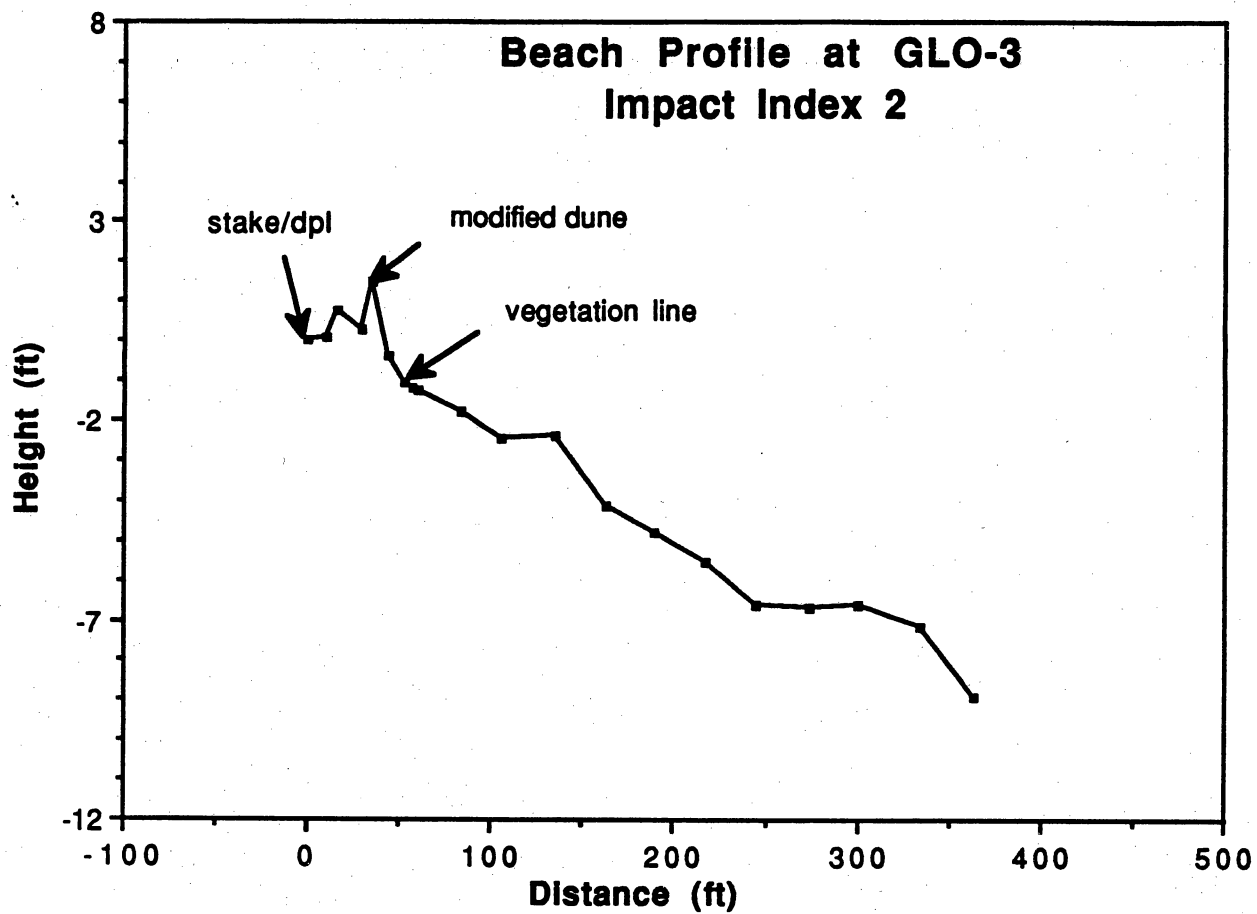
| <u>Index</u> | <u>Description</u> |
|--------------|--|
| 0 | No visible impact of beach scraping or evidence of backbeach dumping. Dune morphologies and plant communities are natural. Essentially no modification of beach and dune profile. |
| 1 | Low, small-volume mounds of sand containing some minor beach trash such as <i>Sargassum</i> . Trash represents less than 20% of mound volume. Altered zone is narrow relative to the entire beach width. |
| 2 | Low, small-volume mounds of sand and some minor beach trash such as <i>Sargassum</i> and small pieces of wood. Trash represents less than 33% of mound volume. Altered zone is narrow relative to the entire beach width. |
| 3 | Moderately large mounds of sand at least 3 ft high. Mounds composed of approximately 33% trash including moderately large pieces of wood or other debris. Several rows (2-3) of modified dunes or sand mounds. Altered zone is moderately wide relative to the entire beach width. |
| 4 | Moderately large mounds of sand greater than 3 ft high. Mounds composed of more than 33% trash. Multiple rows of modified dunes or sand mounds forming moderately wide zone relative to the entire beach width. Modified area may include bypass zone(s) representing former backbeach road(s). |
| 5 | Large mounds of sand up to 6 ft high. Mounds composed of as much as 50% trash containing large logs, cut wood, tires, appliances, and concrete or other rubble. Multiple rows of modified dunes or sand mounds forming wide zone relative to the entire beach width. Modified area may include bypass zone(s) representing former backbeach road(s). |

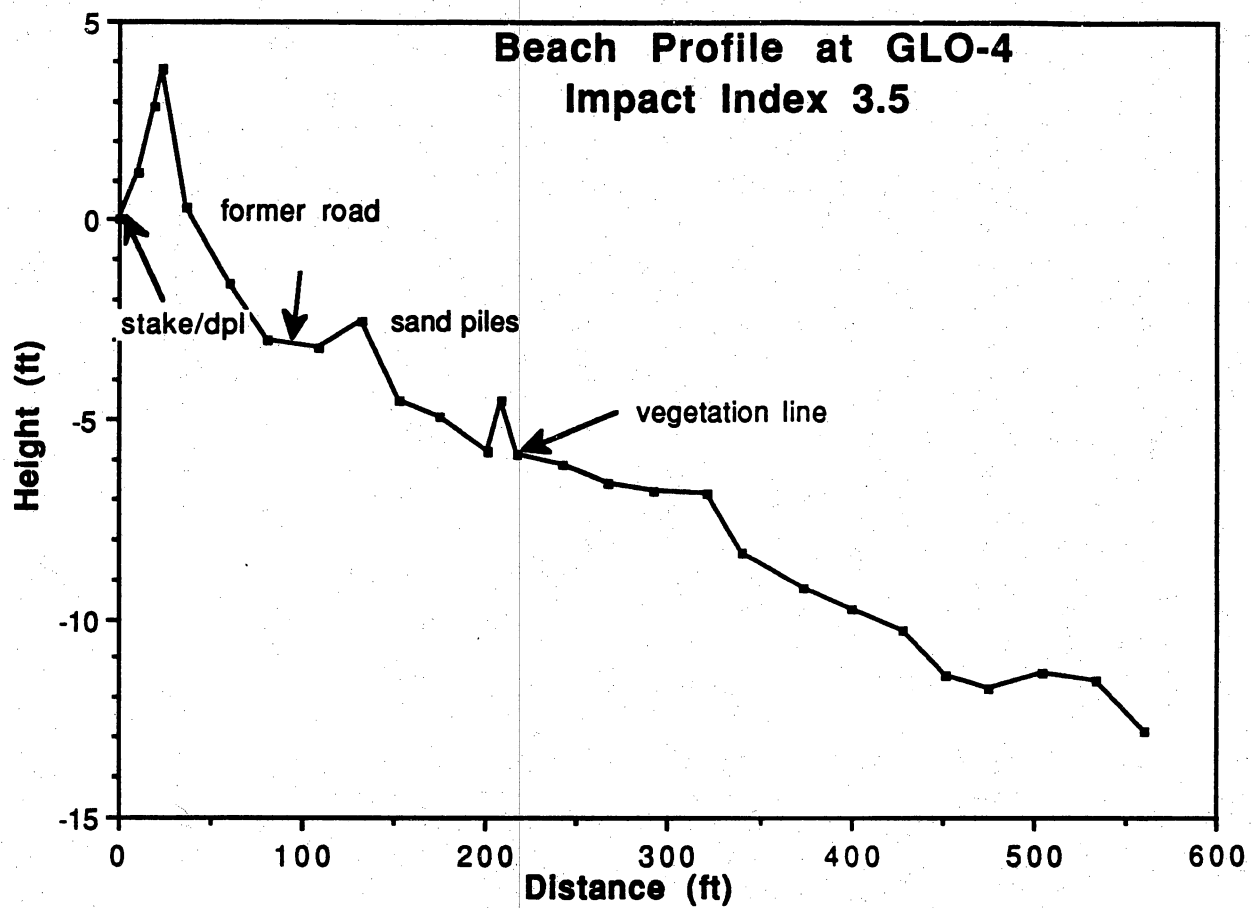
Addendum 3. Beach and Dune Profiles, Galveston County

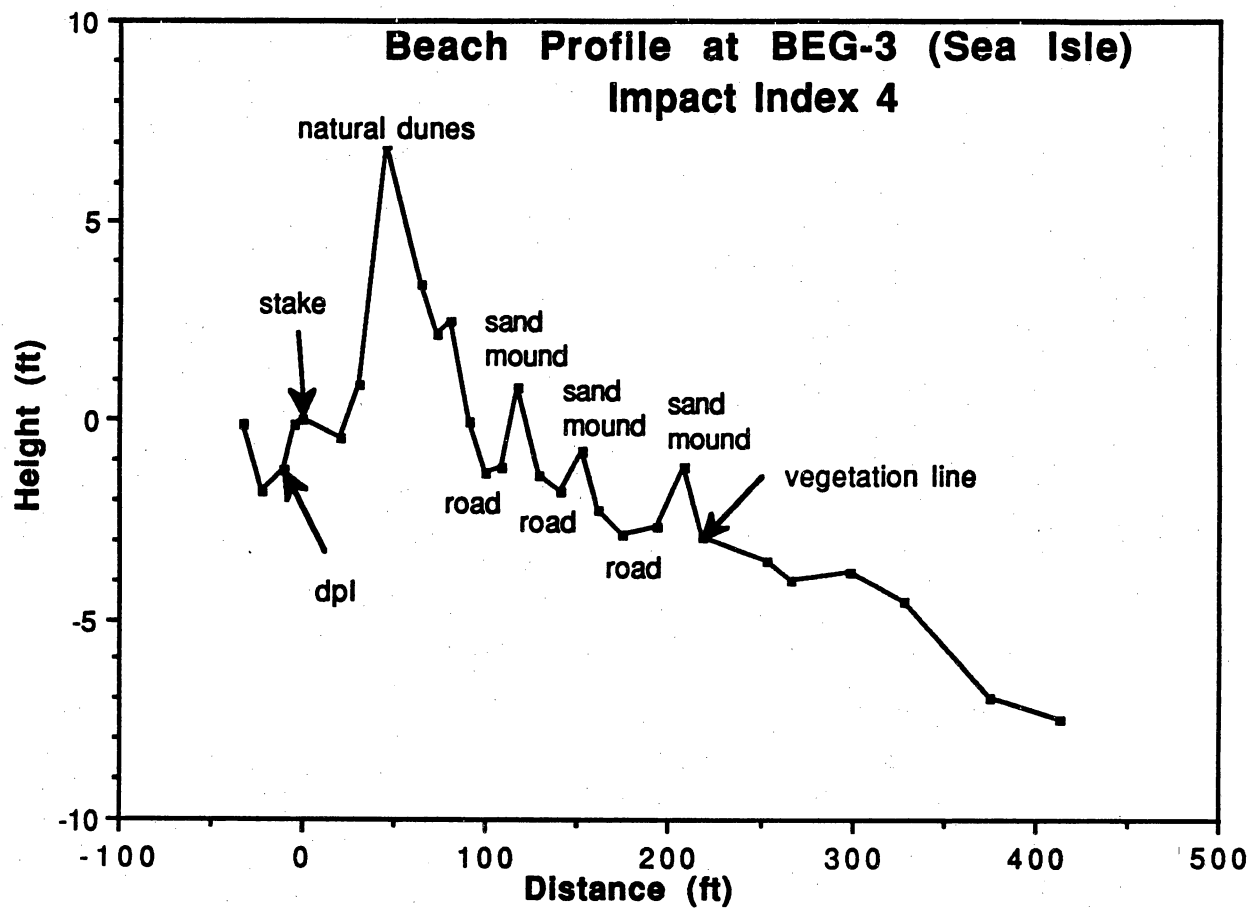


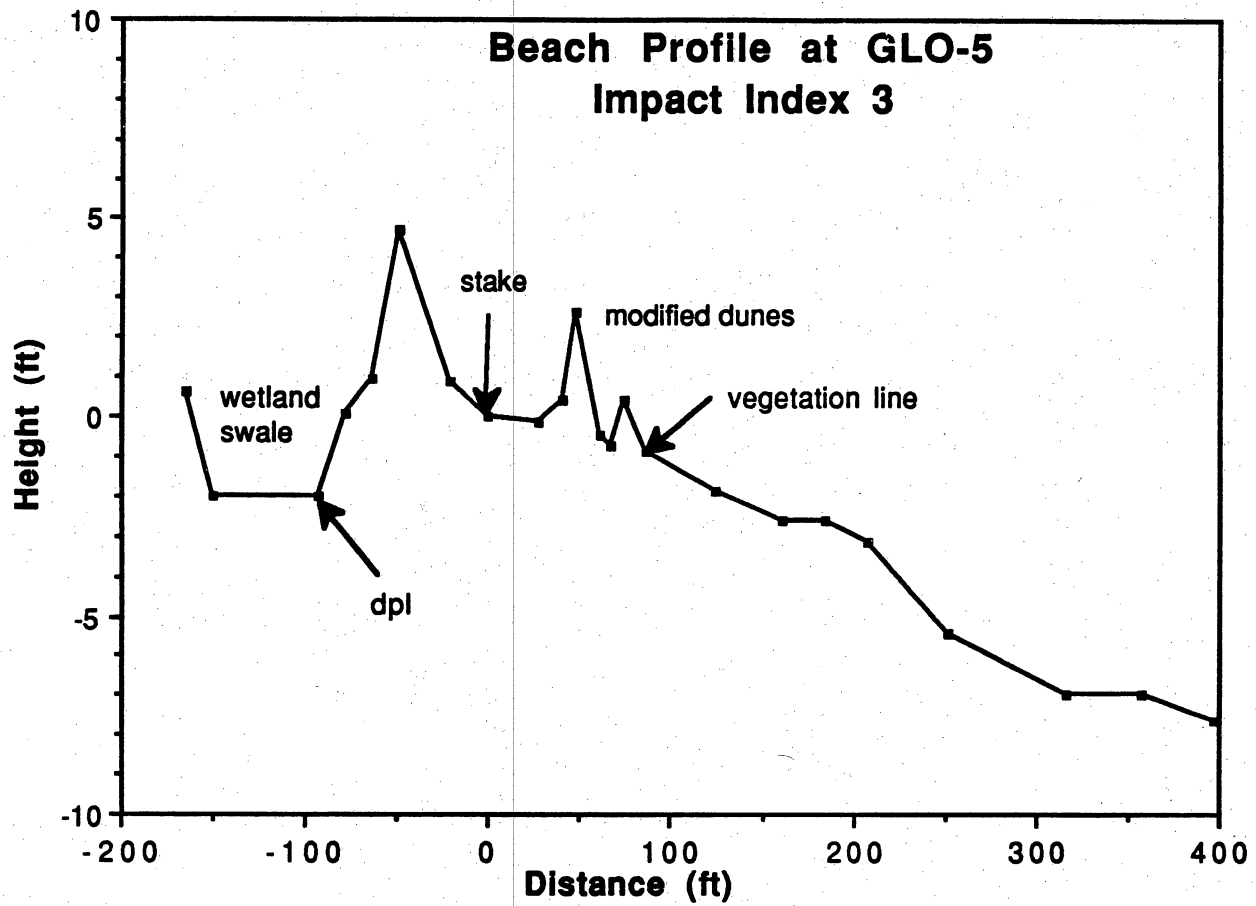


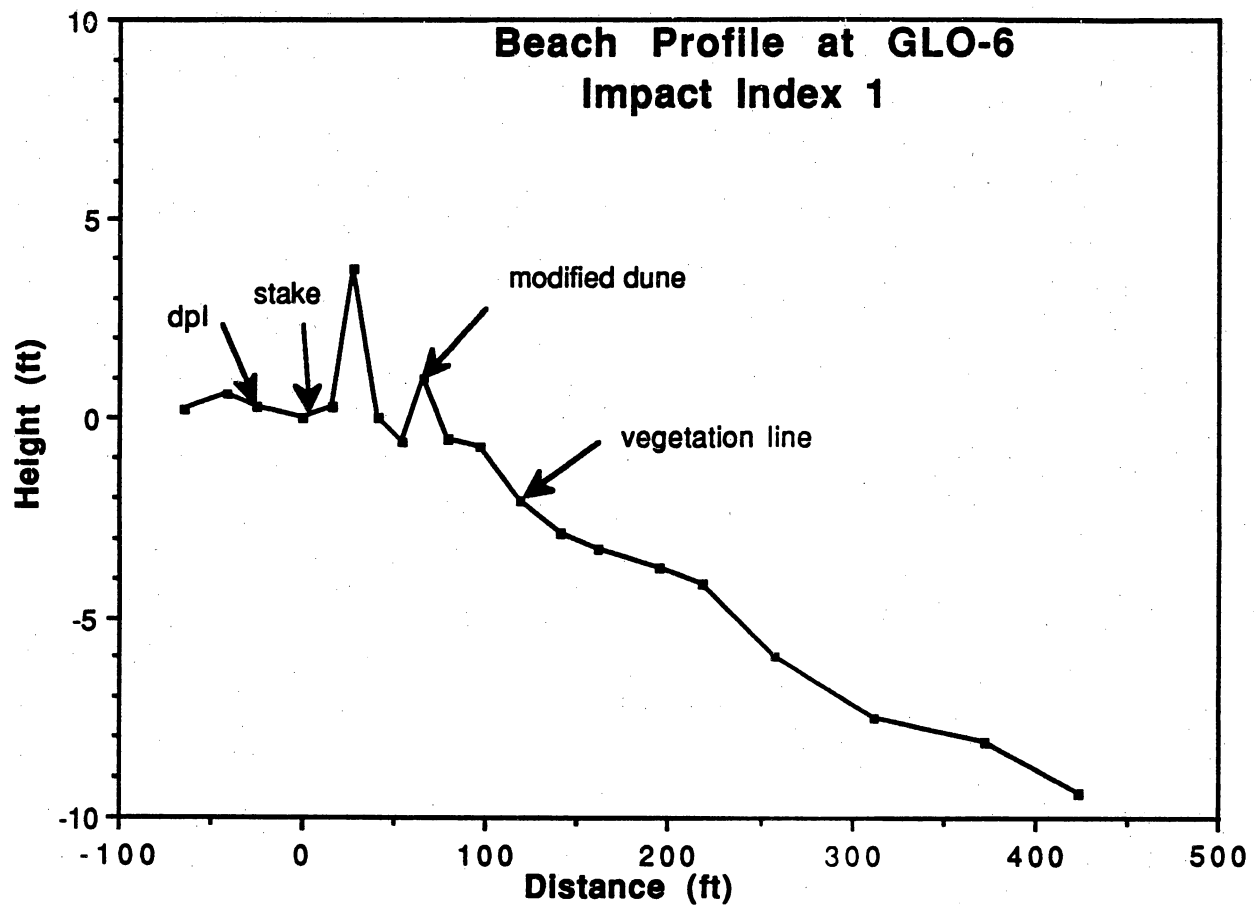


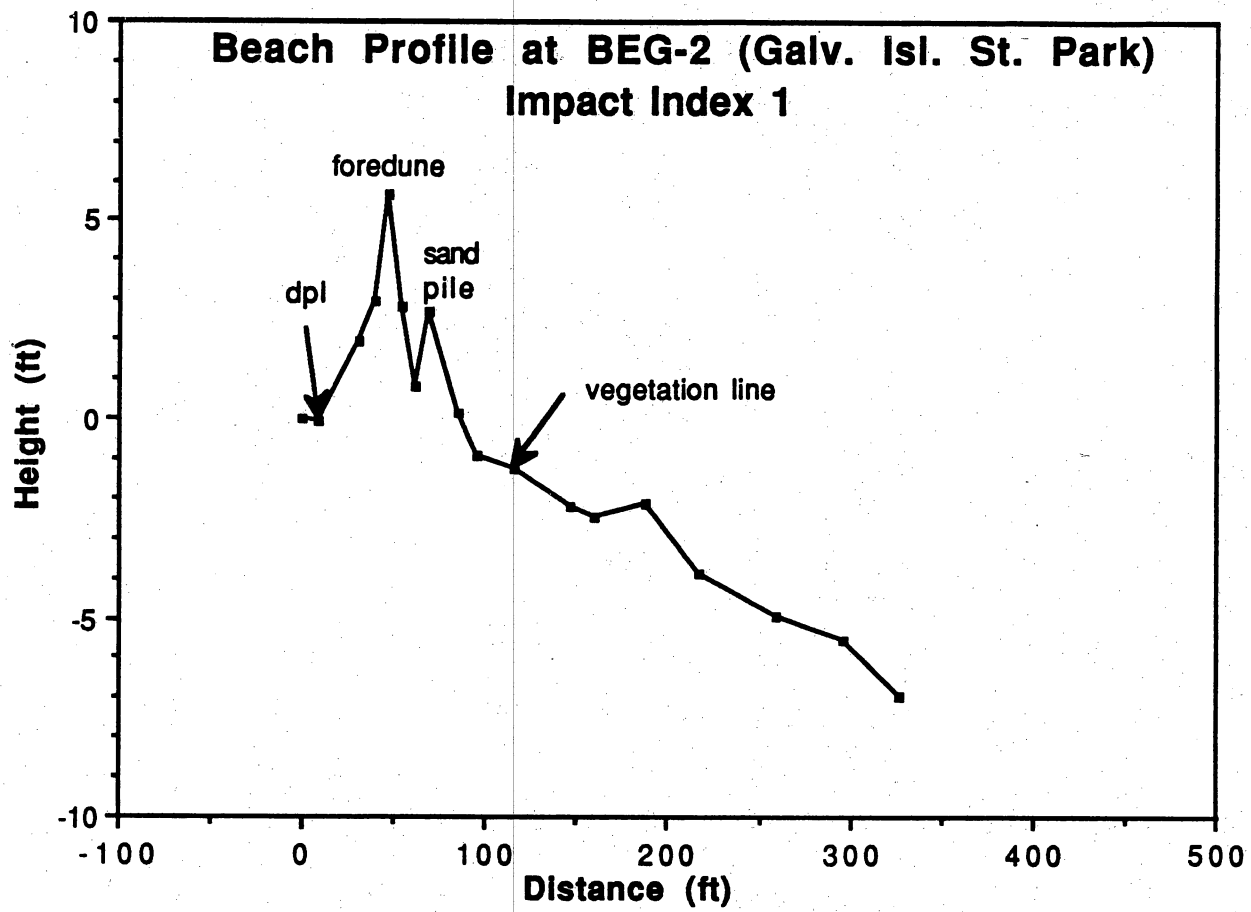


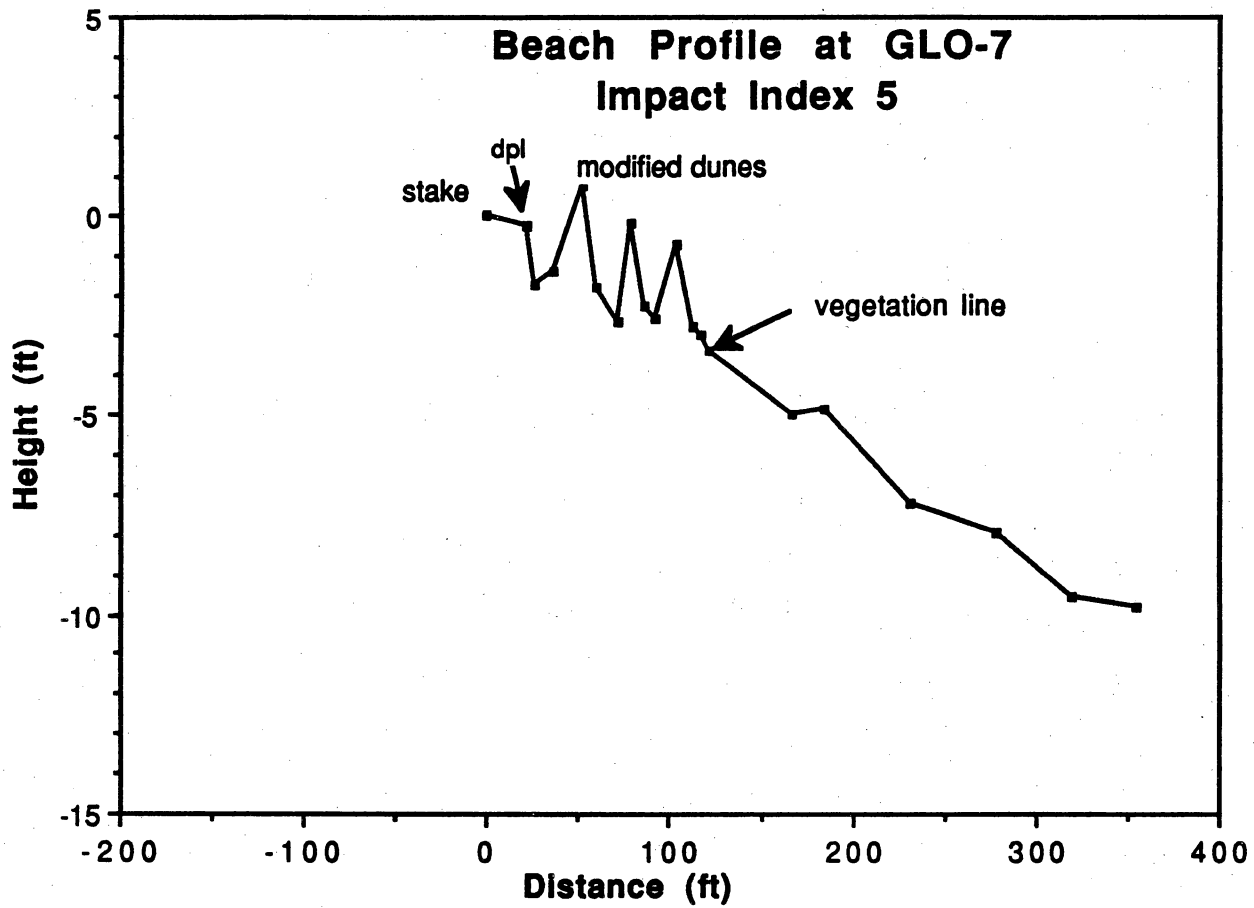


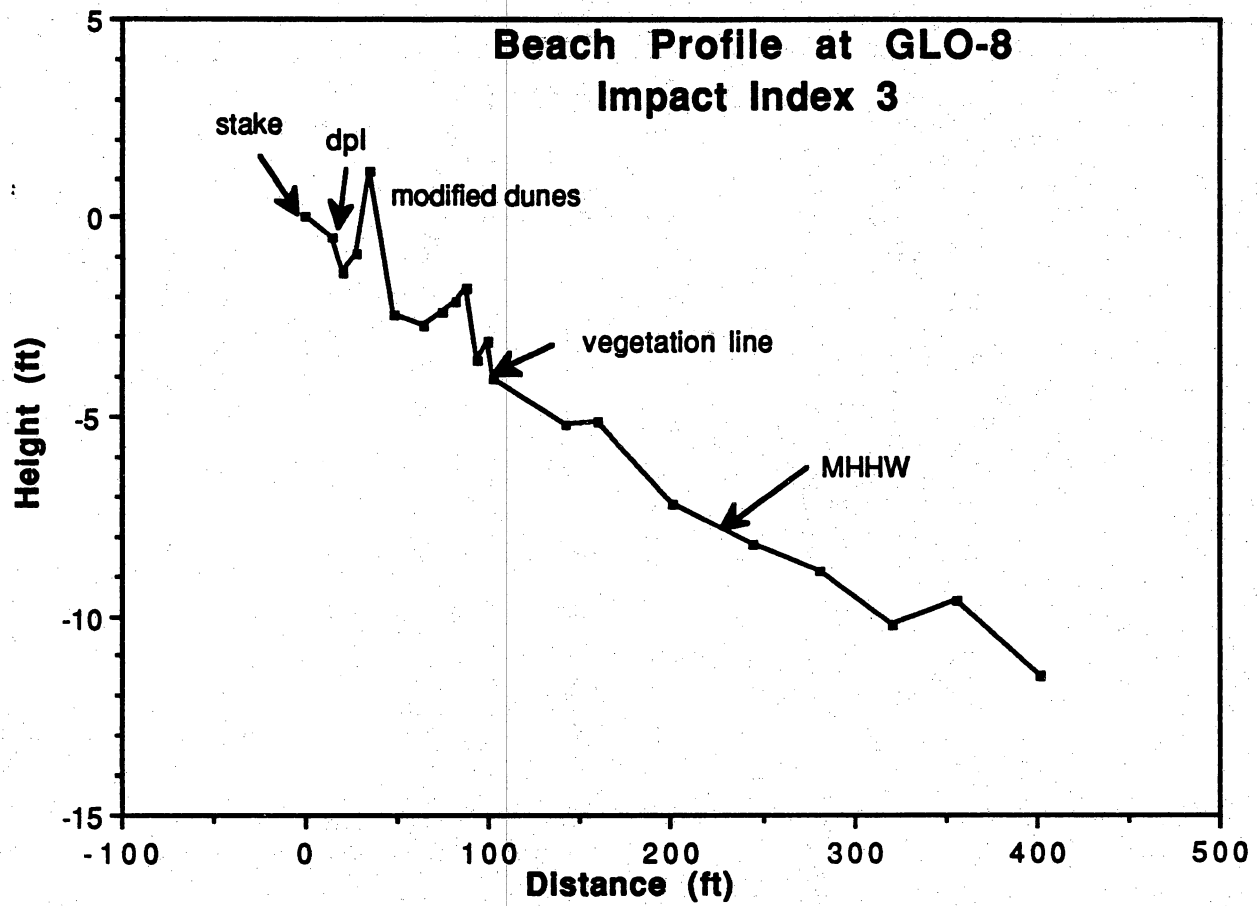


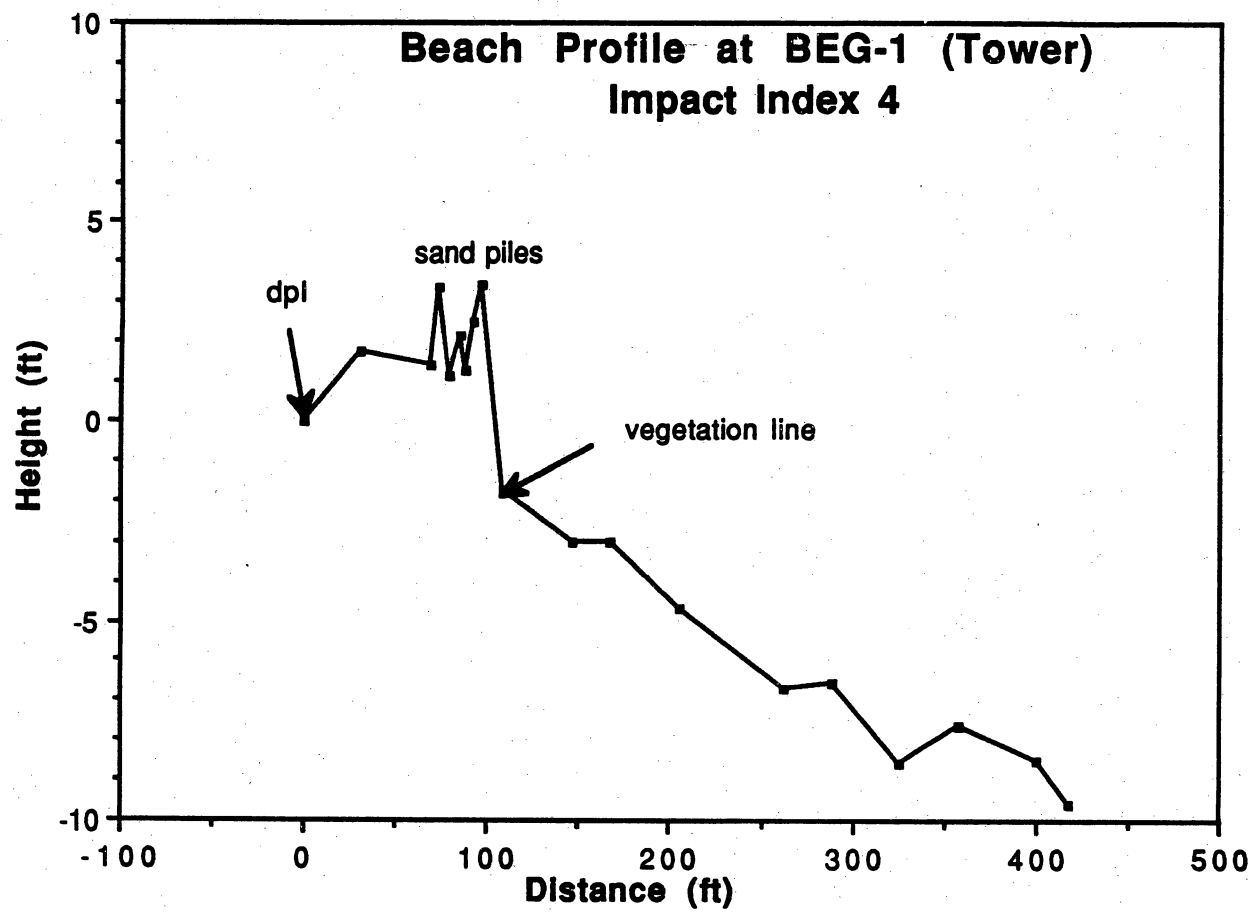


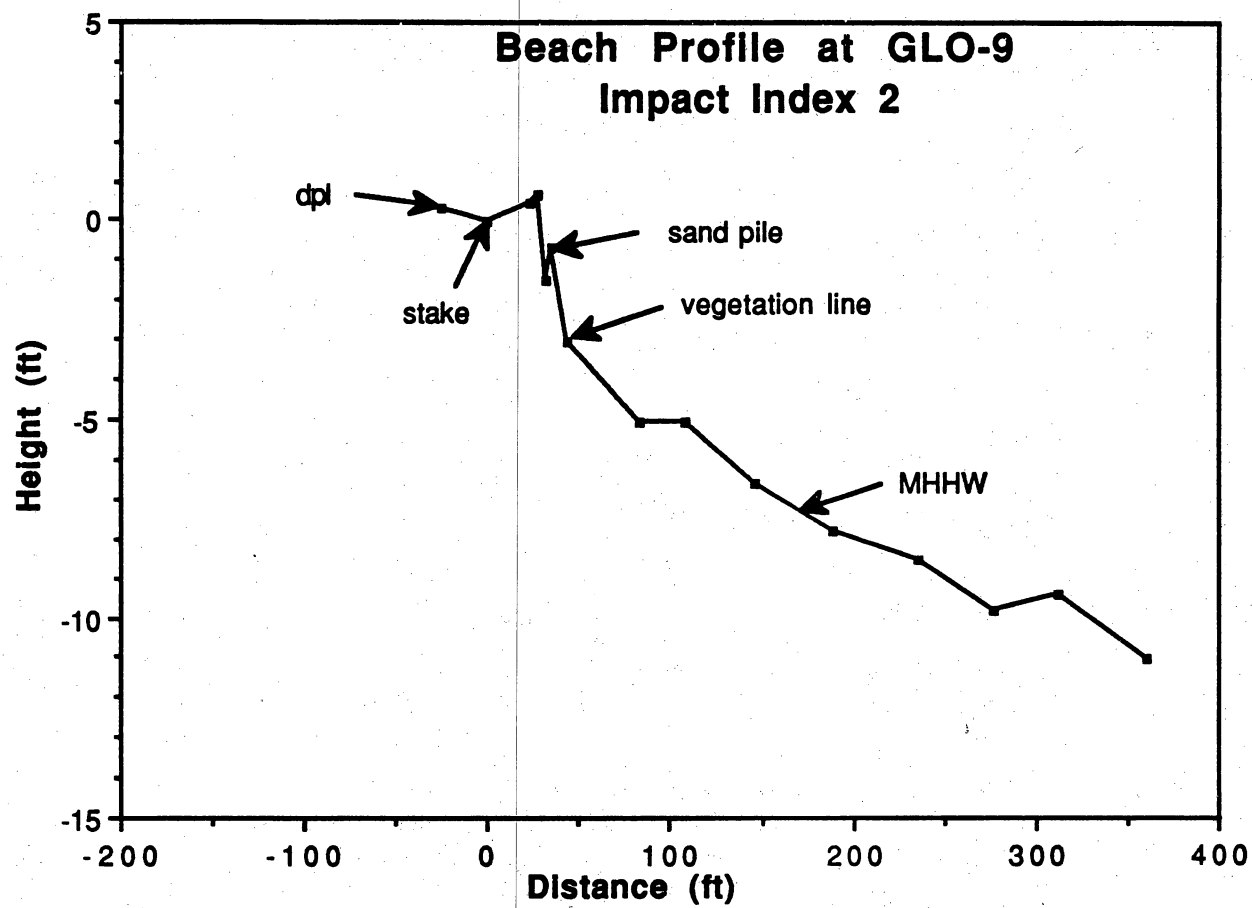


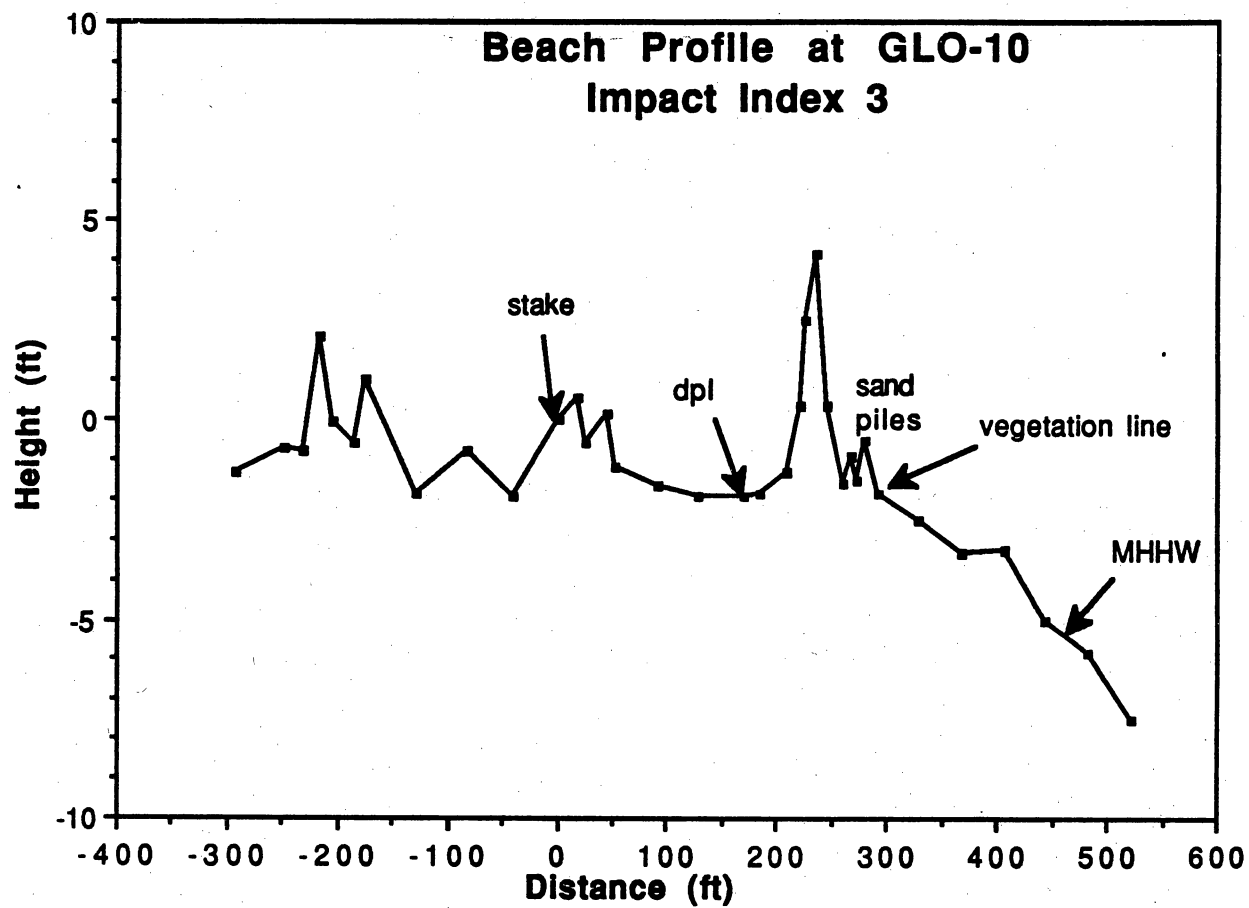


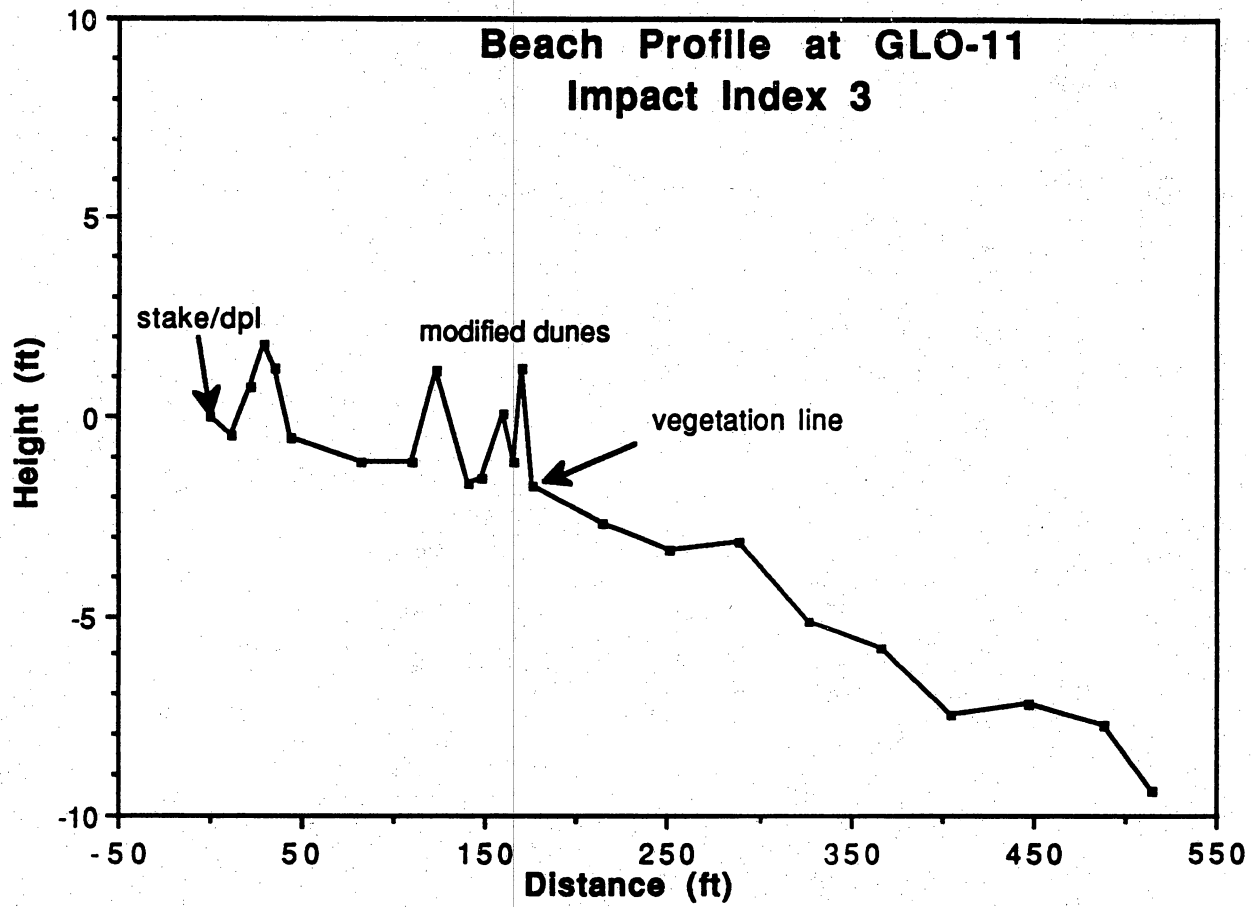


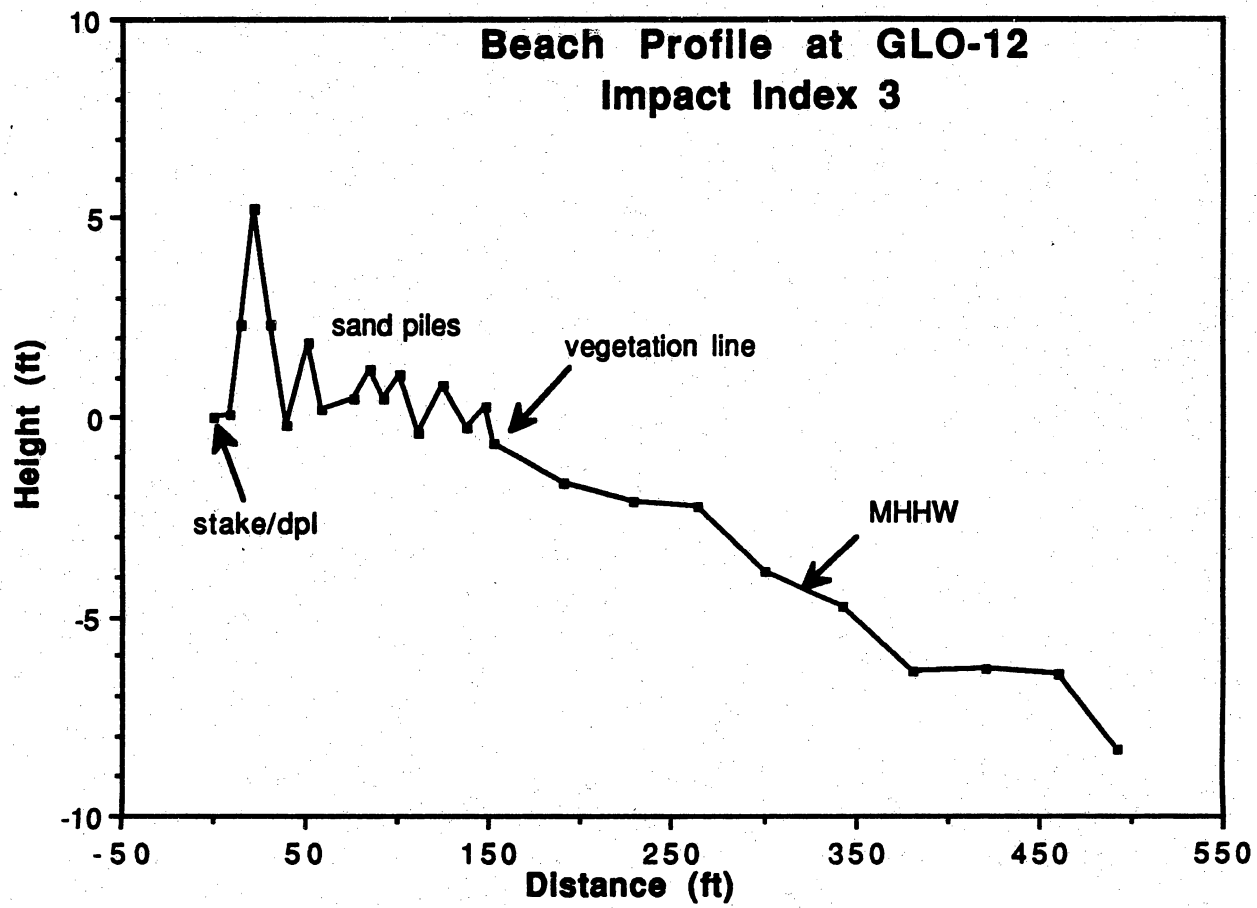


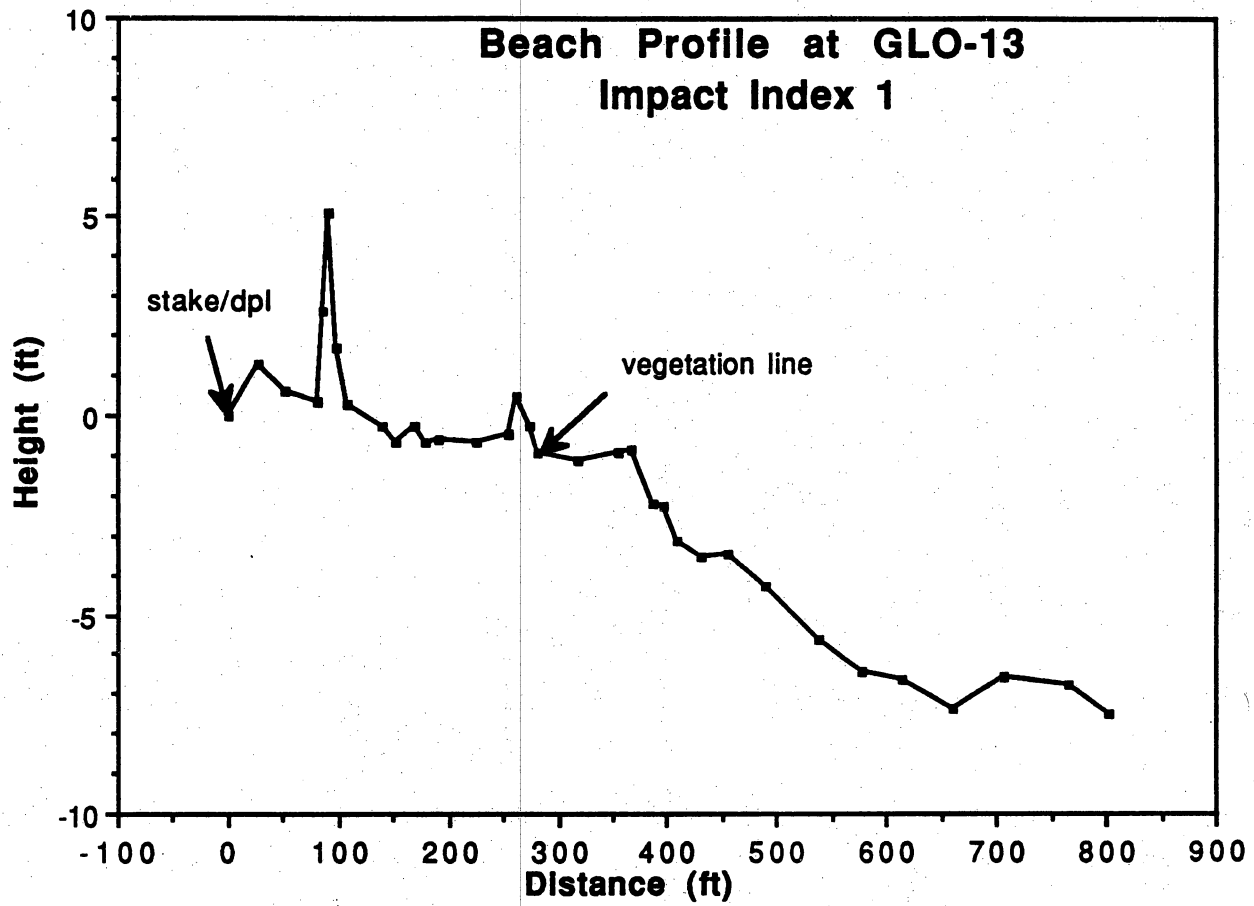


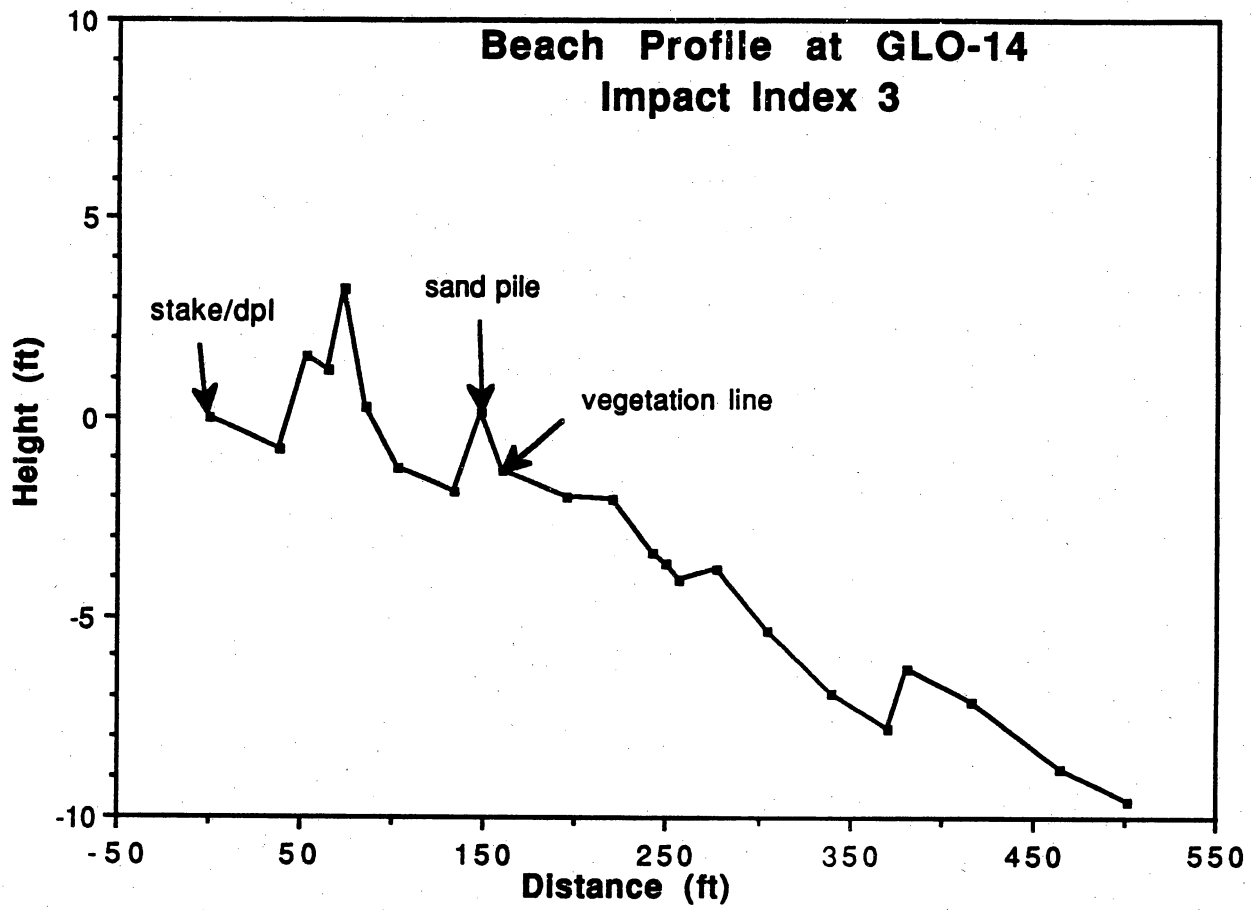


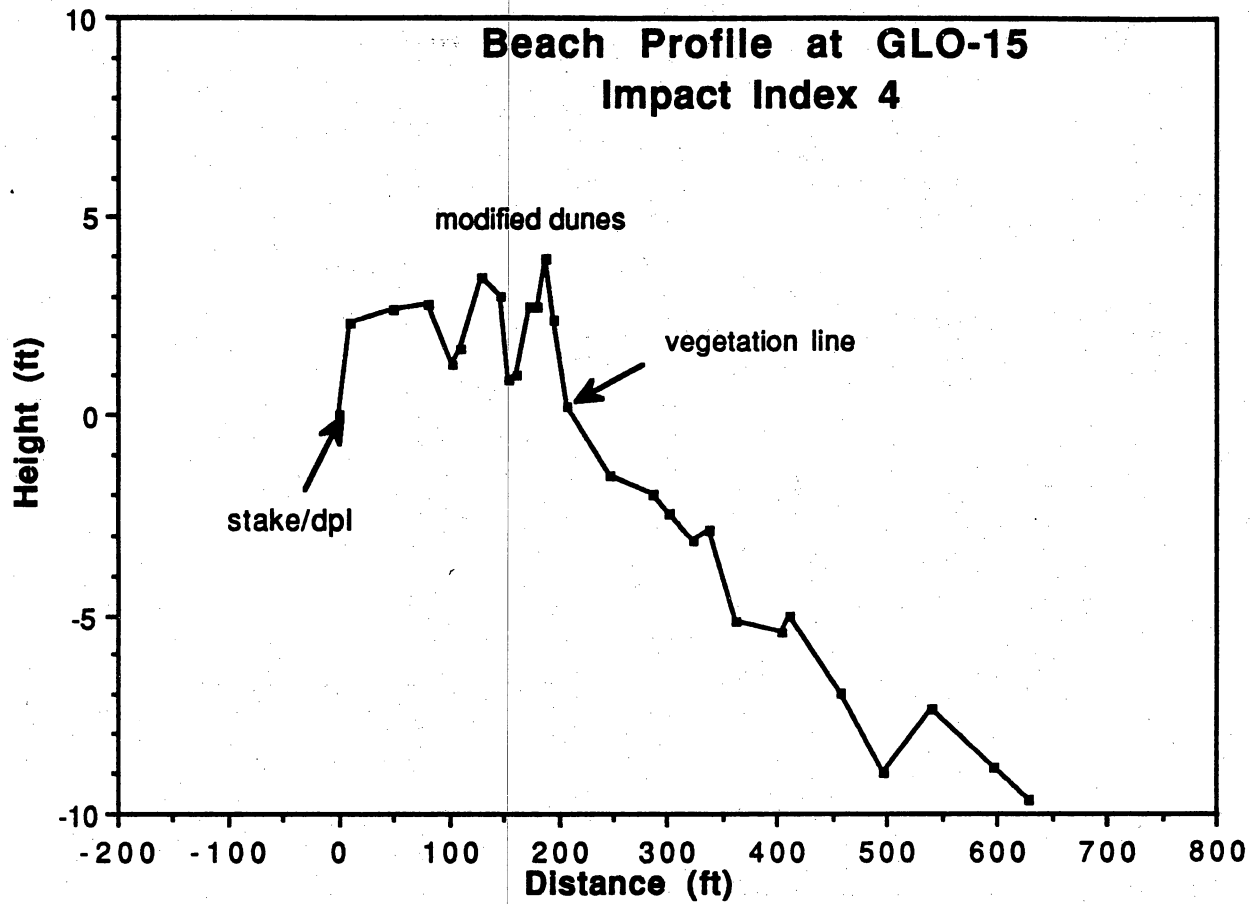


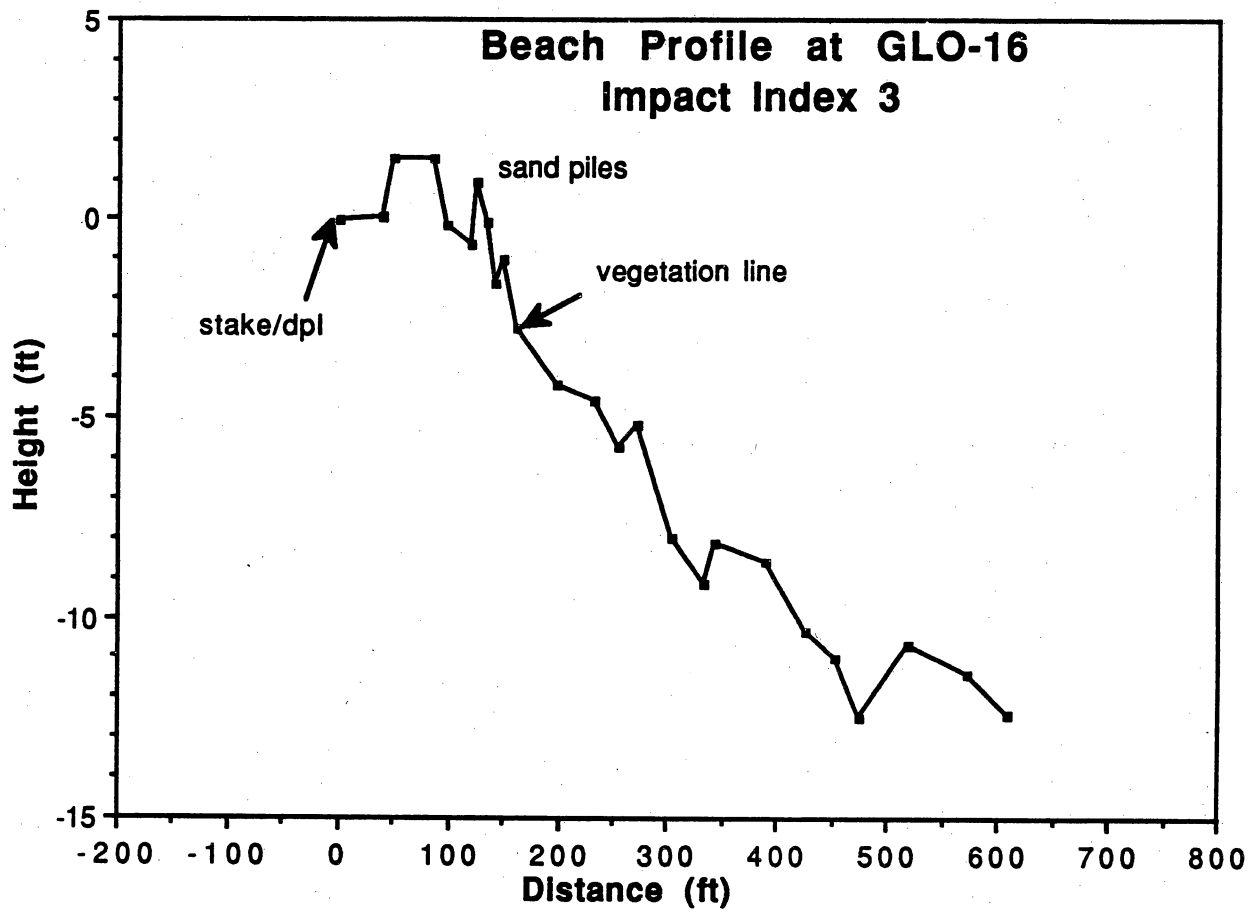


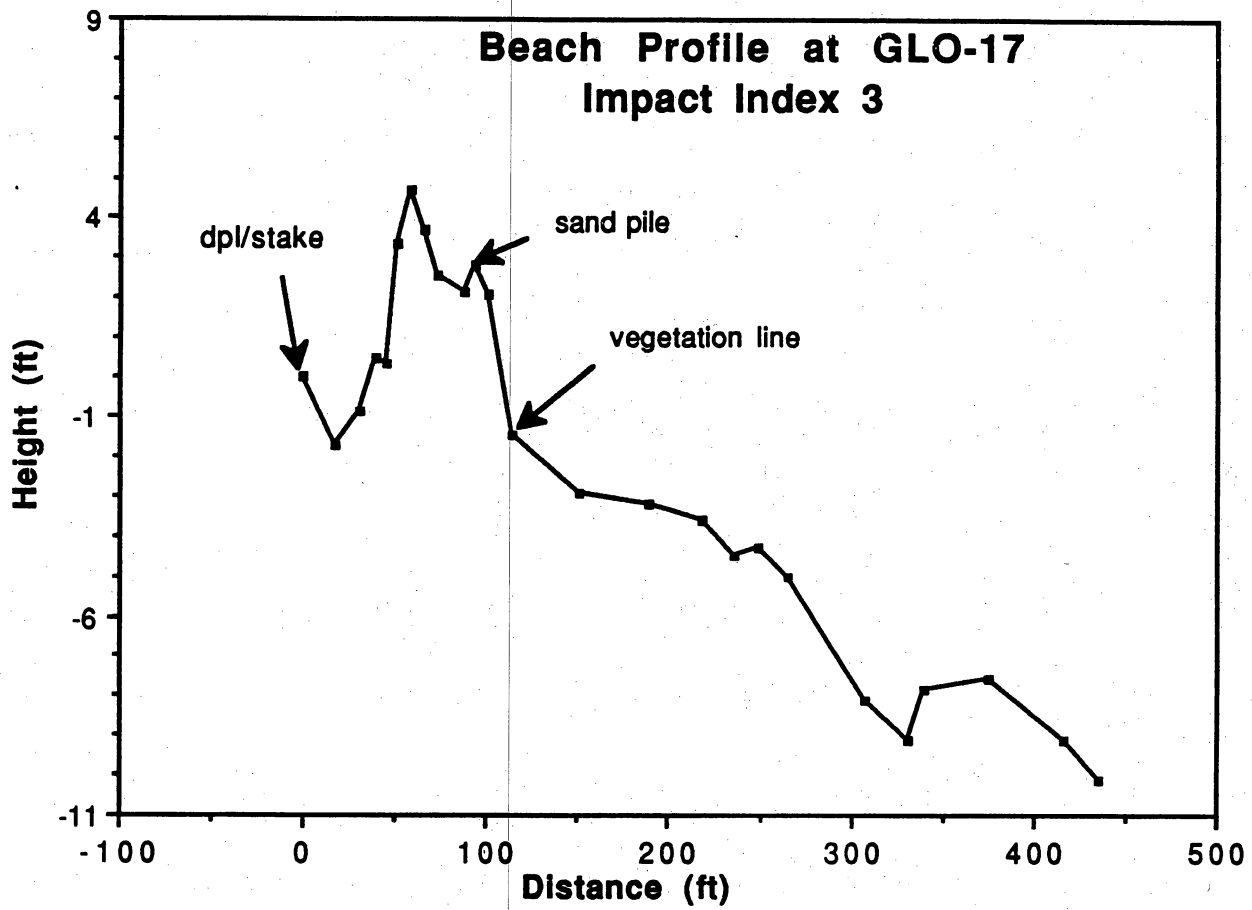


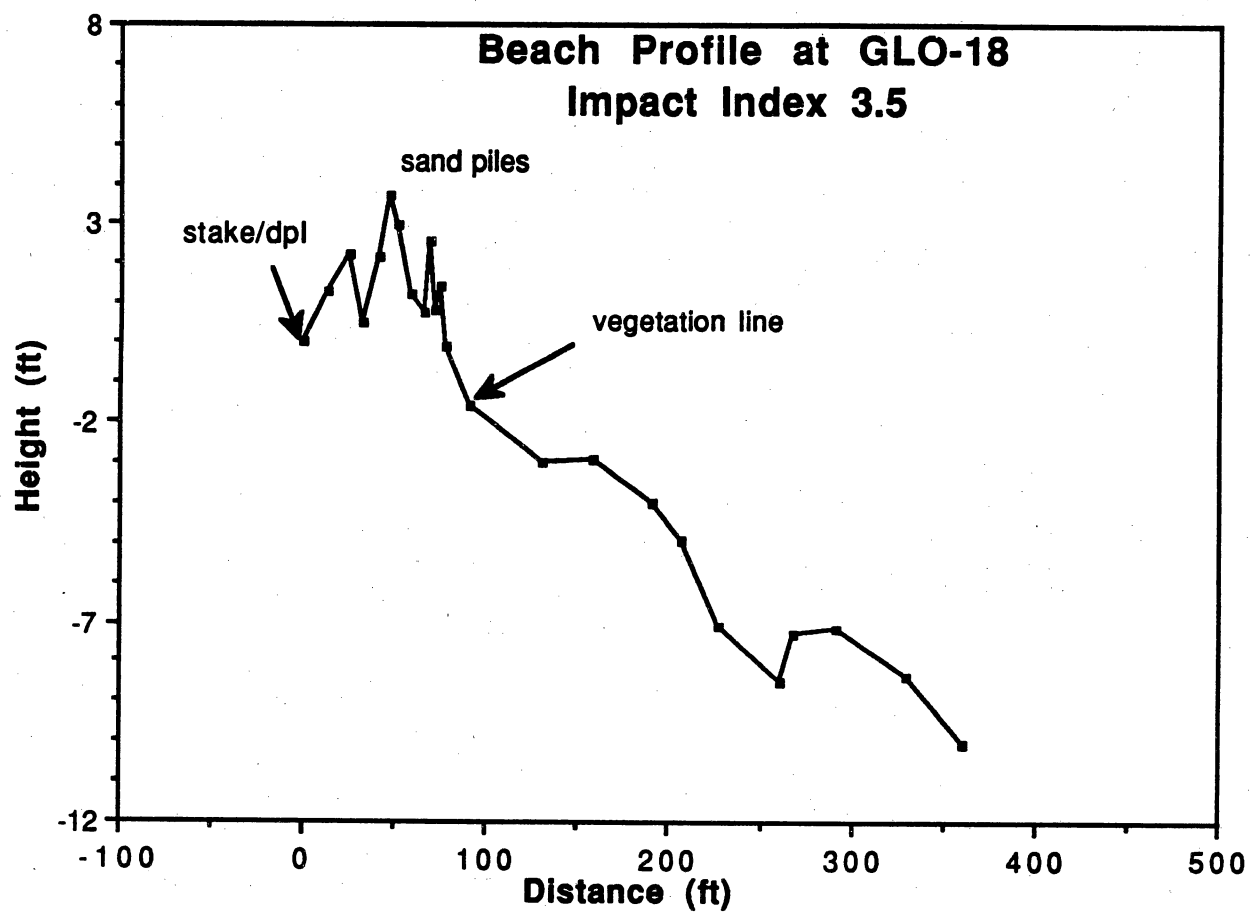


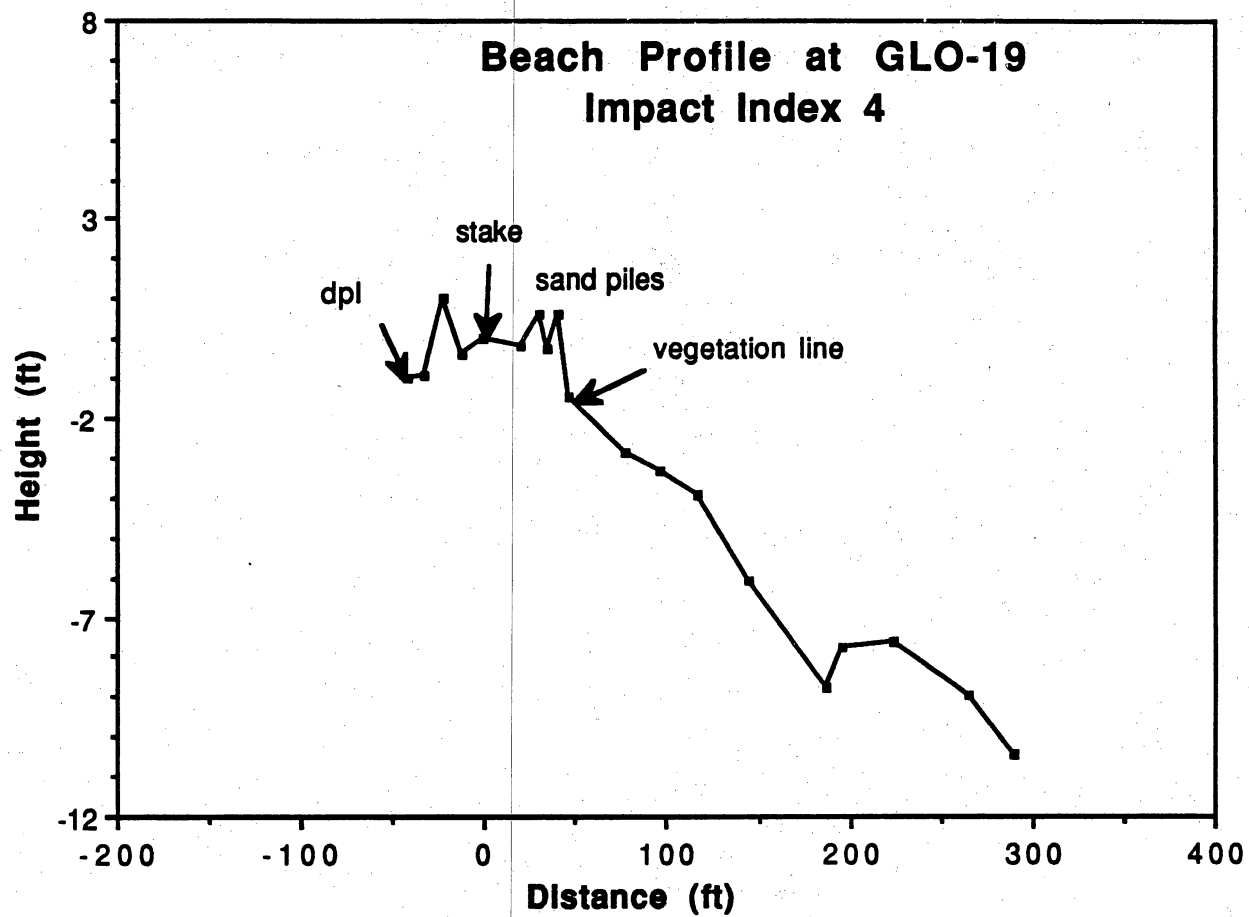


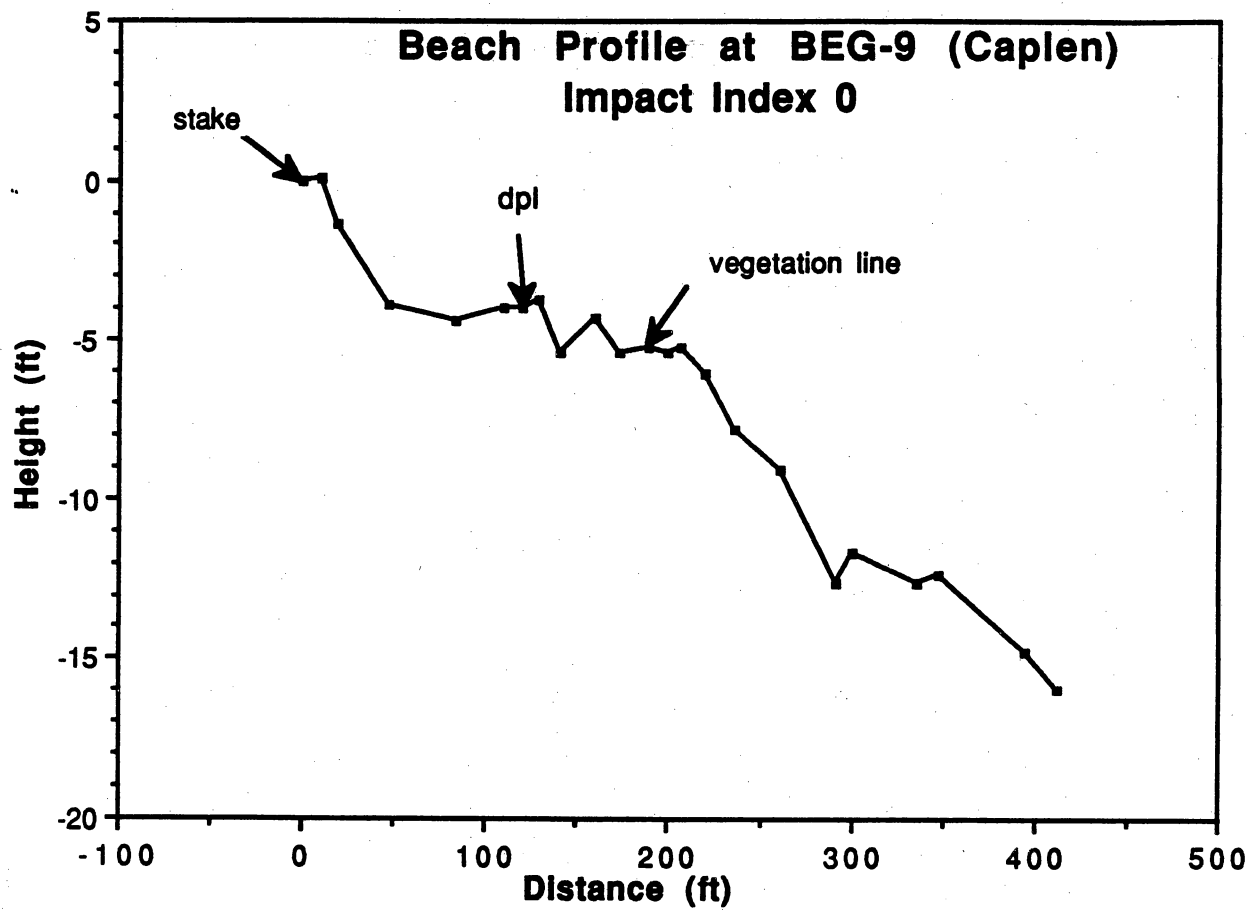


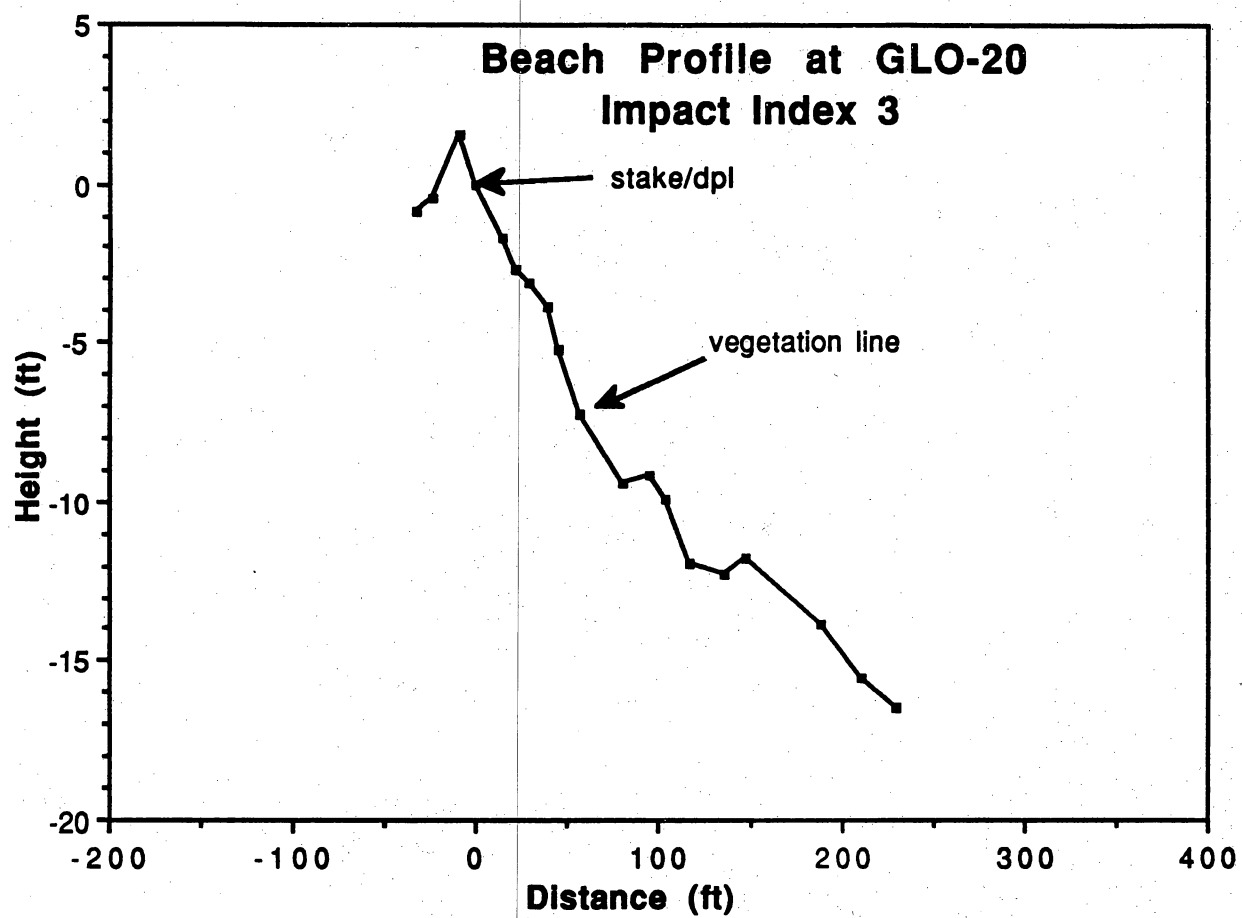


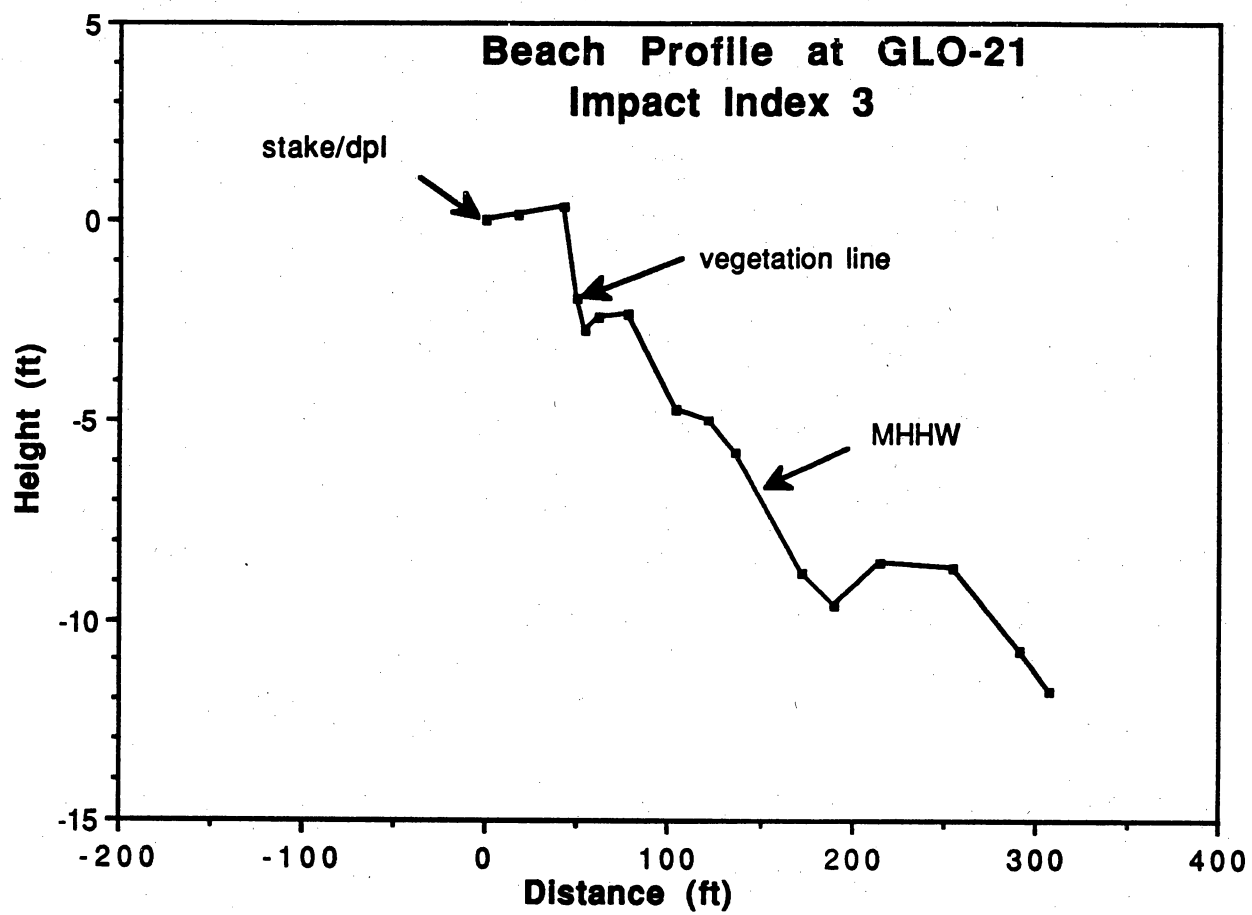


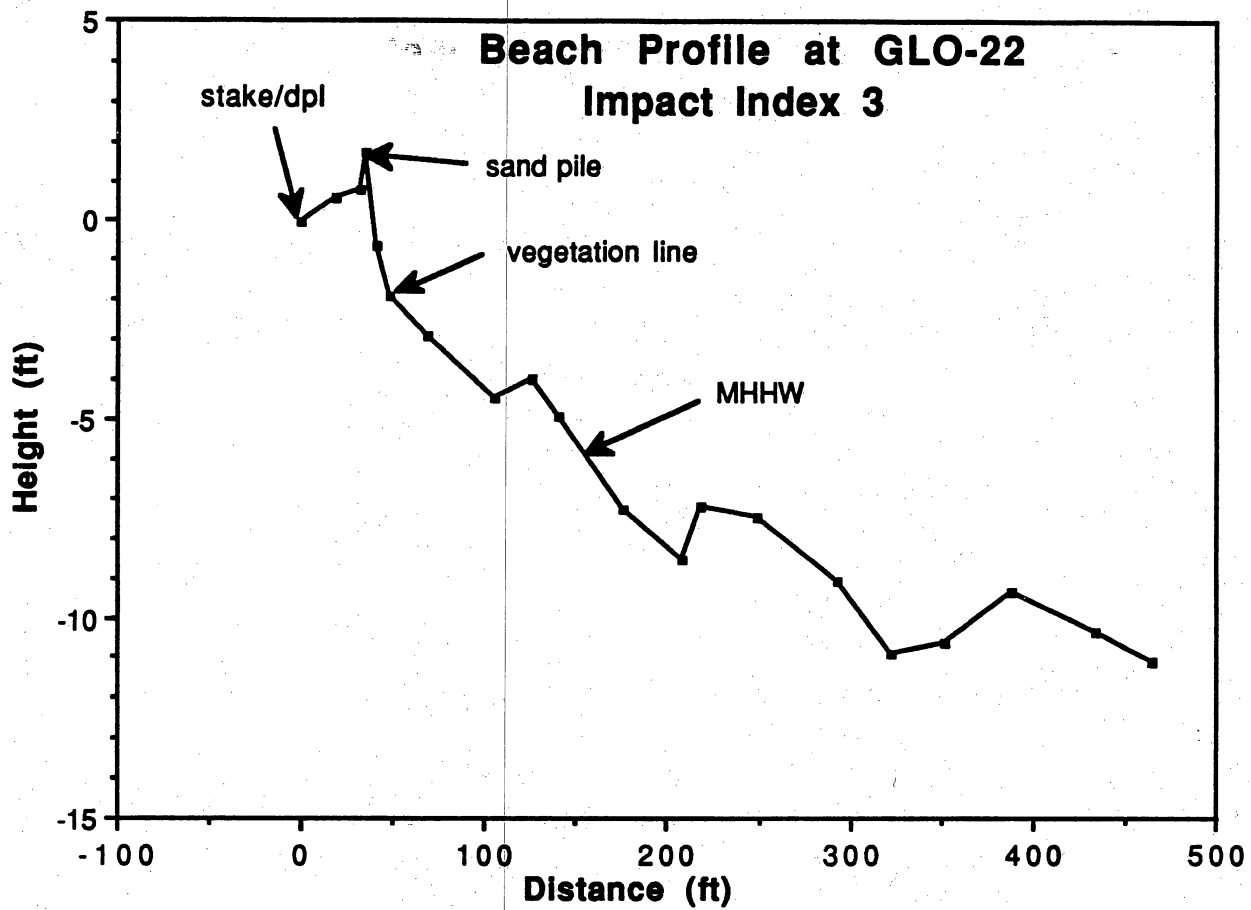


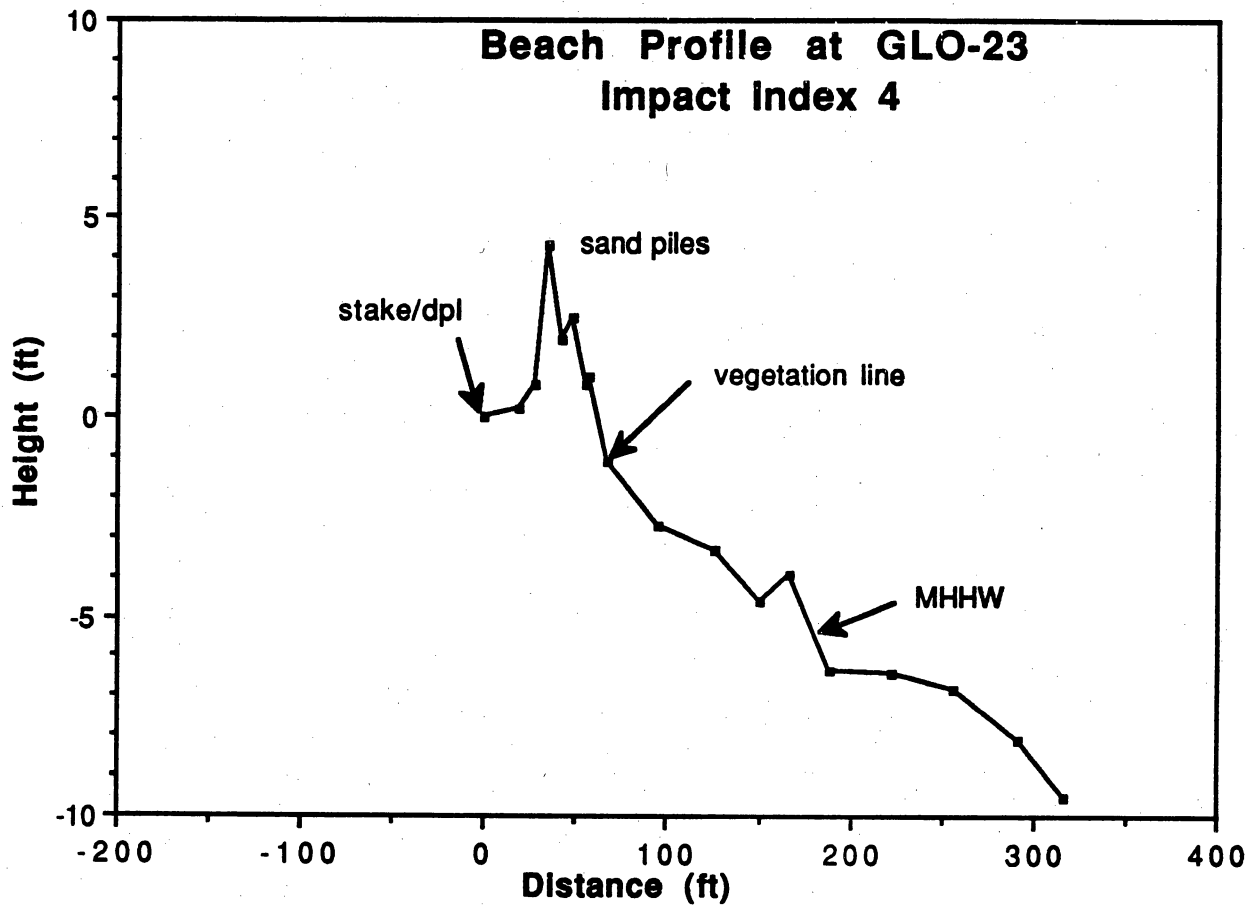


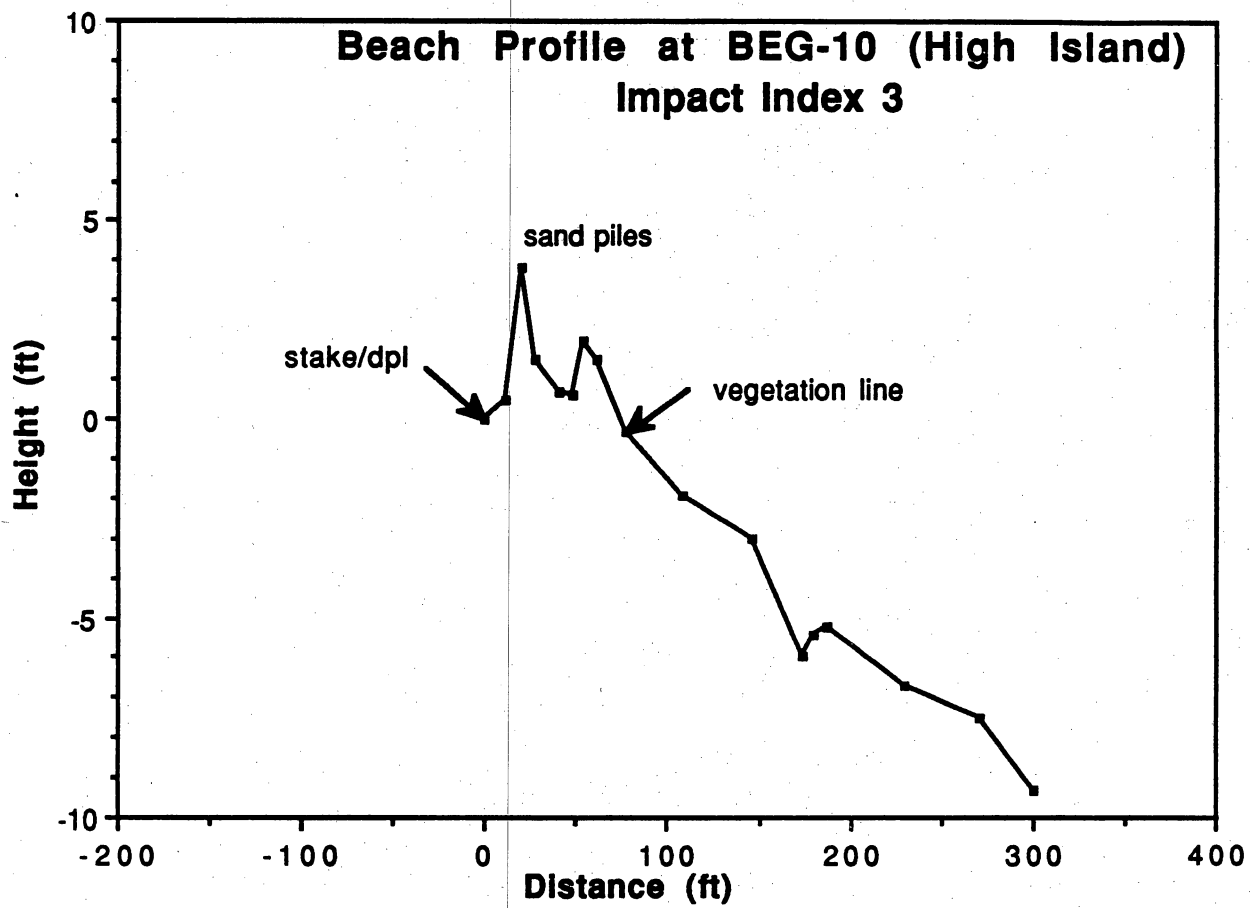


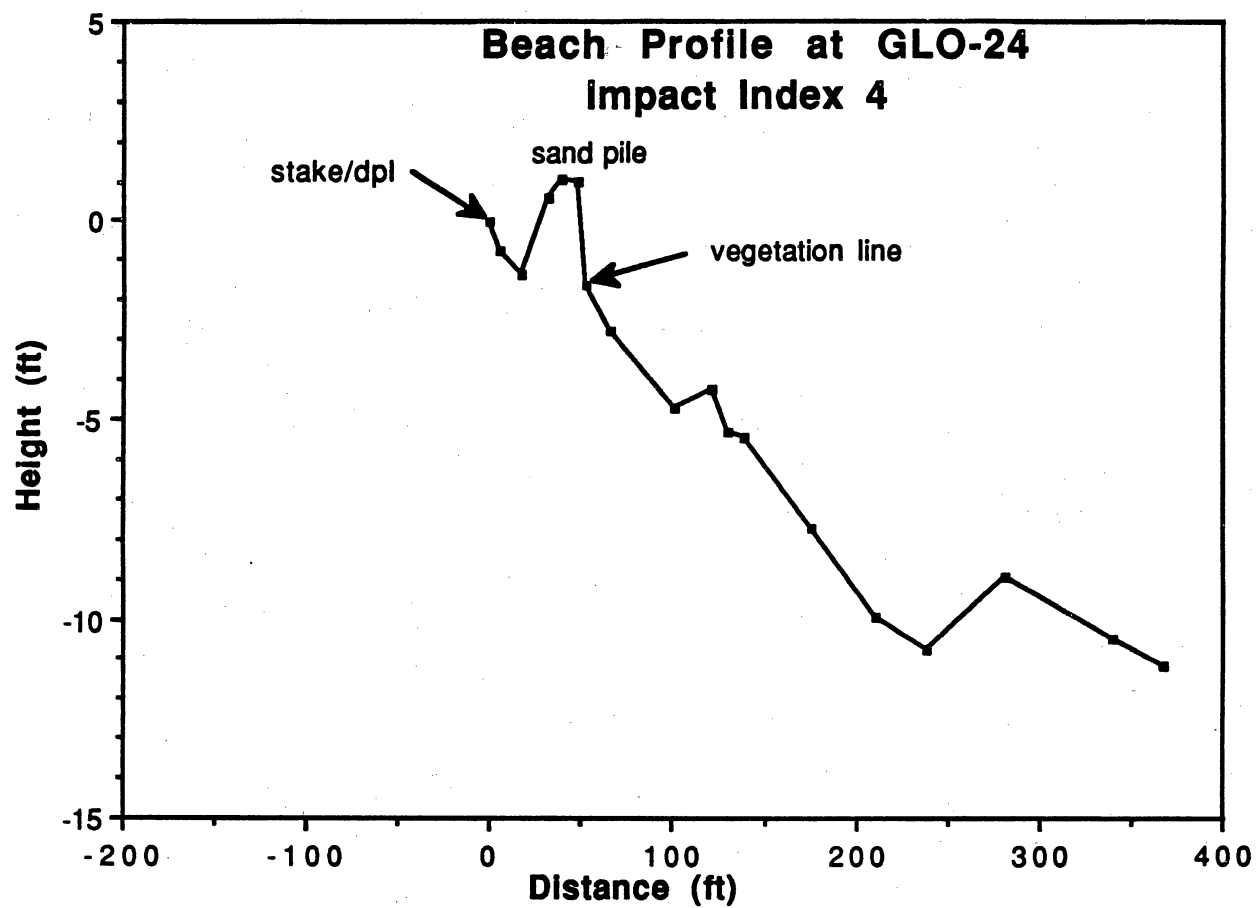












Addendum 4. Foraminifera Analysis

| Sample | misc. agglutinated | A. parkinsoniana | E. gunteri | E. discoidale | E. mexicanum | E. matagordanum | E. sp cf matagordanum | E. poeyanum | E. sp cf poeyanum | E. kugleri | juveniles | Elphidium spp. | rotalid fragments | Nonionella atlantica | Discorbis spp. | Hanzawaia concentrica | Palmerinella palmerae | Buccella hannah | Buliminella elegantissima | Brizalina lowmani | B. striatula | Fissurina sp. | total rare marine |
|----------|--------------------|------------------|------------|---------------|--------------|-----------------|-----------------------|-------------|-------------------|------------|-----------|----------------|-------------------|----------------------|----------------|-----------------------|-----------------------|-----------------|---------------------------|-------------------|--------------|---------------|-------------------|
| CE7-132 | 0 | 92 | 144 | 37 | 11 | 2 | 0 | 1 | 0 | 0 | 0 | 1 | 7 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE7-292 | 0 | 87 | 187 | 5 | 2 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 |
| CE7-445 | 2 | 75 | 170 | 31 | 14 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE7-465 | 0 | 104 | 195 | 22 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE7-498 | 0 | 125 | 199 | 34 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 8 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE7-528 | 0 | 111 | 191 | 24 | 11 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 4 | 2 | 0 | 0 | 0 | 0 | 0 |
| CE7-602 | 0 | 104 | 134 | 22 | 33 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| CE7-629 | 0 | 128 | 103 | 37 | 5 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 4 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE7-640 | 0 | 95 | 199 | 51 | 42 | 2 | 0 | 0 | 0 | 0 | 0 | 11 | 5 | 0 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 |
| CE7-671 | 1 | 108 | 211 | 8 | 0 | 0 | 0 | 0 | 24 | 0 | 0 | 1 | 17 | 0 | 0 | 0 | 0 | 4 | 1 | 1 | 0 | 0 | 2 |
| CE7-693 | 0 | 77 | 237 | 0 | 0 | 2 | 0 | 1 | 26 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 8 | 1 | 0 | 0 | 0 | 0 | 0 |
| CE7-726 | 0 | 0 | 37 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE7-757 | 0 | 131 | 260 | 8 | 1 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| CE7-787 | 0 | 13 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE7-813 | 0 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE10-146 | 6 | 38 | 179 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 103 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 2 |
| CE10-267 | 1 | 139 | 113 | 7 | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE10-295 | 1 | 142 | 113 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE10-330 | 0 | 36 | 51 | 5 | 0 | 0 | 5 | 0 | 4 | 0 | 5 | 0 | 55 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 |
| CE10-368 | 1 | 77 | 156 | 6 | 4 | 1 | 3 | 0 | 1 | 0 | 6 | 0 | 46 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| CE10-394 | 0 | 57 | 206 | 5 | 0 | 2 | 1 | 0 | 0 | 0 | 3 | 0 | 29 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| CE10-439 | 0 | 88 | 177 | 12 | 0 | 1 | 4 | 0 | 23 | 0 | 7 | 0 | 36 | 1 | 0 | 0 | 2 | 4 | 2 | 0 | 1 | 0 | 4 |
| CE10-483 | 0 | 81 | 164 | 4 | 1 | 2 | 6 | 2 | 21 | 1 | 8 | 0 | 33 | 0 | 0 | 0 | 2 | 4 | 0 | 1 | 1 | 0 | 2 |
| CE10-525 | 1 | 82 | 143 | 2 | 1 | 2 | 0 | 0 | 7 | 0 | 4 | 0 | 32 | 0 | 0 | 0 | 2 | 1 | 2 | 0 | 2 | 0 | 4 |
| CE10-561 | 0 | 73 | 165 | 4 | 1 | 0 | 3 | 0 | 6 | 0 | 1 | 0 | 47 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE10-593 | 0 | 80 | 158 | 11 | 6 | 0 | 3 | 0 | 3 | 0 | 4 | 2 | 19 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE10-625 | 0 | 67 | 87 | 3 | 0 | 1 | 103 | 0 | 9 | 0 | 12 | 0 | 20 | 0 | 0 | 0 | 2 | 3 | 2 | 1 | 1 | 0 | 4 |
| CE10-658 | 0 | 73 | 122 | 6 | 0 | 4 | 31 | 0 | 17 | 0 | 28 | 6 | 25 | 0 | 0 | 0 | 15 | 6 | 2 | 0 | 2 | 4 | 8 |
| CE10-688 | 0 | 58 | 114 | 0 | 4 | 0 | 65 | 1 | 5 | 1 | 36 | 0 | 13 | 0 | 0 | 0 | 28 | 7 | 1 | 1 | 1 | 0 | 3 |
| CE10-716 | 1 | 68 | 131 | 4 | 1 | 4 | 47 | 0 | 6 | 4 | 25 | 0 | 13 | 1 | 0 | 0 | 6 | 4 | 1 | 1 | 2 | 0 | 5 |
| CE10-753 | 0 | 131 | 159 | 15 | 4 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE10-793 | 0 | 104 | 158 | 19 | 2 | 2 | 0 | 3 | 2 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 4 | 1 | 0 | 0 | 0 | 0 | 0 |
| CE10-826 | 1 | 119 | 126 | 11 | 6 | 0 | 0 | 1 | 4 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| CE10-839 | 2 | 127 | 176 | 15 | 5 | 4 | 5 | 9 | 10 | 0 | 5 | 0 | 21 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 1 |
| CE10-876 | 0 | 109 | 160 | 11 | 2 | 8 | 0 | 1 | 9 | 4 | 1 | 3 | 20 | 0 | 0 | 0 | 2 | 5 | 1 | 0 | 1 | 0 | 2 |
| CE10-917 | 0 | 107 | 182 | 15 | 0 | 4 | 0 | 0 | 7 | 8 | 3 | 0 | 12 | 0 | 0 | 0 | 2 | 4 | 0 | 1 | 2 | 0 | 3 |
| CE10-950 | 1 | 80 | 182 | 6 | 2 | 1 | 5 | 3 | 4 | 3 | 5 | 0 | 11 | 0 | 2 | 0 | 2 | 2 | 1 | 1 | 4 | 1 | 9 |
| CE10-987 | 0 | 105 | 138 | 6 | 0 | 1 | 8 | 0 | 14 | 7 | 1 | 0 | 14 | 1 | 0 | 0 | 0 | 2 | 1 | 1 | 1 | 0 | 4 |
| CE101024 | 0 | 102 | 122 | 10 | 5 | 3 | 12 | 0 | 14 | 4 | 14 | 0 | 22 | 0 | 1 | 0 | 2 | 6 | 2 | 0 | 6 | 1 | 10 |
| CE101086 | 0 | 80 | 141 | 2 | 1 | 0 | 9 | 2 | 17 | 4 | 18 | 0 | 13 | 0 | 0 | 0 | 0 | 10 | 1 | 1 | 1 | 2 | 5 |

| Sample | Quinqueloculina compla | Q. seminulum | Q. funafutiensis | Q. lamarckiana | Quinqueloculina spp. | Massilina peruviana | Triloculina oblonga | Triloculina spp. | miloid fragments | total miloids | reworked forams | misc. | total forams | %misc. agglutinated | %A. parkinsoniana | %E. gunteri | %E. discoidale | %E. mexicanum | %E. matagordanum | %E. sp cf matagordanum | %E. poeyanum | %E. sp cf poeyanum | %E. kugleri | %juveniles |
|----------|------------------------|--------------|------------------|----------------|----------------------|---------------------|---------------------|------------------|------------------|---------------|-----------------|-------|--------------|---------------------|-------------------|-------------|----------------|---------------|------------------|------------------------|--------------|--------------------|-------------|------------|
| CE7-132 | 4 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 4 | 14 | 4 | 0 | 318 | 0 | 29 | 45 | 12 | 3 | 1 | 0 | 0 | 0 | 0 | 0 |
| CE7-292 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 4 | 0 | 311 | 0 | 28 | 60 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| CE7-445 | 3 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 10 | 2 | 0 | 318 | 1 | 24 | 53 | 10 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE7-465 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 359 | 0 | 29 | 54 | 6 | 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE7-498 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 15 | 1 | 0 | 414 | 0 | 30 | 48 | 8 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE7-528 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 372 | 0 | 30 | 51 | 6 | 3 | 0 | 0 | 0 | 1 | 0 | 0 |
| CE7-602 | 6 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 1 | 12 | 0 | 0 | 313 | 0 | 33 | 43 | 7 | 11 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE7-629 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 286 | 0 | 45 | 36 | 13 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE7-640 | 6 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 5 | 14 | 2 | 0 | 425 | 0 | 22 | 47 | 12 | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE7-671 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 4 | 1 | 0 | 381 | 0 | 28 | 55 | 2 | 0 | 0 | 0 | 0 | 6 | 0 | 0 |
| CE7-693 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 373 | 0 | 21 | 64 | 0 | 0 | 1 | 0 | 0 | 7 | 0 | 0 |
| CE7-726 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 2 | 0 | 0 | 48 | 0 | 0 | 77 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| CE7-757 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 6 | 0 | 0 | 416 | 0 | 31 | 63 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| CE7-787 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 87 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE7-813 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 67 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE10-146 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 332 | 2 | 11 | 54 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE10-267 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 6 | 1 | 0 | 291 | 0 | 48 | 39 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE10-295 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 2 | 0 | 284 | 0 | 50 | 40 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE10-330 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 0 | 169 | 0 | 21 | 30 | 3 | 0 | 0 | 3 | 0 | 2 | 0 | 3 |
| CE10-368 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 10 | 1 | 0 | 313 | 0 | 25 | 50 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 2 |
| CE10-394 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 308 | 0 | 19 | 67 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| CE10-439 | 2 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 10 | 1 | 0 | 369 | 0 | 24 | 48 | 3 | 0 | 0 | 1 | 0 | 6 | 0 | 2 |
| CE10-483 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 9 | 1 | 0 | 341 | 0 | 24 | 48 | 1 | 0 | 1 | 2 | 1 | 6 | 0 | 2 |
| CE10-525 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 11 | 0 | 0 | 292 | 0 | 28 | 49 | 1 | 0 | 1 | 0 | 0 | 2 | 0 | 1 |
| CE10-561 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 0 | 1 | 307 | 0 | 24 | 54 | 1 | 0 | 0 | 1 | 0 | 2 | 0 | 0 |
| CE10-593 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 0 | 294 | 0 | 27 | 54 | 4 | 2 | 0 | 1 | 0 | 1 | 0 | 1 |
| CE10-625 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 4 | 0 | 0 | 315 | 0 | 21 | 28 | 1 | 0 | 0 | 33 | 0 | 3 | 0 | 4 |
| CE10-658 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 0 | 0 | 346 | 0 | 21 | 35 | 2 | 0 | 1 | 9 | 0 | 5 | 0 | 8 |
| CE10-688 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 1 | 0 | 344 | 0 | 17 | 33 | 0 | 1 | 0 | 19 | 0 | 1 | 0 | 10 |
| CE10-716 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 323 | 0 | 21 | 41 | 1 | 0 | 1 | 15 | 0 | 2 | 1 | 8 |
| CE10-753 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 6 | 3 | 0 | 327 | 0 | 40 | 49 | 5 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| CE10-793 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 7 | 1 | 0 | 313 | 0 | 33 | 50 | 6 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| CE10-826 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 2 | 0 | 284 | 0 | 42 | 44 | 4 | 2 | 0 | 0 | 0 | 1 | 0 | 0 |
| CE10-839 | 3 | 1 | 0 | 6 | 0 | 0 | 0 | 0 | 5 | 15 | 0 | 0 | 397 | 1 | 32 | 44 | 4 | 1 | 1 | 1 | 2 | 3 | 0 | 1 |
| CE10-876 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 7 | 1 | 0 | 345 | 0 | 32 | 46 | 3 | 1 | 2 | 0 | 0 | 3 | 1 | 0 |
| CE10-917 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 0 | 0 | 351 | 0 | 30 | 52 | 4 | 0 | 1 | 0 | 0 | 2 | 2 | 1 |
| CE10-950 | 4 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 14 | 0 | 0 | 330 | 0 | 24 | 55 | 2 | 1 | 0 | 2 | 1 | 1 | 1 | 2 |
| CE10-987 | 0 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 7 | 12 | 0 | 0 | 312 | 0 | 34 | 44 | 2 | 0 | 0 | 3 | 0 | 4 | 2 | 0 |
| CE101024 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 6 | 0 | 0 | 332 | 0 | 31 | 37 | 3 | 2 | 1 | 4 | 0 | 4 | 1 | 4 |
| CE101086 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 306 | 0 | 26 | 46 | 1 | 0 | 0 | 3 | 1 | 6 | 1 | 6 |

| Sample | %Elphidium spp. | %totalid fragments | %Nonionella atlantica | %Discorbis spp. | %Hanzawaia concentrica | %Palmerinella palmerae | %Buccella hannah | %Buliminella elegantissima | %Brizalina lowmani | %B. striatula | %Fissurina sp. | %total rare marine | %Quinqueloculina completa | %Q. seminulum | %Q. funafutiensis | %Q. lamarckiana | %Quinqueloculina spp. | %Massilina peruviana | %Triloculina oblonga | %Triloculina spp. | %miliolid fragments | %total miliolids | %reworked forams | %misc. |
|----------|-----------------|--------------------|-----------------------|-----------------|------------------------|------------------------|------------------|----------------------------|--------------------|---------------|----------------|--------------------|---------------------------|---------------|-------------------|-----------------|-----------------------|----------------------|----------------------|-------------------|---------------------|------------------|------------------|--------|
| CE7-132 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 4 | 1 | 0 | |
| CE7-292 | 0 | 4 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | |
| CE7-445 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 3 | 1 | 0 | |
| CE7-465 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | |
| CE7-498 | 1 | 2 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 0 | 0 | |
| CE7-528 | 0 | 5 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | |
| CE7-602 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | |
| CE7-629 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | |
| CE7-640 | 3 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | |
| CE7-671 | 0 | 4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | |
| CE7-693 | 0 | 5 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | |
| CE7-726 | 4 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 4 | 0 | 0 |
| CE7-757 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | |
| CE7-787 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| CE7-813 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| CE10-146 | 0 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| CE10-267 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | |
| CE10-295 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | |
| CE10-330 | 0 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 0 | |
| CE10-368 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 0 | |
| CE10-394 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | |
| CE10-439 | 0 | 10 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | |
| CE10-483 | 0 | 10 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | |
| CE10-525 | 0 | 11 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 0 | 0 | |
| CE10-561 | 0 | 15 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | |
| CE10-593 | 1 | 6 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | |
| CE10-625 | 0 | 6 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | |
| CE10-658 | 2 | 7 | 0 | 0 | 0 | 4 | 2 | 1 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | |
| CE10-688 | 0 | 4 | 0 | 0 | 0 | 8 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | |
| CE10-716 | 0 | 4 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | |
| CE10-753 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | |
| CE10-793 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | |
| CE10-826 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | |
| CE10-839 | 0 | 5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 4 | 0 | 0 | |
| CE10-876 | 1 | 6 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | |
| CE10-917 | 0 | 3 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | |
| CE10-950 | 0 | 3 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 3 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 0 | 0 | |
| CE10-987 | 0 | 4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 4 | 0 | 0 | |
| CE101024 | 0 | 7 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 2 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | |
| CE101086 | 0 | 4 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 1 | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | |

Sabine Lake Area cores
(CE10 CE7)

CORES.XLS

| Sample | total% |
|----------|--------|
| CE7-132 | 100 |
| CE7-292 | 100 |
| CE7-445 | 100 |
| CE7-465 | 100 |
| CE7-498 | 100 |
| CE7-528 | 100 |
| CE7-602 | 100 |
| CE7-629 | 100 |
| CE7-640 | 100 |
| CE7-671 | 100 |
| CE7-693 | 100 |
| CE7-726 | 100 |
| CE7-757 | 100 |
| CE7-787 | 100 |
| CE7-813 | 100 |
| CE10-146 | 100 |
| CE10-267 | 100 |
| CE10-295 | 100 |
| CE10-330 | 100 |
| CE10-368 | 100 |
| CE10-394 | 100 |
| CE10-439 | 100 |
| CE10-483 | 100 |
| CE10-525 | 100 |
| CE10-561 | 100 |
| CE10-593 | 100 |
| CE10-625 | 100 |
| CE10-658 | 100 |
| CE10-688 | 100 |
| CE10-716 | 100 |
| CE10-753 | 100 |
| CE10-793 | 100 |
| CE10-826 | 100 |
| CE10-839 | 100 |
| CE10-876 | 100 |
| CE10-917 | 100 |
| CE10-950 | 100 |
| CE10-987 | 100 |
| CE101024 | 100 |
| CE101086 | 100 |

Sabine Lake Area cores
(CE10 CE7)

CORES.XLS

| Sample | misc. agglutinated | A. parkinsoniana | E. gunteri | E. discoidale | E. mexicanum | E. matagordatum | E. sp cf matagordatum | E. poeyanum | E. sp cf poeyanum | E. kugleri | juveniles | Elphidium spp. | rotalid fragments | Nonionella atlantica | Discorbis spp. | Hanzawaia concentrica | Palmerinella palmerae | Buccella hannah | Buliminella elegantissima | Brizalina lowmani | B. striatula | Fissurina sp. | total rare marine |
|----------|--------------------|------------------|------------|---------------|--------------|-----------------|-----------------------|-------------|-------------------|------------|-----------|----------------|-------------------|----------------------|----------------|-----------------------|-----------------------|-----------------|---------------------------|-------------------|--------------|---------------|-------------------|
| CE101123 | 0 | 89 | 114 | 0 | 3 | 7 | 4 | 0 | 27 | 6 | 3 | 0 | 20 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 2 | 1 | 5 |
| CE101161 | 1 | 110 | 111 | 7 | 4 | 1 | 1 | 0 | 6 | 5 | 16 | 0 | 23 | 0 | 0 | 0 | 4 | 6 | 0 | 0 | 1 | 0 | 1 |
| CE101191 | 0 | 82 | 157 | 7 | 4 | 0 | 24 | 0 | 8 | 0 | 4 | 0 | 12 | 0 | 0 | 0 | 3 | 4 | 0 | 2 | 1 | 0 | 3 |
| CE101238 | 0 | 93 | 144 | 2 | 6 | 0 | 2 | 1 | 11 | 7 | 6 | 2 | 12 | 0 | 0 | 0 | 1 | 5 | 1 | 0 | 0 | 0 | 1 |
| CE101270 | 0 | 98 | 130 | 5 | 3 | 2 | 2 | 3 | 13 | 2 | 1 | 0 | 16 | 0 | 0 | 1 | 0 | 3 | 1 | 0 | 0 | 0 | 2 |
| CE101300 | 0 | 119 | 157 | 12 | 4 | 0 | 1 | 0 | 4 | 2 | 2 | 0 | 16 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 1 |
| CE101334 | 0 | 128 | 183 | 9 | 4 | 1 | 2 | 0 | 2 | 8 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 3 | 0 | 3 |
| CE101372 | 0 | 125 | 212 | 17 | 8 | 0 | 1 | 0 | 10 | 1 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 0 | 2 |
| CE101412 | 0 | 116 | 183 | 12 | 1 | 0 | 3 | 1 | 7 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 2 | 1 | 4 |
| CE101528 | 0 | 90 | 156 | 10 | 6 | 1 | 1 | 0 | 3 | 1 | 2 | 0 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| CE101650 | 0 | 185 | 124 | 4 | 0 | 0 | 3 | 0 | 4 | 0 | 5 | 0 | 13 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |

| Sample | Quinqueloculina compla | Q. seminulum | Q. funafutiensis | Q. lamarckiana | Quinqueloculina spp. | Massilina peruviana | Triloculina oblonga | Triloculina spp. | miliolid fragments | total miliolids | reworked forams | misc. | total forams | %misc. agglutinated | %A. parkinsoniana | %E. gunteri | %E. discoidale | %E. mexicanum | %E. matagordanum | %E. sp cf matagordanum | %E. poeyanum | %E. sp cf poeyanum | %E. kugleri | %juveniles |
|----------|------------------------|--------------|------------------|----------------|----------------------|---------------------|---------------------|------------------|--------------------|-----------------|-----------------|-------|--------------|---------------------|-------------------|-------------|----------------|---------------|------------------|------------------------|--------------|--------------------|-------------|------------|
| CE101123 | 1 | 5 | 0 | 2 | 0 | 0 | 0 | 0 | 4 | 12 | 0 | 1 | 292 | 0 | 30 | 39 | 0 | 1 | 2 | 1 | 0 | 9 | 2 | 1 |
| CE101161 | 1 | 2 | 0 | 3 | 0 | 0 | 0 | 0 | 7 | 13 | 0 | 0 | 309 | 0 | 36 | 36 | 2 | 1 | 0 | 0 | 0 | 2 | 2 | 5 |
| CE101191 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 12 | 0 | 0 | 320 | 0 | 26 | 49 | 2 | 1 | 0 | 8 | 0 | 3 | 0 | 1 |
| CE101238 | 1 | 5 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 10 | 0 | 0 | 303 | 0 | 31 | 48 | 1 | 2 | 0 | 1 | 0 | 4 | 2 | 2 |
| CE101270 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 15 | 1 | 0 | 296 | 0 | 33 | 44 | 2 | 1 | 1 | 1 | 1 | 4 | 1 | 0 |
| CE101300 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 11 | 0 | 0 | 331 | 0 | 36 | 47 | 4 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| CE101334 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 0 | 0 | 361 | 0 | 35 | 51 | 2 | 1 | 0 | 1 | 0 | 1 | 2 | 0 |
| CE101372 | 2 | 3 | 3 | 2 | 0 | 0 | 0 | 0 | 7 | 17 | 0 | 0 | 411 | 0 | 30 | 52 | 4 | 2 | 0 | 0 | 0 | 2 | 0 | 0 |
| CE101412 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 350 | 0 | 33 | 52 | 3 | 0 | 0 | 1 | 0 | 2 | 0 | 0 |
| CE101528 | 2 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 8 | 0 | 0 | 304 | 0 | 30 | 51 | 3 | 2 | 0 | 0 | 0 | 1 | 0 | 1 |
| CE101650 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 342 | 0 | 54 | 36 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 |

| Sample | %Elphidium spp. | %totalid fragments | %Nonionella atlantica | %Discorbis spp. | %Hanzawaia concentrica | %Palmerinella palmerae | %Buccella hannah | %Buliminella elegantissima | %Brizalina lowmani | %B. striatula | %Fissurina sp. | %total rare marine | %Quinqueloculina compta | %Q. seminulum | %Q. funafutiensis | %Q. lamarckiana | %Quinqueiocolina spp. | %Massilina peruviana | %Triloculina oblonga | %Triloculina spp. | %miliolid fragments | %total miliolids | %reworked forams | %misc. |
|----------|-----------------|--------------------|-----------------------|-----------------|------------------------|------------------------|------------------|----------------------------|--------------------|---------------|----------------|--------------------|-------------------------|---------------|-------------------|-----------------|-----------------------|----------------------|----------------------|-------------------|---------------------|------------------|------------------|--------|
| CE101123 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 4 | 0 | 0 |
| CE101161 | 0 | 7 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 4 | 0 | 0 |
| CE101191 | 0 | 4 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 0 | 0 |
| CE101238 | 1 | 4 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 |
| CE101270 | 0 | 5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 0 | 0 |
| CE101300 | 0 | 5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 | 0 |
| CE101334 | 0 | 4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| CE101372 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 0 | 0 |
| CE101412 | 0 | 6 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CE101528 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 |
| CE101650 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |

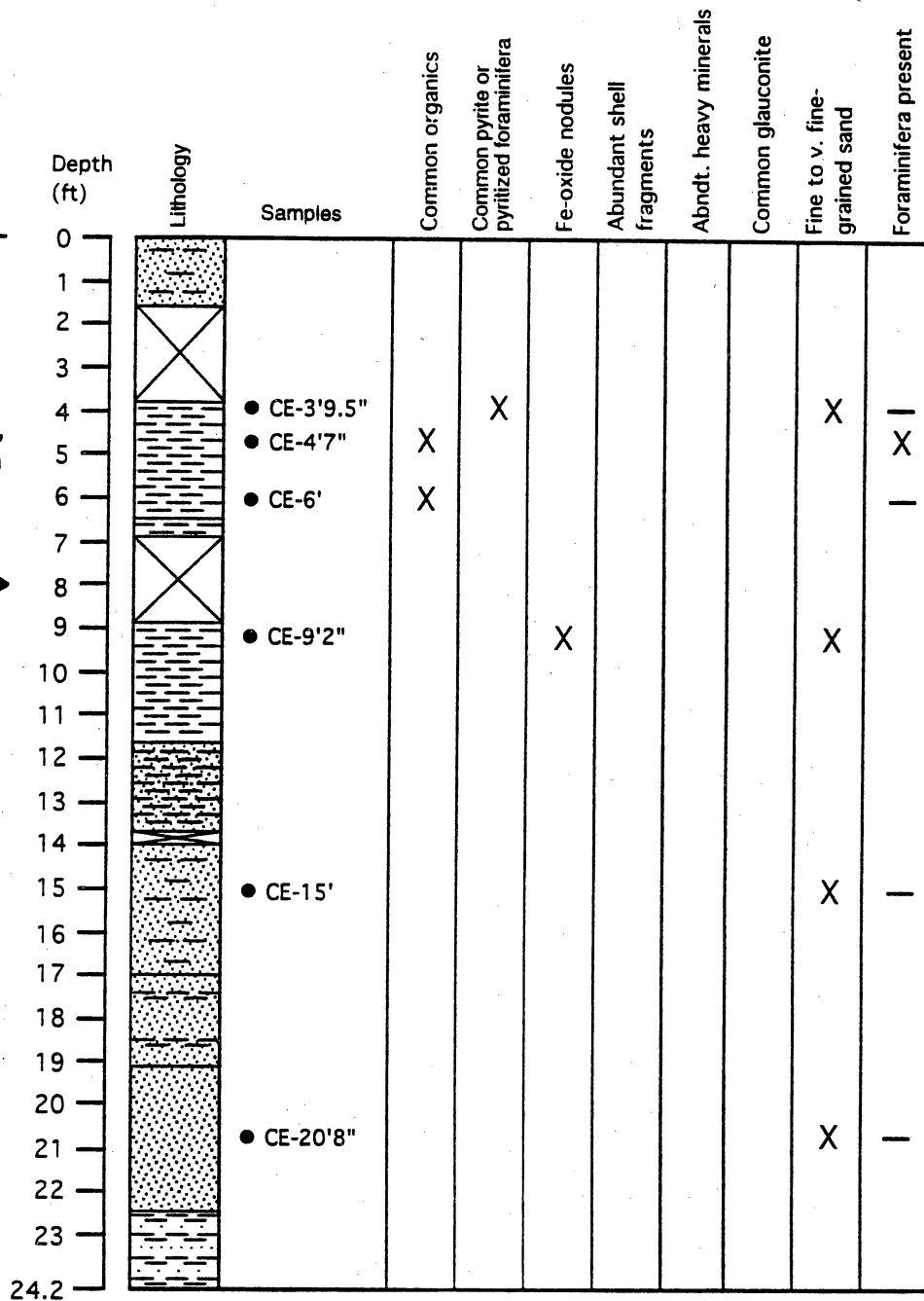
COASTAL EROSION PROJECT, CORE CE-2

PRELIMINARY PALEOENVIRONMENTAL INTERPRETATION:

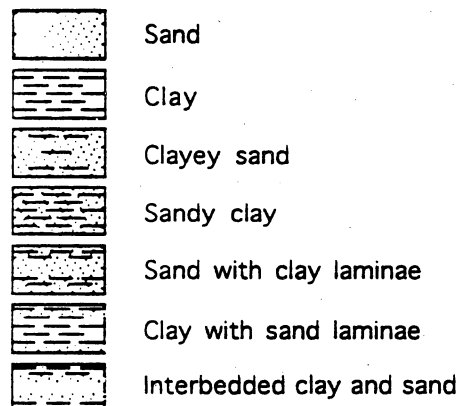
Fill

2- low organic content
Marsh- abundant organics,
very low # of ♂(3); fresh
to brackish marsh?

H/P →



X Applies to sample
— Barren of foraminifera



COASTAL EROSION PROJECT, CORE CE-4

PRELIMINARY PALEOENVIRONMENTAL INTERPRETATION

Strandplain flat/
beach ridge-
46 ♂ in the sample
(gulf assemblage);
abndt. shell fragments.

Marsh- but low organic
content and no ♂ (except
one reworked); fresh to
brackish, with periodic
exposure.






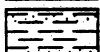

Sample CE-12'7
has 1 ♂ - reworked;
other ♂ either not
present or were agglut.

Samples in this section
have frequent / common
yellow -colored qtz
sand grains and Fe-oxide
grains.

→ H/P →

| Depth (ft) | Lithology | Samples | Common organics | Common pyrite or pyritized foraminifera | Fe-oxide nodules | Abundant shell fragments | Abndt. heavy minerals | Common glauconite | Fine to v. fine- grained sand | Foraminifera present |
|---------------|-----------|--------------|-----------------|--|------------------|-----------------------------|-----------------------|-------------------|----------------------------------|----------------------|
| 0 | | ● CE4 -8" | | | | X | X | | | X |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | ● CE-4'6" | | | | | | | X | — |
| 5 | | ● CE-5'7" | | | X | | | | X | — |
| 6 | | ● CE-6'9" | | | | | | | X | — |
| 7 | | ● CE-7'11" | | | X | | X | | X | — |
| 8 | | ● CE-9'10.5 | | | X | | | | X | — |
| 9 | | ● CE-11'1.5" | X | | | | | | X | — |
| 10 | | ● CE-12'7" | | | X | | | | X | X |
| 11 | | ● CE-14'9.5" | | | | | | | X | — |
| 12 | | ● CE-16' | | | X | | | | X | — |
| 13 | | ● CE-18' | | | X | | | | X | — |
| 14 | | | | | | | | | | |
| 15 | | | | | | | | | | |
| 16 | | | | | | | | | | |
| 17 | | | | | | | | | | |
| 18 | | | | | | | | | | |
| 18.85 | | | | | | | | | | |

X Applies to sample
— Barren of foraminifera

| | |
|---|---------------------------|
|  | Sand |
|  | Clay |
|  | Clayey sand |
|  | Sandy clay |
|  | Sand with clay laminae |
|  | Clay with sand laminae |
|  | Interbedded clay and sand |

COASTAL EROSION PROJECT, CORE CE-6

PRELIMINARY PALEOENVIRONMENTAL INTERPRETATION:

Beach-
Sample has only 5 \odot :
4 *E. gunteri* and 1 *Ammonia*.

Marsh- brackish to fresh;
sample has 52 \odot - *E. gunteri* +
Ammonia, no gulf taxa.

Moderate to high organic
content, Fe-oxide, yellow-
colored qtz sand grains, root
traces. Rare to no \odot .

H/P →

Sample CE6-13' has one
reworked \odot .

| Depth (ft) | Lithology | Samples | Common organics | Common pyrite or pyritized foraminifera | Fe-oxide nodules | Abundant shell fragments | Abndt. heavy minerals | Common glauconite | Fine to v. fine- grained sand | Foraminifera present |
|---------------|-----------|---------------|-----------------|--|------------------|-----------------------------|-----------------------|-------------------|----------------------------------|----------------------|
| 0 | | | | | | | | | | |
| 1 | | ● CE6-1' | | | | | | | X | X |
| 2 | | ● CE6-2'4" | X | | X | | X | | X | X |
| 3 | | | | | | | | | | |
| 4 | | ● CE6-4'2" | X | | X | | | | X | — |
| 5 | | | | | | | | | | |
| 6 | | | | | | | | | | |
| 7 | | | | | | | | | | |
| 8 | | ● CE6-8'6" | X | | | | | | X | — |
| 9 | | ● CE6-9'8" | X | | | | | | X | — |
| 10 | | ● CE6-10'7" | X | | X | | | | X | — |
| 11 | | ● CE6-11'5" | X | | X | | | | X | — |
| 12 | | | | | | | | | | |
| 13 | | ● CE6-13' | X | | | | | | X | X |
| 14 | | | | | | | | | | |
| 15 | | | | | | | | | | |
| 16 | | | | | | | | | | |
| 17 | | | | | | | | | | |
| 18 | | | | | | | | | | |
| 19 | | | | | | | | | | |
| 20 | | ● CE6-19'8.5" | | | | | | | X | — |



Sand



Clay



Clayey sand



Sandy clay



Sand with clay laminae

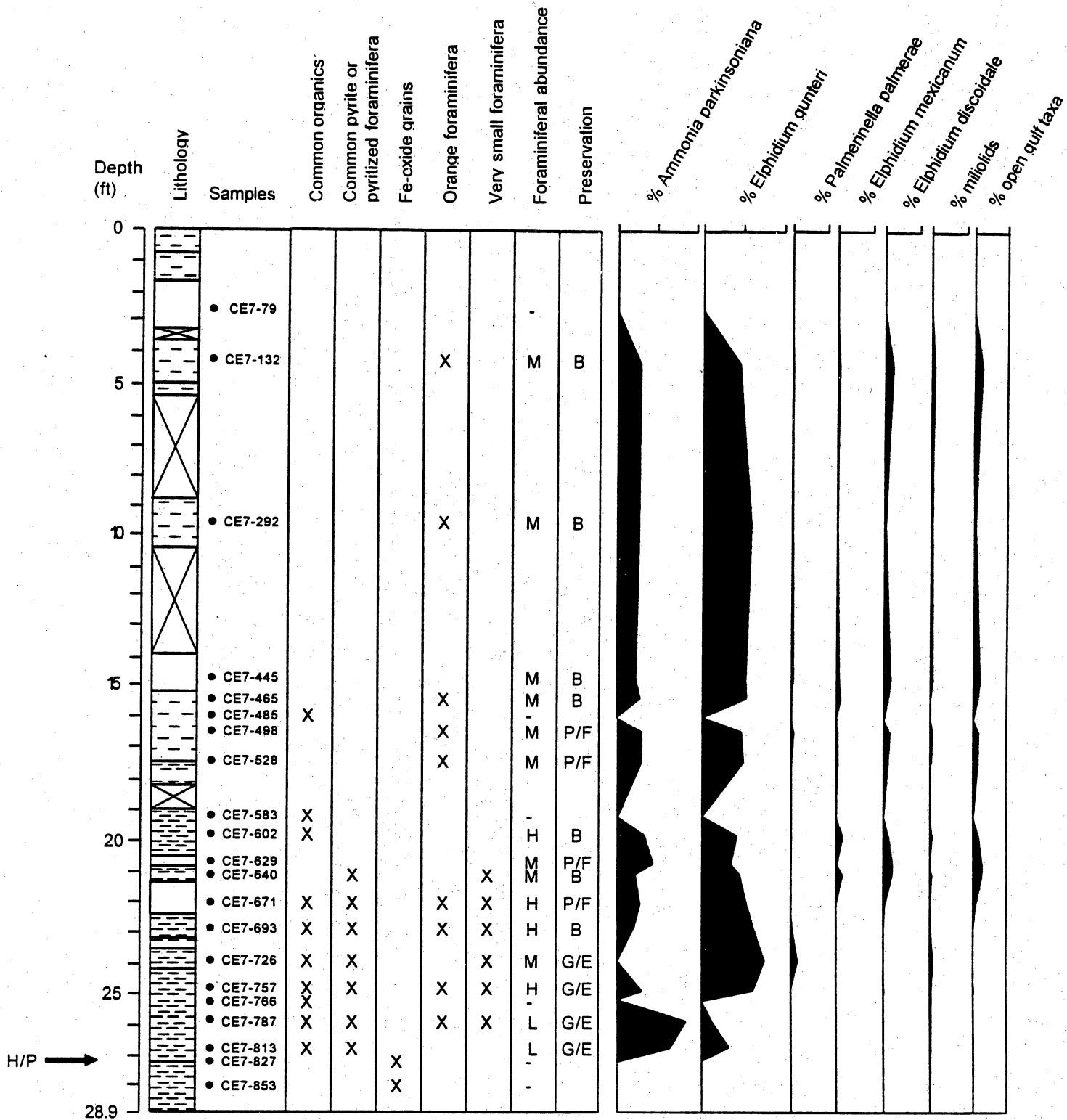


Clay with sand laminae



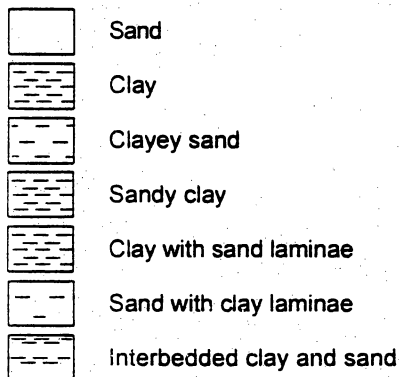
Interbedded clay and sand

COASTAL EROSION PROJECT, CORE 7



X = applies to sample
-- = barren of foraminifera
L = low
M = moderate
H = high
P/F = poor or fair
G/E = good or excellent
B = bimodal

All foraminiferal abundance graphs use the same scale.



| SAMPLE | DEPTH (ft/in) | COMMENTS | ENVIRONMENT |
|----------|---------------|--|-------------------|
| CE10-36 | 2'2" | Barren of all biotics except shell fragments. | [beach/chenier] |
| CE10-99 | 3'3" | " | " |
| CE10-125 | 4'1" | " | " |
| CE10-146 | 4'9.5" | Very poor preservation except 5 agglutinated forams. Mixed gulf and marsh taxa; probably indicates washover of wave-reworked gulf into marsh or mudflat. Or, could be marsh forms transported into nearshore gulf. | marsh/mudflat |
| CE10-267 | 8'9" | Appear reworked, except 1 agglutinated foram; Evidence of fluvial influence (Cretaceous foram and radiolarian due to erosion of upstream deposits). | " |
| CE10-295 | 9'8" | Orange, small, poorly preserved. | " |
| CE10-330 | 10'10" | " w/ many forams pyritized | " |
| CE10-368 | 12'1" | Very poor preservation and low abundance; 1 charophyte. Still mix of gulf fauna and fluvial indicators. | " |
| CE10-394 | 12'11" | Low to moderate diversity, but several "rare" gulf taxa. Orange w/ some very small forams. | " |
| CE10-439 | 14'5" | Very diverse, gulf assemblage but w/ strong fluvial influence (17 Cretaceous radiolarians plus one Cret. planktic foram). | gulf |
| CE10-483 | 15'10" | Small, sparse but quite diverse assemblage. Orange. | " |
| CE10-522 | 17'1.5" | Barren of all biotics. Possibly missing sandier of two samples? | [marsh?] |
| CE10-525 | 17'2.5" | Moderate diversity assemblage w/ a few gulf taxa. This could be the second sample (see CE10-522). | gulf |
| CE10-561 | 18'5" | Poor preservation. Reworked gulf or lower bay assemblage. Ten radiolarians. | gulf or lower bay |
| CE10-593 | 19'5.5" | Reworked, low diversity bay assemblage w/ 12 Cretaceous forms. <u>Very sparse</u> . Appears to be washover of well-worn bay fauna into non-marine environment (marsh, etc.). | marsh? |
| CE10-625 | 20'6" | High diversity. Small forams and many E. sp. cf. matagordanum. Reworked component in otherwise well preserved assemblage. | lower bay or gulf |

| | | | |
|----------|---------|--|--------------------|
| CE10-658 | 21'7" | Probably stressed gulf environ. | |
| CE10-688 | 22'7" | As above, but w/-out the reworked component. | " |
| CE10-716 | 23'6" | " | " |
| CE10-753 | 24'8.5" | Mod. to low diversity, low abundance. Fair preservation w/ some indication of reworking or high energy. Bay or "beach" assemblage. | bay or beach/inlet |
| CE10-793 | 26' | " | " |
| CE10-826 | 27'1" | " | " |
| CE10-839 | 27'6.5" | Moderate diversity, gulf assemblage, but w/ no "rare" gulf spp. | lower bay / gulf |
| CE10-876 | 28'9" | High diversity, gulf assemblage, but w/ no "rare" gulf spp. Good preservation. | " |
| CE10-917 | 30'1" | " | " |
| CE10-950 | 31'4" | Very high diversity (19). Several rare gulf spp. | gulf |
| CE10-987 | 32'4.5" | High diversity. Orange. | " |
| CE101024 | 33'7" | " | " |
| CE101086 | 35'7.5" | As above, but w/ many juveniles. Orange, but good preservation. Must be below wave-base. | " |
| CE101123 | 36'10" | " | " |
| CE101161 | 38'1" | High diversity. No rare gulf. One Ammotium. | lower bay / gulf |
| CE101191 | 39'1" | As above, but no agglut. | " |
| CE101238 | 40'7.5" | " | " |
| CE101270 | 41'8" | " | " |
| CE101300 | 42'8" | Bay assemblage plus a few miliolids. Mod. diversity. | bay |
| CE101334 | 43'9" | Bay assemblage. Sample has coarse fraction- bivalves. | bay |
| CE101372 | 45' | Bay assemblage plus oysters. | bay |
| CE101412 | 46'4" | Bay assemblage plus large bivalves (coarse fraction). | bay |
| CE101528 | 50'1.5" | Bay assemblage. | bay |
| CE101565 | 51'4" | Bay assemblage but no echinoids or bryozoans. Low abundance (< 100 forams picked). This suggests low marsh (washover of forams into nearby marshy area). | low marsh |

| | | | |
|----------|---------|--|---------------------------|
| CE101605 | 52'8" | As above, w/ common, pyritized diatoms. Very few forams. | " |
| CE101650 | 54'1.5" | Abundant, small forams. Very low diversity. Ammonia > Elphidium. Brackish assemblage w/ little gulf influence. Low abundance. | brackish bay or low marsh |
| CE101690 | 55'5.5" | Barren of all biotics. Woody debris and absence of forams suggest brackish to fresh marsh. | " |
| CE101728 | 56'8.5" | Very few forams (~3). "Sandy" looking grains, very roughly resemble foram shapes. Could be gypsum-coated forams as mentioned in the Galveston Bay book. Need to see slide again. | [marsh] |
| CE101836 | 60'3" | " | marsh (low salinity) |
| CE101872 | 61'5" | Barren of forams. Frequent diatoms. | " |
| CE101905 | 62'6" | As above but rare diatoms. | " |
| CE101939 | 63'7.5" | Less than 20 forams. | " |
| CE101988 | 65'2.5" | One Ammonia parkinsoniana. Frequent diatoms | " |
| CE102031 | 66'7.5" | Barren of all biotics. | " |
| CE102066 | 67'9.5" | " | - |
| CE102093 | 68'8" | " | - |
| CE102126 | 69'9" | " | - |
| CE102159 | 70'10" | " | - |
| CE102210 | 72'6" | " | - |

Note: samples with environmental interpretations given in [] are barren of foraminifera and other biotics; Interpretations of these samples are based only on lithology. Otherwise, interpretations given are based on fauna (taxa- forams and other; abundance; diversity; and preservation). Also, lower bay assemblage is very difficult to distinguish from "gulf" (due to proximity); Brackish marsh and brackish lake also have similar assemblages, as do saline marsh (low marsh) and tidal mudflat.

***** DENDROGRAM *****

DERIVED FROM COSINE THETA

Input file: coresb.txt (covers BEG Coastal Erosion cores CE7 & CE10).

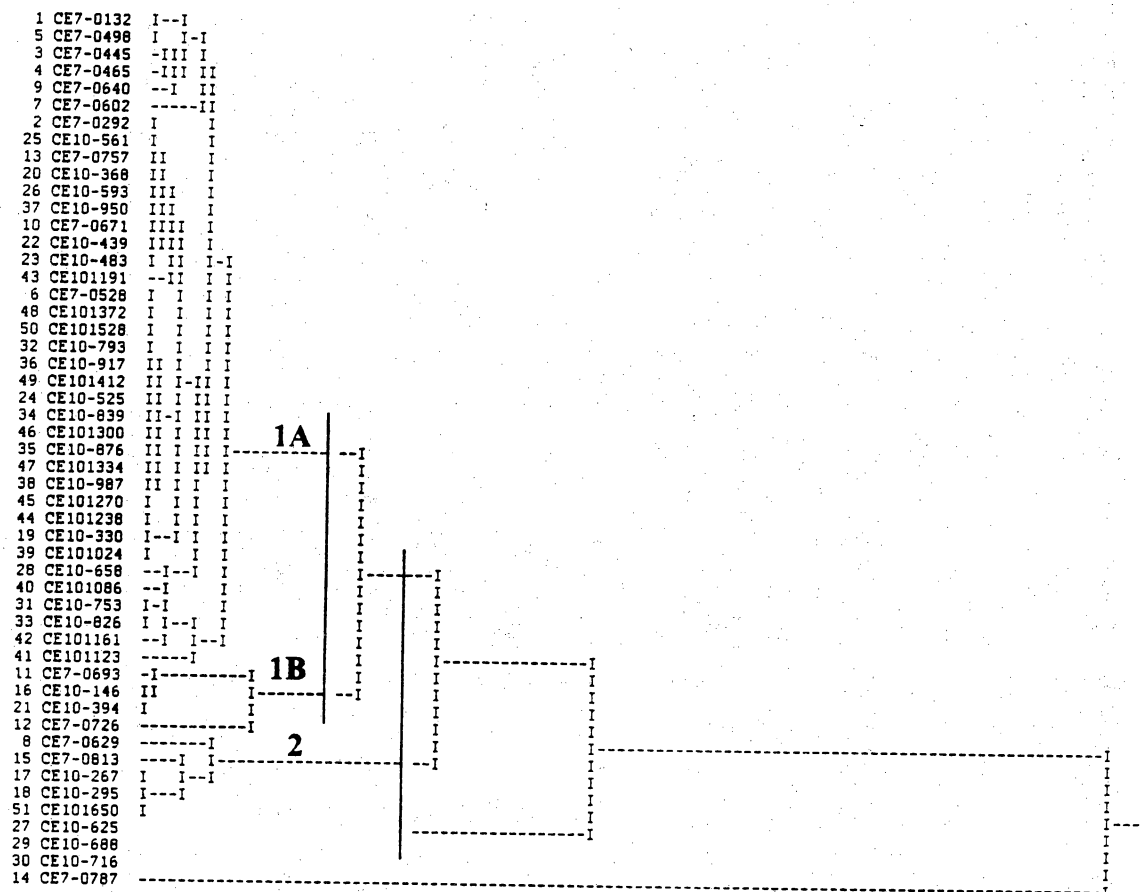
Variables: *Ammonia parkinsoniana*; *Elphidium gunteri*; *E. discoidale*; *E. mexicanum*; *E. sp. cf. matagordanum*; *E. sp. cf. poeyanum*; juveniles (rotalids); *Palmerinella palmerae*; *Buccella hannai*; gulf taxa; total miliolids.

The "total miliolid" category includes: *Quinqueloculina compta*, *Q. seminulum*, *Q. funafutiensis*, *Q. lamarckiana*, *Quinqueloculina* spp., *Massilina peruviana*, *Triloculina oblonga*, *Triloculina* spp., misc. miliolids, and miliolid fragments. *Buliminella elegantissima*, *Brizalina lowmani*, *Brizalina stiatula*, *Fissurina* sp., *Nonionella atlantica*, *Discorbis* spp., and *Hanzawaia concentrica* are lumped in the "gulf taxa" category. Species with mean abundance < 1%, besides those in the "gulf taxa" or "miliolids" categories, are excluded from this run. All core samples containing foraminifera are included in this run.

NUMBER OF INDIVIDUALS = 51

NUMBER OF VARIABLES = 11

COPHENETIC CORRELATION COEFFICIENT = .805969



***** DENDROGRAM *****

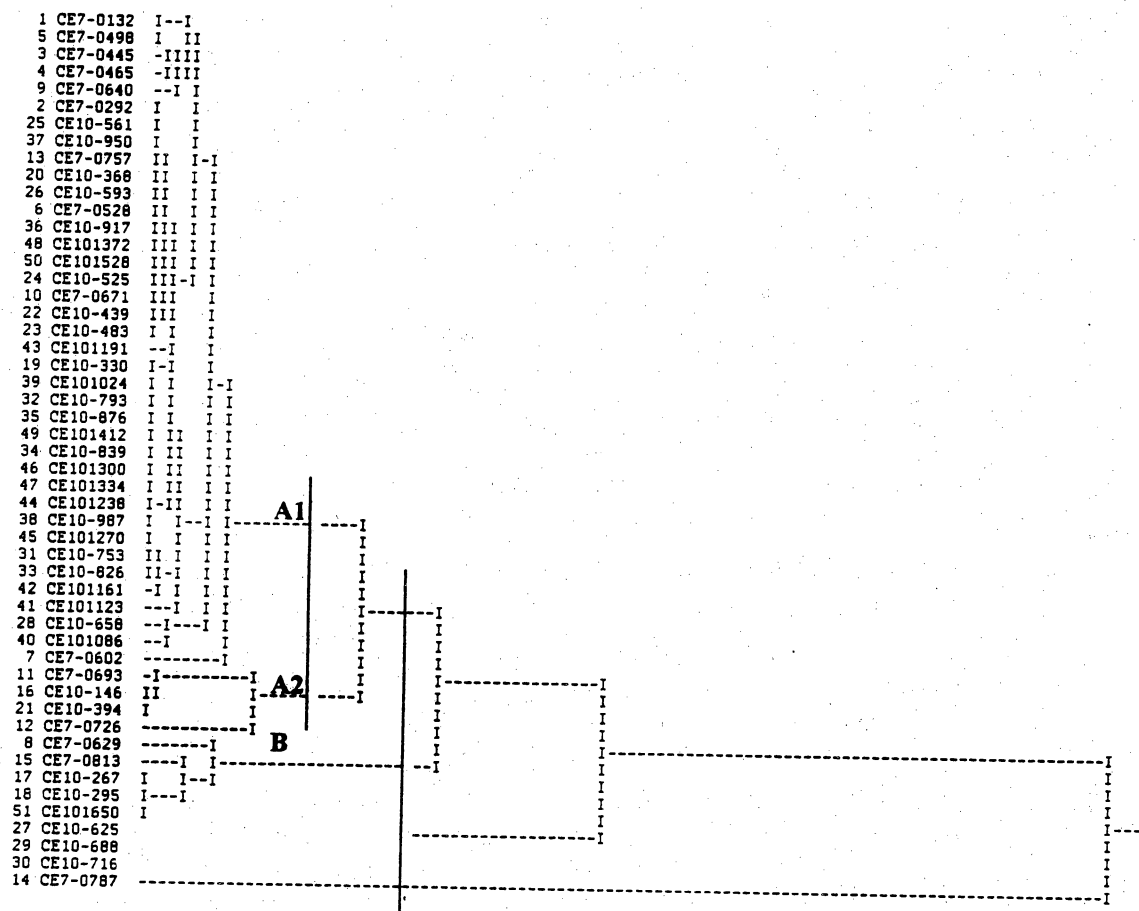
DERIVED FROM COSINE THETA

Input file: coresa.txt (covers BEG Coastal Erosion cores CE7 & CE10). Excludes variables w/ mean abundance < 1%. All core samples containing foraminifera are included in this run.

Variables:

Ammonia parkinsoniana; *Elphidium gunteri*; *E. discoidale*; *E. mexicanum*; *E. sp. cf. matagordanum*; *E. sp. cf. poeyanum*; juveniles (rotalids); *Palmerinella palmerae*; *Buccella hannah*; *Quinqueloculina seminulum*.

NUMBER OF INDIVIDUALS = 51 NUMBER OF VARIABLES = 10
COPHENETIC CORRELATION COEFFICIENT = .805319



Comparison of Biofacies and Cluster Groups

Order: Compiled Biofacies / Sabine Lake Biofacies

I. Marsh #2 / Tidal-Mudflat / Agglutinated #1

Agglutinated spp., *Ammonia*, *E. gunteri* [*E. poeyanum*, *Palmerinella palmerae*]

Cluster Groups: B and 2

II. Marsh #3 / Brackish / Agglutinated #2

Agglutinated spp., *Ammonia*, *E. gunteri*, *E. discoidale*, *E. poeyanum*, *E. matagordanum*, *P. palmerae*

Cluster Groups: A2 and 1B

III. Middle Bay / Ammonia-Elphidium

Ammonia, *E. gunteri*, *E. discoidale*, *E. poeyanum*, *E. matagordanum*, *Ephidium* spp., *P. palmerae*, *Brizalina* spp., *B. elegantissima*, miliolids (mostly *Q. seminulum*, *Q. compta*, *Q. rhodiensis*), [*E. kugleri*, *Buccella hannai*]

Cluster Groups: C and 3

IV. Lower Bay-Bay Mouth / Beach-Tidal Inlet / Shoreface-Gulf / Miliolid

Ammonia, *E. gunteri*, *E. discoidale*, *E. poeyanum*, *E. matagordanum*, *Ephidium* spp., *Brizalina* spp., *B. elegantissima*, *Buccella hannai*, miliolids (*Q. lamarckiana*, *Q. compta*, *Q. seminulum*, *Q. funafutiensis*, etc.), [*E. mexicanum*, *Hanzawaia*, *Discorbis*, *Nonionella atlantica*, *Fissurina* sp.]

Cluster Groups: A1 and 1A

Addendum 5. Radiocarbon Analysis Report

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8398

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. Nature of sample: Wood fragments and clay
2. Submitter's catalogue number: BEG SLV-1 13.85-15.0
3. Name and number of site: Sabine Lake vibracore
4. Descriptive location of site:
Mouth of Sabine River, East Pass of the Sabine delta
5. Latitude: 29°59.50'N Longitude: 093°45.92'W

Country: USA State/Province: Texas County: Jefferson
6. Provenience of sample within site:
Ca. 13.27-14.02 m below sea level
7. Collector and date: R. Morton, 7 Oct 1994
8. Context:
Sample came from Holocene deposits
9. Previous radiocarbon dates:
None
10. Variables affecting validity of date:
Burrowing, sediment reworking
11. Significance of sample:
Determine age of Sabine delta
12. Estimated sample age: < 15,000 BP

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8398

Run Number: II-581

Run Date: 08-23-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG SLV-1 13.85-15.0

Site name: Sabine Lake vibracore

Sample type: Wood

Submitter's age estimate: < 15,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters
Total counting time: 5644 minutes Total counts: 49261
 $\delta^{13}\text{C}$ determination: -26.9‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{8.728 \pm 0.039 - 6.081 \pm 0.034}{0.678} = 3.904 \pm 0.076 \text{ c.p.m./gram C} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{3.904 \pm 0.076}{9.341 \pm 0.024} = 41.794 \pm 0.37\%$$

$$\begin{aligned} \text{Age} &= 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2} \\ &= 8033 \ln \frac{9.341}{3.904} \pm 8033 \left[\left[\frac{0.024}{9.341} \right]^2 + \left[\frac{0.076}{3.904} \right]^2 \right]^{1/2} \\ &= 7008 \pm 158 \text{ years B.P. (rounded to nearest 10: } 7010 \pm 160) \end{aligned}$$

$$\delta^{14}\text{C} = -582.1 \pm 3.7\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 3.919 \pm 0.076 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 41.955 \pm 0.373\%$$

$$\text{Age} = 6977 \pm 157 \text{ years B.P. (rounded to nearest 10: } 6980 \pm 160)$$

$$\delta^{14}\text{C} = -580.5 \pm 3.7\text{‰}$$

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8399

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. Nature of sample: Peat
2. Submitter's catalogue number: BEG SLV-5 11.2-11.4
3. Name and number of site: Sabine Lake vibracore
4. Descriptive location of site:
Mouth of Sabine River, East Pass of the Sabine delta
5. Latitude: 29°59.50'N Longitude: 093°45.92'W
Country: USA State/Province: Texas County: Jefferson
6. Provenience of sample within site:
Ca. 7.98-8.04 m below sea level
7. Collector and date: R. Morton, 8 Oct 1994
8. Context:
Sample came from Holocene deposits
9. Previous radiocarbon dates:
None
10. Variables affecting validity of date:
Burrowing, sediment reworking
11. Significance of sample:
Determine age of Sabine delta
12. Estimated sample age: < 15,000 BP

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8399

Run Number: 1570

Run Date: 08-23-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG SLV-5 11.2-11.4

Site name: Sabine Lake vibracore

Sample type: Peat

Submitter's age estimate: < 15,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters

Total counting time: 5500 minutes

Total counts: 63351

$\delta^{13}\text{C}$ determination: -27.3‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{11.518 \pm 0.046 - 5.841 \pm 0.033}{1.826} = 3.109 \pm 0.031 \text{ c.p.m./gram} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{3.109 \pm 0.031}{7.220 \pm 0.021} = 43.061 \pm 0.18\%$$

$$\text{Age} = 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2}$$

$$= 8033 \ln \frac{7.220}{3.109} \pm 8033 \left[\left[\frac{0.021}{7.220} \right]^2 + \left[\frac{0.031}{3.109} \right]^2 \right]^{1/2}$$

$$= 6768 \pm 83 \text{ years B.P. (rounded to nearest 10: } 6770 \pm 80)$$

$$\delta^{14}\text{C} = -569.4 \pm 1.8\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 3.123 \pm 0.031 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 43.255 \pm 0.180\%$$

$$\text{Age} = 6732 \pm 83 \text{ years B.P. (rounded to nearest 10: } 6730 \pm 80)$$

$$\delta^{14}\text{C} = -567.5 \pm 1.8\text{‰}$$

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8400

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. **Nature of sample:** Organic mud and peat
2. **Submitter's catalogue number:** BEG CE-6 10.3-11.0
3. **Name and number of site:** Auger core
4. **Descriptive location of site:**
Beach at Sea Rim State Park
5. **Latitude:** 29°40'02"N **Longitude:** 094°04'23"W
Country: USA **State/Province:** Texas **County:** Jefferson
6. **Provenience of sample within site:**
Ca. 1.91-2.13 m below sea level
7. **Collector and date:** R. Morton, 4 Jun 1993
8. **Context:**
Sample came from Holocene deposits
9. **Previous radiocarbon dates:**
None
10. **Variables affecting validity of date:**
Burrowing, sediment reworking
11. **Significance of sample:**
Determine time of coastal plain aggradation
12. **Estimated sample age:** < 10,000 BP

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8400

Run Number: 1577

Run Date: 09-08-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG CE-6 10.3-11.0

Site name: Auger core

Sample type: Organic matter

Submitter's age estimate: < 10,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters

Total counting time: 3900 minutes

Total counts: 47130

$\delta^{13}\text{C}$ determination: -18.0‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{12.085 \pm 0.056 - 5.867 \pm 0.033}{1.400} = 4.441 \pm 0.046 \text{ c.p.m./gram} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{4.441 \pm 0.046}{7.229 \pm 0.021} = 61.433 \pm 0.25\%$$

$$\text{Age} = 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2}$$

$$= 8033 \ln \frac{7.229}{4.441} \pm 8033 \left[\left[\frac{0.021}{7.229} \right]^2 + \left[\frac{0.046}{4.441} \right]^2 \right]^{1/2}$$

$$= 3914 \pm 86 \text{ years B.P. (rounded to nearest 10: } 3910 \pm 90)$$

$$\delta^{14}\text{C} = -385.7 \pm 2.6\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 4.379 \pm 0.046 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 60.575 \pm 0.252\%$$

$$\text{Age} = 4027 \pm 88 \text{ years B.P. (rounded to nearest 10: } 4030 \pm 90)$$

$$\delta^{14}\text{C} = -394.2 \pm 2.5\text{‰}$$

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8401

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. **Nature of sample:** Shell fragments
2. **Submitter's catalogue number:** BEG CE-8 10.9-11.3
3. **Name and number of site:** Auger core
4. **Descriptive location of site:**
3.2 km W of Sabine Pass, Highway 87
5. **Latitude:** 29°42'47"N **Longitude:** 093°54'45"W

Country: USA **State/Province:** Texas **County:** Jefferson
6. **Provenience of sample within site:**
Ca. 1.18-1.31 m below sea level
7. **Collector and date:** R. Morton, 4 Jun 1993
8. **Context:**
Sample came from Holocene deposits
9. **Previous radiocarbon dates:**
See Gould & McFarlan, 1959, GCAGS, v. 9
10. **Variables affecting validity of date:**
Burrowing, sediment reworking
11. **Significance of sample:**
Determine time of beach ridge progradation
12. **Estimated sample age:** < 10,000 BP

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8401

Run Number: II-583

Run Date: 08-29-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG CE-8 10.9-11.3

Site name: Auger core

Sample type: Shell

Submitter's age estimate: < 10,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters

Total counting time: 2767 minutes

Total counts: 43636

$\delta^{13}\text{C}$ determination: -0.8‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{15.770 \pm 0.075 - 6.123 \pm 0.033}{1.465} = 6.585 \pm 0.056 \text{ c.p.m./gram} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{6.585 \pm 0.056}{9.350 \pm 0.024} = 70.428 \pm 0.43$$

$$\text{Age} = 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2}$$

$$= 8033 \ln \frac{9.350}{6.585} \pm 8033 \left[\left[\frac{0.024}{9.350} \right]^2 + \left[\frac{0.056}{6.585} \right]^2 \right]^{1/2}$$

$$= 2816 \pm 71 \text{ years B.P. (rounded to nearest 10: } 2820 \pm 70)$$

$$\delta^{14}\text{C} = -295.7 \pm 4.3\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 6.266 \pm 0.056 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 67.016 \pm 0.417\%$$

$$\text{Age} = 3215 \pm 75 \text{ years B.P. (rounded to nearest 10: } 3220 \pm 80)$$

$$\delta^{14}\text{C} = -329.8 \pm 4.2\text{‰}$$

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8402

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. Nature of sample: Shell fragments (oysters, ⁹^Mulinia^)
2. Submitter's catalogue number: BEG CE-~~8~~⁹ 29.2-29.3
3. Name and number of site: Auger core
4. Descriptive location of site:
Sabine Pass State Park
5. Latitude: 29°43'58"N Longitude: 093°52'34"W

Country: USA State/Province: Texas County: Jefferson
6. Provenience of sample within site:
Ca. 7.07-7.10 m below sea level
7. Collector and date: R. Morton, 4 Jun 1993
8. Context:
Sample came from Holocene valley fill
9. Previous radiocarbon dates:
None
10. Variables affecting validity of date:
Burrowing, sediment reworking
11. Significance of sample:
Determine age of Holocene fill
12. Estimated sample age: < 10,000 BP

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8402

Run Number: II-587

Run Date: 09-06-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG CE-8 29.2-29.3

Site name: Auger core

Sample type: Shell

Submitter's age estimate: < 10,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters

Total counting time: 2804 minutes

Total counts: 53321

$\delta^{13}\text{C}$ determination: -1.6‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{19.016 \pm 0.082 - 6.210 \pm 0.034}{2.411} = 5.311 \pm 0.037 \text{ c.p.m./gram C} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{5.311 \pm 0.037}{9.328 \pm 0.024} = 56.936 \pm 0.29\%$$

$$\text{Age} = 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2}$$

$$= 8033 \ln \frac{9.328}{5.311} \pm 8033 \left[\left[\frac{0.024}{9.328} \right]^2 + \left[\frac{0.037}{5.311} \right]^2 \right]^{1/2}$$

$$= 4525 \pm 60 \text{ years B.P. (rounded to nearest 10: } 4530 \pm 60)$$

$$\delta^{14}\text{C} = -430.6 \pm 3.0\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 5.062 \pm 0.037 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 54.267 \pm 0.292\%$$

$$\text{Age} = 4910 \pm 62 \text{ years B.P. (rounded to nearest 10: } 4910 \pm 60)$$

$$\delta^{14}\text{C} = -457.3 \pm 2.9\text{‰}$$

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8403

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. Nature of sample: Oyster shell
2. Submitter's catalogue number: BEG CE-10 46.2-47.0
3. Name and number of site: Auger core
4. Descriptive location of site:
Highway 87, Sabine Pass
5. Latitude: 29°43'49"N Longitude: 093°53'02"W

Country: USA State/Province: Texas County: Jefferson
6. Provenience of sample within site:
Ca. 12.86-13.11 m below sea level
7. Collector and date: R. Morton, 5 Jun 1993
8. Context:
Sample came from Holocene valley fill
9. Previous radiocarbon dates:
None
10. Variables affecting validity of date:
Burrowing, sediment reworking
11. Significance of sample:
Determine age of valley fill
12. Estimated sample age: < 15,000 BP

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8403

Run Number: 1574

Run Date: 09-02-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG CE-10 46.2-47.0

Site name: Auger core

Sample type: Shell

Submitter's age estimate: < 15,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters

Total counting time: 2700 minutes

Total counts: 45459

$\delta^{13}\text{C}$ determination: -1.2‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{16.837 \pm 0.079 - 5.868 \pm 0.033}{2.347} = 4.674 \pm 0.036 \text{ c.p.m./gram} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{4.674 \pm 0.036}{7.230 \pm 0.021} = 64.647 \pm 0.227$$

$$\text{Age} = 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2}$$

$$= 8033 \ln \frac{7.230}{4.674} \pm 8033 \left[\left[\frac{0.021}{7.230} \right]^2 + \left[\frac{0.036}{4.674} \right]^2 \right]^{1/2}$$

$$= 3504 \pm 66 \text{ years B.P. (rounded to nearest 10: } 3500 \pm 70)$$

$$\delta^{14}\text{C} = -353.5 \pm 2.3\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 4.452 \pm 0.036 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 61.577 \pm 0.221\%$$

$$\text{Age} = 3895 \pm 69 \text{ years B.P. (rounded to nearest 10: } 3900 \pm 70)$$

$$\delta^{14}\text{C} = -384.2 \pm 2.2\text{‰}$$

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8404

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. Nature of sample: Wood
2. Submitter's catalogue number: BEG CE-10 72.3-72.5
3. Name and number of site: Auger core
4. Descriptive location of site:
Highway 87, Sabine Pass
5. Latitude: 29°43'49"N Longitude: 093°53'02"W
Country: USA State/Province: Texas County: Jefferson
6. Provenience of sample within site:
Ca. 20.82-20.88 m below sea level
7. Collector and date: R. Morton, 5 Jun 1993
8. Context:
Sample came from late Pleistocene or Holocene valley fill
(Deweyville Formation?)
9. Previous radiocarbon dates:
None
10. Variables affecting validity of date:
Burrowing, sediment reworking
11. Significance of sample:
Determine age of valley fill and of a possible fluvial terrace

12. Estimated sample age: < 25,000 BP

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8404

Run Number: 972c

Run Date: 08-23-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG CE-10 72.3-72.5

Site name: Auger core

Sample type: Wood

Submitter's age estimate: < 25,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters

Total counting time: 5500 minutes

Total counts: 53198

$\delta^{13}\text{C}$ determination: -25.5‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{9.672 \pm 0.042 - 6.957 \pm 0.036}{0.939} = 2.891 \pm 0.059 \text{ c.p.m./gram C} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{2.891 \pm 0.059}{8.834 \pm 0.021} = 32.726 \pm 0.252\%$$

$$\begin{aligned} \text{Age} &= 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2} \\ &= 8033 \ln \frac{8.834}{2.891} \pm 8033 \left[\left[\frac{0.021}{8.834} \right]^2 + \left[\frac{0.059}{2.891} \right]^2 \right]^{1/2} \\ &= 8973 \pm 165 \text{ years B.P. (rounded to nearest 10: } 8970 \pm 170) \end{aligned}$$

$$\delta^{14}\text{C} = -672.7 \pm 2.5\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 2.894 \pm 0.059 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 32.760 \pm 0.252\%$$

$$\text{Age} = 8965 \pm 165 \text{ years B.P. (rounded to nearest 10: } 8970 \pm 170)$$

$$\delta^{14}\text{C} = -672.4 \pm 2.5\text{‰}$$

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8415

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. **Nature of sample:** Organic clay
2. **Submitter's catalogue number:** BEG CE-11 16.4-17.6
3. **Name and number of site:** Auger core
4. **Descriptive location of site:**
1.8 km N of Sabine Pass, Highway 87
5. **Latitude:** 29°44'21"N **Longitude:** 093°54'20"W
Country: USA **State/Province:** Texas **County:** Jefferson
6. **Provenience of sample within site:**
Ca. 4.08-4.45 m below sea level
7. **Collector and date:** R. Morton, 8 Jun 1993
8. **Context:**
Sample came from Holocene valley fill
9. **Previous radiocarbon dates:**
None
10. **Variables affecting validity of date:**
Burrowing, sediment reworking
11. **Significance of sample:**
Determine age of valley fill
12. **Estimated sample age:** < 10,000 BP

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8415

Run Number: II-588

Run Date: 09-08-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG CE-11 16.4-17.6

Site name: Auger core

Sample type: Organic matter

Submitter's age estimate: < 10,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters

Total counting time: 4000 minutes

Total counts: 60752

$\delta^{13}\text{C}$ determination: -25.1‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{15.188 \pm 0.062 - 6.210 \pm 0.034}{1.661} = 5.405 \pm 0.043 \text{ c.p.m./gram C} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{5.405 \pm 0.043}{9.333 \pm 0.024} = 57.913 \pm 0.323\%$$

$$\begin{aligned} \text{Age} &= 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2} \\ &= 8033 \ln \frac{9.333}{5.405} \pm 8033 \left[\left[\frac{0.024}{9.333} \right]^2 + \left[\frac{0.043}{5.405} \right]^2 \right]^{1/2} \\ &= 4388 \pm 67 \text{ years B.P. (rounded to nearest 10: } 4390 \pm 70) \end{aligned}$$

$$\delta^{14}\text{C} = -420.9 \pm 3.2\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 5.406 \pm 0.043 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 57.923 \pm 0.323\%$$

$$\text{Age} = 4386 \pm 67 \text{ years B.P. (rounded to nearest 10: } 4390 \pm 70)$$

$$\delta^{14}\text{C} = -420.8 \pm 3.2\text{‰}$$

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8415

Run Number: II-588

Run Date: 09-08-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG CE-11 16.4-17.6

Site name: Auger core

Sample type: Organic matter

Submitter's age estimate: < 10,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters

Total counting time: 4000 minutes

Total counts: 60752

$\delta^{13}\text{C}$ determination: -25.1‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{15.188 \pm 0.062 - 6.210 \pm 0.034}{1.661} = 5.405 \pm 0.043 \text{ c.p.m./gram} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{5.405 \pm 0.043}{9.333 \pm 0.024} = 57.913 \pm 0.32\%$$

$$\text{Age} = 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2}$$

$$= 8033 \ln \frac{9.333}{5.405} \pm 8033 \left[\left[\frac{0.024}{9.333} \right]^2 + \left[\frac{0.043}{5.405} \right]^2 \right]^{1/2}$$

$$= 4388 \pm 67 \text{ years B.P. (rounded to nearest 10: } 4390 \pm 70)$$

$$\delta^{14}\text{C} = -420.9 \pm 3.2\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 5.406 \pm 0.043 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 57.923 \pm 0.323\%$$

$$\text{Age} = 4386 \pm 67 \text{ years B.P. (rounded to nearest 10: } 4390 \pm 70)$$

$$\delta^{14}\text{C} = -420.8 \pm 3.2\text{‰}$$

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8405

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. **Nature of sample:** Shell fragments (oysters, [^]Mulinae[^])
2. **Submitter's catalogue number:** BEG CE-11 24.0-25.5
3. **Name and number of site:** Auger core
4. **Descriptive location of site:**
1.8 km N of Sabine Pass, Highway 87
5. **Latitude:** 29°44'21"N **Longitude:** 093°54'20"W
Country: USA **State/Province:** Texas **County:** Jefferson
6. **Provenience of sample within site:**
Ca. 6.40-6.86 m below sea level
7. **Collector and date:** R. Morton, 6 Jun 1993
8. **Context:**
Sample came from Holocene valley fill
9. **Previous radiocarbon dates:**
None
10. **Variables affecting validity of date:**
Burrowing, sediment reworking
11. **Significance of sample:**
Determine age of valley fill
12. **Estimated sample age:** < 10,000 BP

Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results

TX- 8405 Run Number: 978C Run Date: 09-06-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BGC CE-11 24.0-25.5

Site name: Auger core

Sample type: Shell

Submitter's age estimate: < 10,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters
 Total counting time: 2700 minutes
 Total counts: 50098
¹³C determination: -1.4‰

Rate of unknown = avg. counts/minute - background

grams carbon in sample

$$18.555 \pm 0.083 - 6.899 \pm 0.036$$

$$= \frac{2.400}{4.857 \pm 0.038 \text{ c.p.m./gram}}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{4.857 \pm 0.038}{8.837 \pm 0.021} = 54.962 \pm 0.261$$

$$\text{Age} = 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2}$$

$$= 8033 \ln \frac{8.837}{4.857} \pm 8033 \left[\left[\frac{0.021}{8.837} \right]^2 + \left[\frac{0.038}{4.857} \right]^2 \right]^{1/2}$$

$$= 4808 \pm 66 \text{ years B.P. (rounded to nearest 10: 4810 } \pm 70)$$

$$\delta^{14}\text{C} = -450.4 \pm 2.6\text{‰}$$

Corrections for ¹³C

$$\text{Rate of unknown} = 4.628 \pm 0.038 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 52.371 \pm 0.256\%$$

$$\text{Age} = 5196 \pm 69 \text{ years B.P. (rounded to nearest 10: 5200 } \pm 70)$$

$$\delta^{14}\text{C} = -476.3 \pm 2.6\text{‰}$$

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8406

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. Nature of sample: Marine shells (^Mulinia^)
2. Submitter's catalogue number: BEG CE-12A 12.4-12.7
3. Name and number of site: Auger core
4. Descriptive location of site:
3.2 km N of Sabine Pass, Highway 87
5. Latitude: 29°44'52"N Longitude: 093°55'40"W

Country: USA State/Province: Texas County: Jefferson
6. Provenience of sample within site:
Ca. 2.25-2.34 m below sea level
7. Collector and date: R. Morton, 6 Jun 1993
8. Context:
Sample came from Holocene valley fill
9. Previous radiocarbon dates:
None
10. Variables affecting validity of date:
Burrowing, sediment reworking
11. Significance of sample:
Determine time of beach ridge progradation
12. Estimated sample age: < 10,000 BP

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8406

Run Number: 975c

Run Date: 08-31-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG CE-12A 12.4-12.7

Site name: Auger core

Sample type: Shell

Submitter's age estimate: < 10,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters

Total counting time: 2700 minutes

Total counts: 54958

$\delta^{13}\text{C}$ determination: -1.2‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{20.355 \pm 0.087 - 6.875 \pm 0.036}{2.281} = 5.910 \pm 0.041 \text{ c.p.m./gram C} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{5.910 \pm 0.041}{8.839 \pm 0.021} = 66.863 \pm 0.30\%$$

$$\begin{aligned} \text{Age} &= 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2} \\ &= 8033 \ln \frac{8.839}{5.910} \pm 8033 \left[\left[\frac{0.021}{8.839} \right]^2 + \left[\frac{0.041}{5.910} \right]^2 \right]^{1/2} \\ &= 3234 \pm 59 \text{ years B.P. (rounded to nearest 10: } 3230 \pm 60) \end{aligned}$$

$$\delta^{14}\text{C} = -331.4 \pm 3.1\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 5.629 \pm 0.041 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 63.684 \pm 0.296\%$$

$$\text{Age} = 3625 \pm 62 \text{ years B.P. (rounded to nearest 10: } 3630 \pm 60)$$

$$\delta^{14}\text{C} = -363.2 \pm 3.0\text{‰}$$

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8407

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. Nature of sample: Marine shell fragments (^Mulina^)
2. Submitter's catalogue number: BEG CE-13 1.2-1.6
3. Name and number of site: Auger core
4. Descriptive location of site:
5.6 km N of Sabine Pass, Highway 87
5. Latitude: 29°45'58"N Longitude: 093°56'13"W

Country: USA State/Province: Texas County: Jefferson
6. Provenience of sample within site:
Ca. 0.83-0.85 m below sea level
7. Collector and date: R. Morton, 7 Jun 1993
8. Context:
Sample came from the chenier ridge
9. Previous radiocarbon dates:
None
10. Variables affecting validity of date:
Burrowing, sediment reworking
11. Significance of sample:
Determine age of the chenier ridge
12. Estimated sample age: < 10,000 BP

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8407

Run Number: 979c

Run Date: 09-08-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG CE-13 1.2-1.6

Site name: Auger core

Sample type: Shell

Submitter's age estimate: < 10,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters

Total counting time: 3900 minutes

Total counts: 51378

$\delta^{13}\text{C}$ determination: -1.8‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{13.174 \pm 0.058 - 6.899 \pm 0.036}{1.054} = 5.954 \pm 0.065 \text{ c.p.m./gram C} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{5.954 \pm 0.065}{8.838 \pm 0.021} = 67.368 \pm 0.42\%$$

$$\begin{aligned} \text{Age} &= 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2} \\ &= 8033 \ln \frac{8.838}{5.954} \pm 8033 \left[\left[\frac{0.021}{8.838} \right]^2 + \left[\frac{0.065}{5.954} \right]^2 \right]^{1/2} \\ &= 3173 \pm 90 \text{ years B.P. (rounded to nearest 10: } 3170 \pm 90) \end{aligned}$$

$$\delta^{14}\text{C} = -326.3 \pm 4.3\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 5.678 \pm 0.065 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 64.245 \pm 0.413\%$$

$$\text{Age} = 3554 \pm 94 \text{ years B.P. (rounded to nearest 10: } 3550 \pm 90)$$

$$\delta^{14}\text{C} = -357.5 \pm 4.1\text{‰}$$

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8408

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. **Nature of sample:** Oyster shell fragments
2. **Submitter's catalogue number:** BEG CE-13 20.7-20.9
3. **Name and number of site:** Auger core
4. **Descriptive location of site:**
5.6 km N of Sabine Pass, Highway 87
5. **Latitude:** 29°45'58"N **Longitude:** 093°56'13"W
Country: USA **State/Province:** Texas **County:** Jefferson
6. **Provenience of sample within site:**
Ca. 5.09-5.15 m below sea level
7. **Collector and date:** R. Morton, 7 Jun 1993
8. **Context:**
Sample came from Holocene valley fill
9. **Previous radiocarbon dates:**
None
10. **Variables affecting validity of date:**
Burrowing, sediment reworking
11. **Significance of sample:**
Determine age of valley fill
12. **Estimated sample age:** < 15,000 BP

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8408

Run Number: 1573

Run Date: 08-31-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG CE-13 20.7-20.9

Site name: Auger core

Sample type: Shell

Submitter's age estimate: < 15,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters

Total counting time: 2700 minutes

Total counts: 47588

$\delta^{13}\text{C}$ determination: -1.7‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{17.625 \pm 0.081 - 5.868 \pm 0.033}{2.422} = 4.854 \pm 0.036 \text{ c.p.m./gram C} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{4.854 \pm 0.036}{7.230 \pm 0.021} = 67.137 \pm 0.23\%$$

$$\begin{aligned} \text{Age} &= 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2} \\ &= 8033 \ln \frac{7.230}{4.854} \pm 8033 \left[\left[\frac{0.021}{7.230} \right]^2 + \left[\frac{0.036}{4.854} \right]^2 \right]^{1/2} \\ &= 3201 \pm 64 \text{ years B.P. (rounded to nearest 10: } 3200 \pm 60) \end{aligned}$$

$$\delta^{14}\text{C} = -328.6 \pm 2.3\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 4.628 \pm 0.036 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 64.011 \pm 0.225\%$$

$$\text{Age} = 3584 \pm 67 \text{ years B.P. (rounded to nearest 10: } 3580 \pm 70)$$

$$\delta^{14}\text{C} = -359.9 \pm 2.3\text{‰}$$

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8409

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. Nature of sample: Oyster shell fragments
2. Submitter's catalogue number: BEG CE-13 38.0-38.5
3. Name and number of site: Auger core
4. Descriptive location of site:
5.6 km N of Sabine Pass, Highway 87
5. Latitude: 29°45'58"N Longitude: 093°56'13"W

Country: USA State/Province: Texas County: Jefferson
6. Provenience of sample within site:
Ca. 10.36-10.51 m below sea level
7. Collector and date: R. Morton, 7 Jun 1993
8. Context:
Sample came from Holocene valley fill
9. Previous radiocarbon dates:
None
10. Variables affecting validity of date:
Burrowing, sediment reworking
11. Significance of sample:
Determine age of valley fill
12. Estimated sample age: < 15,000 BP

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8409

Run Number: II-585

Run Date: 09-02-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG CE-13 38.0-38.5

Site name: Auger core

Sample type: Shell

Submitter's age estimate: < 15,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters

Total counting time: 2757 minutes

Total counts: 47645

$\delta^{13}\text{C}$ determination: -2.1‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{17.281 \pm 0.079 - 6.123 \pm 0.033}{2.415} = 4.620 \pm 0.035 \text{ c.p.m./gram} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{4.620 \pm 0.035}{9.336 \pm 0.024} = 49.486 \pm 0.27$$

$$\begin{aligned} \text{Age} &= 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2} \\ &= 8033 \ln \frac{9.336}{4.620} \pm 8033 \left[\left[\frac{0.024}{9.336} \right]^2 + \left[\frac{0.035}{4.620} \right]^2 \right]^{1/2} \\ &= 5651 \pm 64 \text{ years B.P. (rounded to nearest 10: } 5650 \pm 60) \end{aligned}$$

$$\delta^{14}\text{C} = -505.1 \pm 2.8\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 4.408 \pm 0.035 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 47.215 \pm 0.272\%$$

$$\text{Age} = 6028 \pm 67 \text{ years B.P. (rounded to nearest 10: } 6030 \pm 70)$$

$$\delta^{14}\text{C} = -527.8 \pm 2.7\text{‰}$$

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8410

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. Nature of sample: "Rangia" shell fragments
2. Submitter's catalogue number: BEG CE-13 82.8-83.0
3. Name and number of site: Auger core
4. Descriptive location of site:
5.6 km N of Sabine Pass, Highway 87
5. Latitude: 29°45'58"N Longitude: 093°56'13"W

Country: USA State/Province: Texas County: Jefferson
6. Provenience of sample within site:
Ca. 24.01-24.08 m below sea level
7. Collector and date: R. Morton, 7 Jun 1993
8. Context:
Sample came from Holocene valley fill
9. Previous radiocarbon dates:
None
10. Variables affecting validity of date:
Burrowing, sediment reworking
11. Significance of sample:
Determine age of valley fill
12. Estimated sample age: < 15,000 BP

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8410

Run Number: 1572

Run Date: 08-29-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG CE-13 82.8-83.0

Site name: Auger core

Sample type: Shell

Submitter's age estimate: < 15,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters

Total counting time: 2700 minutes

Total counts: 25305

$\delta^{13}\text{C}$ determination: -7.3‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{9.372 \pm 0.059 - 5.868 \pm 0.033}{1.306} = 2.683 \pm 0.052 \text{ c.p.m./gram} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{2.683 \pm 0.052}{7.231 \pm 0.021} = 37.104 \pm 0.206$$

$$\text{Age} = 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2}$$

$$= 8033 \ln \frac{7.231}{2.683} \pm 8033 \left[\left[\frac{0.021}{7.231} \right]^2 + \left[\frac{0.052}{2.683} \right]^2 \right]^{1/2}$$

$$= 7964 \pm 157 \text{ years B.P. (rounded to nearest 10: } 7960 \pm 160)$$

$$\delta^{14}\text{C} = -629.0 \pm 2.1\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 2.588 \pm 0.052 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 35.790 \pm 0.203\%$$

$$\text{Age} = 8254 \pm 163 \text{ years B.P. (rounded to nearest 10: } 8250 \pm 160)$$

$$\delta^{14}\text{C} = -642.1 \pm 2.0\text{‰}$$

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8414

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. Nature of sample: Peat
2. Submitter's catalogue number: BEG CE-14 8.2-8.6
3. Name and number of site: Auger core
4. Descriptive location of site:
Neches floodplain N of Neches River, Highway 87
5. Latitude: 30°32'N Longitude: 092°51'30"W

Country: USA State/Province: Texas County: Jefferson
6. Provenience of sample within site:
Ca. 1.58-1.70 m below sea level
7. Collector and date: R. Morton, 8 Jun 1993
8. Context:
Sample came from Holocene valley fill
9. Previous radiocarbon dates:
None
10. Variables affecting validity of date:
Burrowing, sediment reworking
11. Significance of sample:
Determine age of valley fill
12. Estimated sample age: < 10,000 BP

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8414

Run Number: 974c

Run Date: 08-29-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG CE-14 8.2-8.6

Site name: Auger core

Sample type: Peat

Submitter's age estimate: < 10,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters
Total counting time: 2700 minutes Total counts: 73819
 $\delta^{13}\text{C}$ determination: -28.2‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{27.340 \pm 0.101 - 6.875 \pm 0.036}{2.416} = 8.471 \pm 0.044 \text{ c.p.m./gram} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{8.471 \pm 0.044}{8.839 \pm 0.021} = 95.837 \pm 0.41\%$$

$$\begin{aligned} \text{Age} &= 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2} \\ &= 8033 \ln \frac{8.839}{8.471} \pm 8033 \left[\left[\frac{0.021}{8.839} \right]^2 + \left[\frac{0.044}{8.471} \right]^2 \right]^{1/2} \\ &= 342 \pm 46 \text{ years B.P. (rounded to nearest 10: } 340 \pm 50) \end{aligned}$$

$$\delta^{14}\text{C} = -41.6 \pm 4.2\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 8.525 \pm 0.044 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 96.448 \pm 0.419\%$$

$$\text{Age} = 291 \pm 46 \text{ years B.P. (rounded to nearest 10: } 290 \pm 50)$$

$$\delta^{14}\text{C} = -35.5 \pm 4.2\text{‰}$$

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8411

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. Nature of sample: "Rangia" shell fragments
2. Submitter's catalogue number: BEG CE-14 23.0-23.5
3. Name and number of site: Auger core
4. Descriptive location of site:
Neches floodplain N of Neches River, Highway 87
5. Latitude: 30°32'N Longitude: 092°51'30"W

Country: USA State/Province: Texas County: Jefferson
6. Provenience of sample within site:
Ca. 6.10-6.25 m below sea level
7. Collector and date: R. Morton, 8 Jun 1993
8. Context:
Sample came from Holocene valley fill
9. Previous radiocarbon dates:
None
10. Variables affecting validity of date:
Burrowing, sediment reworking
11. Significance of sample:
Determine age of valley fill
12. Estimated sample age: < 10,000 BP

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8411

Run Number: 1576

Run Date: 09-06-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG CE-14 23.0-23.5

Site name: Auger core

Sample type: Shell

Submitter's age estimate: < 10,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters

Total counting time: 2700 minutes

Total counts: 37582

$\delta^{13}\text{C}$ determination: -6.3‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{13.919 \pm 0.072 - 5.867 \pm 0.033}{2.412} = 3.338 \pm 0.033 \text{ c.p.m./gram} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{3.338 \pm 0.033}{7.226 \pm 0.021} = 46.194 \pm 0.18\%$$

$$\begin{aligned} \text{Age} &= 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2} \\ &= 8033 \ln \frac{7.226}{3.338} \pm 8033 \left[\left[\frac{0.021}{7.226} \right]^2 + \left[\frac{0.033}{3.338} \right]^2 \right]^{1/2} \\ &= 6204 \pm 83 \text{ years B.P. (rounded to nearest 10: } 6200 \pm 80) \end{aligned}$$

$$\delta^{14}\text{C} = -538.1 \pm 1.9\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 3.213 \pm 0.033 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 44.464 \pm 0.185\%$$

$$\text{Age} = 6511 \pm 86 \text{ years B.P. (rounded to nearest 10: } 6510 \pm 90)$$

$$\delta^{14}\text{C} = -555.4 \pm 1.9\text{‰}$$

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8412

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. **Nature of sample:** Peat
2. **Submitter's catalogue number:** BEG CE-15 14.5-15.5
3. **Name and number of site:** Auger core
4. **Descriptive location of site:**
Neches floodplain N of Neches River, Highway 87
5. **Latitude:** 30°00'11"N **Longitude:** 092°51'52"W

Country: USA State/Province: Texas County: Jefferson
6. **Provenience of sample within site:**
Ca. 3.50-3.81 m below sea level
7. **Collector and date:** R. Morton, 8 Jun 1993
8. **Context:**
Sample came from Holocene valley fill
9. **Previous radiocarbon dates:**
None
10. **Variables affecting validity of date:**
Burrowing, sediment reworking
11. **Significance of sample:**
Determine age of the Holocene valley fill
12. **Estimated sample age:** < 10,000 BP

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8412

Run Number: II-584

Run Date: 08-31-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG CE-15 14.5-15.5

Site name: Auger core

Sample type: Peat

Submitter's age estimate: < 10,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters

Total counting time: 2771 minutes

Total counts: 56180

$\delta^{13}\text{C}$ determination: -23.1‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{20.274 \pm 0.086 - 6.123 \pm 0.033}{2.409} = 5.874 \pm 0.038 \text{ c.p.m./gram} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{5.874 \pm 0.038}{9.342 \pm 0.024} = 62.877 \pm 0.316$$

$$\begin{aligned} \text{Age} &= 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2} \\ &= 8033 \ln \frac{9.342}{5.874} \pm 8033 \left[\left[\frac{0.024}{9.342} \right]^2 + \left[\frac{0.038}{5.874} \right]^2 \right]^{1/2} \\ &= 3727 \pm 56 \text{ years B.P. (rounded to nearest 10: } 3730 \pm 60) \end{aligned}$$

$$\delta^{14}\text{C} = -371.2 \pm 3.2\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 5.852 \pm 0.038 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 62.642 \pm 0.316\%$$

$$\text{Age} = 3757 \pm 56 \text{ years B.P. (rounded to nearest 10: } 3760 \pm 60)$$

$$\delta^{14}\text{C} = -373.6 \pm 3.2\text{‰}$$

RADIOCARBON ANALYSIS REPORT
Radiocarbon Laboratory
The University of Texas
Balcones Research Center, Austin, TX 78712

Sample: Tx- 8413

Submitter: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

Bill to: Morton, Robert A.
Bureau of Economic Geology
University of Texas
J.J. Pickle Research Campus
Austin, TX 78712

DATA FROM SAMPLE GREEN SHEET
PLEASE CHECK, AND CORRECT IF NECESSARY

1. Nature of sample: Peat
2. Submitter's catalogue number: BEG CE-15 33.0-33.5
3. Name and number of site: Auger core
4. Descriptive location of site:
Neches floodplain N of Neches River, Highway 87
5. Latitude: 30°00'11"N Longitude: 092°51'52"W

Country: USA State/Province: Texas County: Jefferson
6. Provenience of sample within site:
Ca. 9.14-9.29 m below sea level
7. Collector and date: R. Morton, 8 Jun 1993
8. Context:
Sample came from Holocene valley fill
9. Previous radiocarbon dates:
None
10. Variables affecting validity of date:
Burrowing, sediment reworking
11. Significance of sample:
Determine age of the Holocene valley fill
12. Estimated sample age: < 10,000 BP

**Radiocarbon Laboratory, The University of Texas at Austin
Analysis Results**

TX- 8413

Run Number: 976c

Run Date: 09-02-1995

Submitter: Morton, Robert A.

Submitter's catalogue number: BEG CE-15 33.0-33.5

Site name: Auger core

Sample type: Peat

Submitter's age estimate: < 10,000 BP

Counting method: Liquid scintillation, using one of four Beckman counters

Total counting time: 2700 minutes

Total counts: 42337

$\delta^{13}\text{C}$ determination: -28.7‰

$$\begin{aligned} \text{Rate of unknown} &= \frac{\text{avg. counts/minute} - \text{background}}{\text{grams carbon in sample}} \\ &= \frac{15.680 \pm 0.076 - 6.875 \pm 0.036}{2.403} = 3.664 \pm 0.035 \text{ c.p.m./gram} \end{aligned}$$

$$\text{Percent Modern Carbon} = \frac{\text{unknown rate}}{\text{NBS standard rate}} = \frac{3.664 \pm 0.035}{8.840 \pm 0.021} = 41.448 \pm 0.226\%$$

$$\text{Age} = 8033 \ln \frac{\text{std. rate}}{\text{unk. rate}} \pm 8033 \left[\left[\frac{\text{std. error}}{\text{std. rate}} \right]^2 + \left[\frac{\text{unk. error}}{\text{unk. rate}} \right]^2 \right]^{1/2}$$

$$= 8033 \ln \frac{8.840}{3.664} \pm 8033 \left[\left[\frac{0.021}{8.840} \right]^2 + \left[\frac{0.035}{3.664} \right]^2 \right]^{1/2}$$

$$= 7075 \pm 79 \text{ years B.P. (rounded to nearest 10: } 7080 \pm 80)$$

$$\delta^{14}\text{C} = -585.5 \pm 2.3\text{‰}$$

Corrections for $\delta^{13}\text{C}$

$$\text{Rate of unknown} = 3.691 \pm 0.035 \text{ c.p.m./gram C}$$

$$\text{Percent Modern Carbon} = 41.753 \pm 0.226\%$$

$$\text{Age} = 7016 \pm 79 \text{ years B.P. (rounded to nearest 10: } 7020 \pm 80)$$

$$\delta^{14}\text{C} = -582.5 \pm 2.3\text{‰}$$

Addendum 6. "Deweyville" Terraces and Deposits of the Texas Gulf Coastal Plain

"DEWEYVILLE" TERRACES AND DEPOSITS OF THE TEXAS GULF COASTAL PLAIN

Michael D. Blum¹, Robert A. Morton², James M. Durbin¹

¹ Department of Geology, University of Nebraska - Lincoln, Lincoln, Nebraska 68588

² Bureau of Economic Geology, The University of Texas at Austin, Austin, Texas 78758

ABSTRACT

Bernard (1950) defined the Deweyville beds as underlying a terrace along Sabine River that is intermediate in elevation between Pleistocene Beaumont alluvial plain surfaces and Holocene floodplains, and which has abandoned meanders that are considerably larger than those of the Beaumont surface or modern highly sinuous Sabine channel. Subsequent workers identify 2 or 3 distinct terraces and/or suites of deposits that fit the original morphostratigraphic concept of the Deweyville along the Sabine and other rivers of the Texas Coastal Plain, but most commonly attribute oversized meanders to greater annual discharge and/or extreme high magnitude floods during the late Pleistocene glacial period. This paper builds on the idea of a broader stratigraphic concept for "Deweyville" terraces and deposits, and suggests a process model that emphasizes fluvial responses to interacting climatic and glacio-eustatic controls.

We suggest the multiple "Deweyville" terraces and underlying fills of the Texas Gulf Coast should be treated as a series of unconformity-bounded allostratigraphic units that record: (a) abandonment of Beaumont isotope stage 5 alluvial plains ca. 100 ka, which partitioned post-Beaumont incised valleys; and (b) multiple episodes of lateral migration, aggradation, and/or degradation within those valleys during the stage 4, 3, and 2 glacial cycle when channels were graded to shorelines at mid-shelf or farther basinward positions. "Deweyville" allostratigraphic units of the Sabine, Trinity, Guadalupe, and Nueces Rivers have steeper gradients than modern floodplains, and the youngest "Deweyville" surfaces are onlapped by Holocene strata at or near modern bay-head

deltas. Similar units are present in the Colorado and Brazos(?) valleys, but onlap by Holocene strata occurs 100 km or more inland from the present highstand shoreline.

"Deweyville" allostratigraphic units may represent a glacial period process regime with more annual runoff, but smaller peak discharges than present. The deep inland penetration of tropical moisture and/or tropical cyclones, responsible for most extreme floods on Coastal Plain rivers, was rare through the 80-90 ky of the glacial cycle when temperatures were cooler and the Gulf was smaller. "Deweyville" allostratigraphic units also lack clear evidence for high magnitude overbank floods, as they are sand-dominated, much like channel facies of late Holocene streams, but there is a paucity of vertical accretion floodplain facies which suggests most flood events remained within bankfull channel perimeters. The shorter wavelength, highly sinuous meanders typical of the present interglacial process regime may reflect adjustments to bank-stabilizing vertical accretion facies produced by deep overbank floods, and, in lowermost reaches of the Coastal Plain, to a forced flattening of gradients due to post-glacial sea level rise.

INTRODUCTION

The Texas Gulf Coastal Plain consists of a series of low-gradient, fan-shaped alluvial-deltaic plains that emanate from each major river valley (Fig. 1). Coastal plain deposits were initially subdivided into three "morphostratigraphic units" of presumed Pleistocene age, and designated the Willis (oldest), Lissie, and Beaumont (youngest) Formations (Hayes and Kennedy, 1903; Duessan, 1914; 1924; Doering, 1935; see Morton and Price, 1987; DuBar et al., 1991 for reviews). Bernard (1950) first differentiated post-Beaumont landforms and deposits when he described the Deweyville terrace and beds along east Texas rivers. Elsewhere, post-Beaumont strata went, for the most part unnamed and undifferentiated, but were assumed to be Holocene in age.

Most genetic interpretations for Texas Coastal Plain surfaces and deposits were developed when the Pleistocene was divided into four long glacials with sea level lowstand and three long interglacials characterized by sea level highstand. Following Fisk's (1944) model for the Mississippi River, valley

entrenchment and sediment bypass was inferred for glacial periods, and large-scale depositional units were interpreted to represent alluvial terraces and deltaic plains constructed during transgression and highstand. Beaumont strata were assigned to the "Sangamon" interglacial (e.g. Doering, 1956; Winker, 1979), or to a subsequent shorter-lived "Peorian" interglacial (e.g. Bernard and LeBlanc, 1965), whereas post-Beaumont valleys were presumed to represent entrenchment during the "Wisconsin" glacial, and filling with post-glacial sea level rise.

This paper is part of a continuing reevaluation of the genetic stratigraphy of Texas Gulf Coastal Plain fluvial deposits. This type of reevaluation becomes necessary when the empirical foundations of previous models have been substantially revised. Such is the case for the simple linkage between coastal plain depositional units and glacio-eustasy, a satisfactory model when the concept of four long Pleistocene interglacials was accepted, but one that needs reevaluation today. Willis, Lissie, Beaumont, and post-Beaumont strata are, for example, now thought to represent the entire Plio-Pleistocene to Holocene (DuBar et al., 1991), but studies of oxygen isotopes in marine sediments show seven glacial-interglacial cycles during the last 700,000 years alone (Chappell and Shackleton, 1986; Williams et al., 1988). Blum and Price (1994; in press) present the first stages of this reevaluation, showing that Beaumont alluvial plains consist of cross-cutting incised valley fills deposited over the last 3-400 ky or more. This paper builds on previous work to suggest a "Deweyville allostratigraphic framework", as well as a genetic model that emphasizes fluvial response to interacting glacio-eustatic and climatic controls.

BACKGROUND TO DEWEYVILLE TERRACES AND DEPOSITS

Barton (1930) first discussed the large relict channels on terraces of east Texas Rivers as distinct from those on older Beaumont or younger floodplains. Some 20 years later, Bernard (1950) formally recognized the Deweyville beds as underlying a terrace along Sabine River that is intermediate in elevation between Pleistocene Beaumont surfaces and Holocene floodplains, and which has channel dimensions much larger than the modern Sabine. He also noted similar terraces

along the Neches, Trinity, San Jacinto, and Nueces Rivers (Angelita terrace of Price, 1933), and suggested that large arcuate scars along valley walls in the Brazos and Colorado valleys were correlative to Deweyville meanders, but buried by younger deposits.

Following this early work, similar terraces were recognized and studied throughout the Gulf Coastal Plain in Arkansas, Louisiana, and Texas, and in most cases workers identify 2-3 terraces that fit Bernard's Deweyville concept (e.g. Gagliano and Thom, 1967; Saucier and Fleetwood, 1970; Aten, 1983; Alford and Holmes, 1985; Pearson et al., 1986; Blum and Valastro, 1994). Moreover, Environmental Geologic Atlas maps published by The University of Texas' Bureau of Economic Geology identify at least 2 "Deweyville" terraces in the lower reaches of coastal plain valleys, except those of the Rio Grande, Colorado, and Brazos Rivers (Fisher et al., 1972; Brown et al., 1976; McGowen et al., 1976). Finally, seismic reflection and core-based studies of recent strata of the now-submerged east Texas shelf interpret terraces within the incised valley of the Sabine and Trinity Rivers, and suggest they correlate with Deweyville terraces onshore (Pearson et al., 1986; Thomas, 1990; Anderson et al., 1992; Thomas and Anderson, 1994).

Few chronometric controls are available for Deweyville terraces. Bernard (1950) inferred a latest Pleistocene age, whereas Bernard and LeBlanc (1965), Gagliano and Thom (1967), and Saucier and Fleetwood (1970) cite unpublished radiocarbon ages of ca. 30-17 ka from Deweyville deposits. Saucier and Fleetwood (1970) also suggest Deweyville terraces in Arkansas can be traced to late Wisconsin valley trains of Mississippi River. More recent estimates range over an order of magnitude, as Alford and Holmes (1985) suggest an early to middle Holocene age for Deweyville terraces along Sabine River, based on associated archaeological materials, and Thomas (1990) places Deweyville terraces of the Trinity valley in isotope stage 5c, ca. 100 ka, based on correlations with the Trinity incised valley fill offshore, and ages for the offshore record from oxygen isotope curves.

Barton (1930) provided an initial explanation for large meanders on terraces of east Texas rivers, suggesting late Pleistocene streams were larger than modern channels, and rainfall must have been greater. Bernard (1950) reviewed a number of explanations, but clearly favored linking Deweyville deposition and terrace formation to a cycle of rising then falling sea level during the latest

Wisconsin. Subsequent workers (Gagliano and Thom, 1967; Saucier and Fleetwood, 1970; Alford and Holmes, 1985) favored climatic controls, using hydraulic geometry relations to suggest Deweyville meander scars represent mean annual discharges significantly greater than modern. Most recently, Saucier (in Autin et al., 1991) suggests changes in precipitation seasonality and intensity, and changes in vegetation, were more important than changes in mean annual discharge, whereas Thomas (1990) linked deposition to rising sea level during isotope stage 5c. and Gagliano (1992) suggests Deweyville terraces represent Pleistocene "superfloods".

"DEWEYVILLE" ALLOSTRATIGRAPHIC FRAMEWORK

Studies that followed Bernard (1950) illustrate the complexity of post-Beaumont alluvial deposits of the Texas Gulf Coastal Plain, but also muddy the "Deweyville" waters a bit, as it seems that different workers are talking about different things. Because of the regional significance of the "Deweyville" phenomenon, we outline a broader conceptual framework, one that future studies can test and refine.

We suggest the distribution and variability of the "Deweyville" phenomenon can best be understood within the context of the large-scale geomorphology of the Texas Coastal Plain. For example, Winker (1979) and Galloway (1981) differentiate extrabasinal from basin fringe and intrabasinal fluvial systems. Extrabasinal systems (Rio Grande, Colorado, and Brazos) drain tectonic hinterlands, have large sediment supplies, and construct laterally extensive alluvial-deltaic headlands. By contrast, basin fringe fluvial systems (Sabine, Trinity, Guadalupe, and Nueces) cannibalize basin margins, whereas intrabasinal streams (San Jacinto, Navidad, and Aransas) drain updip parts of the basin fill. Because of the small drainage areas and sediment loads of basin-fringe and intrabasinal streams, they commonly flow into the basin at interdeltic bights that consist of alluvial, bay-head deltaic, estuarine, and barrier island/strandplain depositional systems. Complementary to the above, Morton and McGowen (1980) show that rivers entering the basin over deep-seated structural lows have gradients much less steep than those that enter the basin, or flow over, deep structural highs.

Examples of low gradient streams would be the Sabine, Neches, Trinity, and Brazos, which enter the basin over the Houston embayment, and the Rio Grande, which enters the basin over the Rio Grande embayment. High gradient streams like the Colorado, Guadalupe, and Nueces emerge from the high-relief Edwards Plateau and cross the San Marcos arch before discharging into the Gulf.

Within this larger context, our mapping and construction of long profiles shows multiple terraces with Deweyville characteristics within post-Beaumont valleys of basin fringe fluvial axes (Fig. 2). For low-gradient east Texas rivers, like the Trinity, Sabine, and Neches, two terraces occur below the Beaumont surface and above the level of modern floodplains, and project seaward beyond modern bay-head deltas until they are cut out by modern bays. In addition, large arcuate scars are ubiquitous along valley walls (i.e. Lake Anahuac in the Trinity valley), and have always been referred to as "Deweyville" (see Gagliano and Thom, 1967; Aten, 1983; Pearson et al., 1986); but their long profiles coincide with modern floodplains, and they have been buried by veneers of younger floodbasin and/or delta plain facies, hence they are no longer terraces in the classic sense. By contrast, for the steeper gradient basin fringe rivers like the Guadalupe and Nueces, three distinct terraces occur well above modern floodplains, at least down to the bay-head delta plain, where the lowest "Deweyville" surface is onlapped and buried.

For the extrabasinal Colorado and Brazos valleys, Bernard (1950) suggested similar terraces might have been present, but they are now buried by younger alluvial deposits. Indeed, Blum and Valastro (1994) show that terraces with "Deweyville" characteristics are present in the Colorado valley, but onlap by Holocene strata occurs 100 km updip from the modern shoreline (Fig. 3). Mapping and stratigraphic data remain unavailable for much of the Brazos system, but White and Weigand (1989) correlate a Brazos terrace near the confluence with Navasota River, with the Deweyville. Bernard et al. (1970) show that modern floodplain facies veneer the post-Beaumont Brazos valley through the lowermost 100 km. By inference, Deweyville deposits would be buried by Holocene strata through the lower part of the Brazos valley, as they are in the Colorado, but the updip limits of onlap might be considerably greater due to the lower valley gradient.

In summary, landforms and/or deposits that correspond to Bernard's (1950) concept appear to be present along all of the major Texas Coastal Plain rivers except perhaps Rio Grande(?). However, the presence of multiple "Deweyvilles" complicates the picture, as do morphologic and stratigraphic differences that correspond to large-scale geomorphological setting. Hence, following recent efforts in the Gulf Coast (Autin, 1992; Blum and Valastro, 1994), we suggest "Deweyville" landforms and deposits should be treated as unconformity-bounded allostratigraphic units (NACSN, 1983), since some deposits have a similar age, origin, and genetic significance, but no longer have surface expression as a terrace. Fundamental characteristics of a "Deweyville" allostratigraphic framework might be as follows (Fig. 4): (a) the entire post-Beaumont succession should be bounded by a composite basal unconformity that traces up and out of the valley to soils on Beaumont surfaces; (b) the oldest "Deweyville" allostratigraphic unit occurs at the highest elevations, with successively younger units at successively lower elevations; (c) each "Deweyville" unit should be bounded by unconformities that trace up, and laterally to, soils developed on older units, and the upper boundary to each "Deweyville" unit should be defined by a soil profile; (d) "Deweyville" units project seaward to shorelines lower in elevation and farther seaward than today; and (e) the updip limits of onlap and burial of "Deweyville" units by younger strata depends on sediment supply and valley gradient.

Lithological characteristics play no formal role in definition of allostratigraphic units, but a number of workers note that facies underlying Deweyville terraces are coarser than Beaumont or Holocene deposits (e.g. Gagliano and Thom, 1967; Saucier and Fleetwood, 1970; see also Autin et al., 1991). Blum and Valastro (1994) suggest that gravely or sandy channel facies extend to the top of most sections in "Deweyville" correlatives of the Colorado valley, and vertical accretion facies are rare, which contrasts with late Holocene deposits where vertical accretion facies are thick and volumetrically significant. Our observations in the Sabine, Neches, Trinity, and Nueces valleys supports the view of limited to non-existent vertical accretion facies in "Deweyville" units, and an abundance of such facies in Holocene deposits. We also note that gravel and sand quarries occur frequently on "Deweyville" surfaces because of the lack of fine-grained overburden.

A precise chronology for "Deweyville" allostratigraphic units awaits future work, but stratigraphic relations indicate they fall between deposition of Beaumont alluvial plain strata and development of modern floodplains. The Colorado River is the only fluvial system with chronological control on Beaumont or younger strata. The youngest Beaumont meanderbelts have, for example, produced thermoluminescence ages ranging from ca. 119 to 102 ka, suggesting alluvial plains were abandoned during late isotope stage 5 as the Colorado incised in response to sea level lowering (Blum and Price, 1994; in press). At the other end of the time window, the youngest deposits correlative to Deweyville have produced radiocarbon ages that fall within isotope stage 2, ca. 20-14 ka (Blum and Valastro, 1994). From this, we infer that "Deweyville" allostratigraphic units were deposited sometime within the isotope stage 4, 3, and 2 glacial period.

GENETIC MODEL FOR "DEWEYVILLE" ALLOSTRATIGRAPHIC UNITS

Although climate change and/or changes in base level undoubtedly played a significant role in determining "Deweyville" morphological and stratigraphic characteristics, two problems should be addressed. First, values of precipitation or discharge suggested by previous workers seem extreme, perhaps out of the range of possibilities for the climate system in this region. It seems unlikely, for example, that mean annual discharge could have been significantly more than present, or that the glacial period would have had larger peak discharges than the present interglacial. Second, the nature of base level influence needs reevaluation in light of present understanding of glacio-eustasy, which is very different from the model that prevailed when Bernard (1950) conducted his work. Here we present a revised genetic model that can be tested or refined in future investigations.

Glacial versus Interglacial Climate Systems

Our model draws on Porter's (1989) concept of "average Pleistocene conditions". Most discussions of Quaternary climate or sea-level change focus on end-members such as the full-glacial or interglacial. However, oxygen isotope curves (Chappell and Shackleton, 1986; Williams et al., 1988) show that 80% of any middle to late Pleistocene 100 ky glacial cycle was intermediate in character, with global temperatures cooler than full interglacial conditions, but not as cold as a full-glacial, and with eustatic sea level at -15 to -65 meters (Fig. 5a). For Texas Coastal Plain rivers, this would translate to cooler land temperatures, and a cooler and smaller Gulf precipitation source for the entire stage 4, 3, and 2 glacial cycle. Moreover, rivers were extended to shorelines in mid-shelf or farther basinward positions, and much of the shelf was a subaerial extension of the coastal plain (Fig. 5b). Such conditions represent the norm for the last 100 ky, and the Holocene interglacial should be regarded as unique, with a warm climate, a large and warm Gulf precipitation source, and rivers graded to updip shoreline positions.

At a more specific level, Toomey et al. (1993) reconstruct the isotope stage 2 glacial climate of the Edwards Plateau, source terrain for the Colorado, Guadalupe, and Nueces Rivers. Regional temperatures were significantly cooler, and there was more effective moisture, but perhaps more important were the types of precipitation events, and the nature of upland soil mantles. Tropical cyclones were probably rare to non-existent when sea level was low and the Gulf was cooler (e.g. Wendland, 1977; Hobgood and Cervený, 1988), as were high-intensity convectional storms, and most precipitation would have been derived from midlatitude cyclonic storms. Several lines of evidence also converge to show that full-glacial precipitation fell on uplands that were covered by deep soil mantles no longer present in the area today.

Precipitation events characteristic of the full-glacial on the Edwards Plateau might have prevailed through earlier parts of the last glacial cycle, and throughout the southcentral United States. Given the relationship between tropical cyclone frequency and sea surface temperature, or convectional storm frequency and land temperature, such storms should have been infrequent at best during the entire stage 4, 3, and 2 glacial period. Moreover, deep soils present at full-glacial time on the Edwards Plateau should have been present through earlier parts of the last glacial cycle as well.

since soils on these limestone uplands would have required a long time to form, probably through some combination of eolian dust influx and in situ weathering of bedrock, and therefore reflect long-term landscape stability. Although details may have differed elsewhere in the southcentral United States, landscape stability may have been the norm for the entire glacial period, especially if convectional and tropical storms were insignificant, and most precipitation resulted from less intense but areally widespread midlatitude cyclones.

Global climate changes that led to wastage of isotope stage 2 ice sheets resulted in changes in climate and vegetation in the southcentral United States. Toomey et al. (1993) suggest that post-glacial sea level rise, coupled with increased surface temperatures, promoted frequent inland penetration of warm, moist tropical air, and corresponding increases in the frequency of tropical cyclones and convectional storms. On the Edwards Plateau, these changes triggered a period of landscape instability and soil erosion so that upland landscapes now consist of exposed bedrock. Again, although details may differ, Holocene landscape instability may have been widespread in the southcentral United States due to the shift from glacial to interglacial climates.

Glacial versus Interglacial Fluvial Systems

Fundamental differences between glacial and interglacial climates would have resulted in equally fundamental differences in fluvial process regimes. While glacial periods had more effective moisture, related mean annual discharge values are not critical to explaining "Deweyville" characteristics (see Saucier, in Autin et al., 1991), since the morphology and depositional style of alluvial channels depend on floods that are less frequent (recurrence intervals of 1-10 years), and 1-3 orders of magnitude greater, than mean annual discharge (Wolman and Miller, 1960; Wolman and Gerson, 1978; Knox, 1983). Hence glacial to interglacial changes in storm types and landscape stability, and their effects on floods, should have been the most important factors.

Most extreme floods on the larger coastal plain rivers result from the inland penetration of tropical cyclones, or El Nino phenomena, and the related extreme rainfalls. Most importantly, these

would be the only historic floods comparable in magnitude to those needed to explain the large channels common to "Deweyville" surfaces on hydraulic geometry grounds alone. As outlined above, it seems unlikely that tropical flood-generating mechanisms would have been significant during the glacial period. By contrast, precipitation from midlatitude cyclones, common to Spring and Fall months during the late Holocene, produces frequent moderate magnitude floods. We suggest such storms were the dominant flood-producing mechanism during the glacial period, and frequent moderate magnitude floods dominated "Deweyville" discharge regimes.

Regardless of meteorological cause, flood peaks, as contrasted with flood volume, are conditioned by rates at which precipitation is converted to discharge, which in turn reflects vegetation cover, soil mantles, and other landscape characteristics. For the Edwards Plateau, source region for the Colorado, Guadalupe, and Nueces Rivers, rates at which runoff was transferred to stream channels would have been at a minimum through the glacial period when uplands were covered by deep soils and a good vegetation cover, and a maximum during the Holocene interglacial when the bedrock landscape was exposed. By comparison, holding flood volume constant, glacial period discharge hydrographs would have been less peaked and more broad-based than those characteristic of the Holocene. Hence, not only were extreme flood-generating mechanisms less likely during the glacial period, but rates of runoff and resultant flood hydrographs were conditioned by upland landscape stability, and flood peaks should have been smaller and more broad-based than today (less flashy).

Sedimentary facies typical of "Deweyville" allostratigraphic units also suggest extreme floods were unimportant during their formative period. The paucity of vertical accretion facies indicates that most floods remained within bankfull channel perimeters, overbank flooding was a rare to non-existent occurrence, and "Deweyville" floodplains were constructed by lateral accretion and migration of point bars and channels. This contrasts with the late Holocene, with flashy floods that exceed bankfull channels, floodplain construction by vertical accretion and avulsion, and thick successions of fine-grained vertical accretion facies (Blum and Valastro, 1994). Waters and Nordt (1995) suggest similar changes in processes of floodplain construction for the Brazos River near College Station.

The absence of vertical accretion facies, and the inferred absence of overbank floods, may help explain the enigmatic large Deweyville channels. Examination of curves that relate discharge characteristics to channel geometry, upon which many empirical hydraulic geometry equations are based (e.g. Carlston, 1965; Dury, 1965), shows considerable variability in meander geometry for a given discharge. This may reflect largely on the influence of bank-stabilizing muds (see Schumm, 1960; 1969), with higher than average meander wavelengths and radii of curvature reflecting a lack of muds in floodplain settings, and lower values reflecting muddy systems. More recent thinking on floodplain processes support these views, as Brackenridge (1988) argues the thickness of vertical accretion facies is related to flashiness of the discharge regime.

In sum, we suggest that channels on Deweyville terraces may reflect hydraulic adjustments to the absence of bank-stabilizing muds, which in turn reflects an absence of deep and flashy overbank floods through the isotope stage 4, 3, and 2 glacial. Smaller channel dimensions on Holocene floodplains may simply reflect the presence of bank-stabilizing muds, which in turn may result from the deep, flashy overbank floods characteristic of the present interglacial.

Role of Glacio-Eustasy and Base Level Change

"Deweyville" allostratigraphic units extend farther upstream than the influence of base level changes during the last glacio-eustatic cycle, so their fundamental characteristics must be attributed to other causes, perhaps those outlined above. Nevertheless, base level changes played a major role in shaping the geomorphic and stratigraphic framework in downstream reaches of valleys on the present-day coastal plain. Post-Beaumont valleys initially formed in response to sea level lowering below isotope stage 5 interglacial positions, when channels incised Beaumont alluvial plains, and extended across the newly subaerial shelf. Glacial period rivers then flowed through a series of laterally-confined valleys, with channels extended to shorelines in mid-shelf or farther basinward positions (see Suter and Berryhill, 1985; Suter, 1987; Anderson et al., 1992; Thomas, 1990; Thomas and Anderson, 1994). However, this long-term degradational mode was punctuated by multiple

"Deweyville" episodes of lateral migration and/or minor aggradation with sediment storage, followed by renewed valley incision with terrace formation. With post-glacial sea-level rise, the lower reaches of coastal plain rivers switched from degradational to aggradational modes, with progressive onlap of "Deweyville" profiles by Holocene deposits.

In upstream reaches of the coastal plain, differences between "Deweyville" and Holocene depositional systems may be a function of changes in the climate system. But the volumetric significance of vertical accretion facies in downstream reaches of Holocene floodplains is greatly enhanced by a forced shortening of channels, flattening of longitudinal gradients, and forced storage of sediments in response to post-glacial sea level rise and shoreline transgression. Indeed channel shortening, valley aggradation, and reductions in depositional slope during late transgression and highstand has promoted avulsion and development of the anastomosing or distributary channel patterns seen in the lowermost reaches of modern-day streams. Low sediment yield basin fringe and smaller systems have yet to fill post-Beaumont incised valleys, so avulsion remains confined within the boundaries of the valley itself. At the other end of the spectrum, the high sediment yield Colorado River has filled its incised valley, and avulsed to reoccupy a Beaumont isotope stage 5 channel course (Blum, 1994; Blum and Valastro, 1994; Blum and Price, in press).

ACKNOWLEDGMENTS

Blum's recent research on "Deweyville" and other Texas Gulf Coastal Plain fluvial deposits has been supported by the National Science Foundation, the donors to the Petroleum Research Fund of the American Chemical Society, Exxon Production Research Company, Union Pacific Resources, and the Office of Research Development and Administration of Southern Illinois University. Morton's recent research on fluvial systems of the Texas Gulf Coastal Plain has been partly supported by the U.S. Geological Survey Coastal Geology Program and the National Science Foundation. We thank Dave Amsbury, John Suter, and GCAGS reviewer Whitney Autin for discussions or comments that clarified ideas presented in this paper.

REFERENCES

- Alford, J. J. and Holmes, J. C., 1985, Meander scars as evidence of major climate changes in southeast Louisiana: Association of American Geographers Annals, v. 75, p. 395-403.
- Anderson, J. B., Thomas, M. A., Siringin, F. P., and Smyth, W. C., 1992. Quaternary evolution of the Texas Coast and Shelf, *in* C. H. Fletcher III and J. F. Wehmiller, eds., Quaternary Coasts of the United States: Marine and Lacustrine Systems: Special Publication 48, Society for Sedimentary Geology. Tulsa. p. 253-265.
- Aten, L. E., 1983, Indians of the Upper Texas Coast: New York, Academic Press.
- Autin, W. J., 1992, Use of alloformations for definition of Holocene meanderbelts in the middle Amite River, southeastern Louisiana: Geological Society of America Bulletin, v. 104, p. 233-241.
- Autin, W. J., Burns, S. F., Miller, B. J., Saucier, R. T. and Snead, J. J. , 1991, Quaternary geology of the Lower Mississippi Valley, *in* R. B., Morrison, ed. Quaternary Non-Glacial Geology of the Conterminous United States, v. K-2, The Geology of North America: Geological Society of North America, Boulder, Colorado. p. 547-582.
- Barton, D. C., 1930, Surface geology of coastal southeast Texas: American Association of Petroleum Geologists Bulletin, v. 14, p. 1301-1320.
- Bernard, H. A., 1950, Quaternary Geology of Southeast Texas: Unpublished Ph.D. Dissertation, Louisiana State University, Baton Rouge, Louisiana.
- Bernard, H. A. and LeBlanc, R. J., 1965, Resume of the Quaternary Geology of the Northwestern Gulf of Mexico Province, *in* H. E. Wright and D. G. Frey, eds., The Quaternary of the United States: Princeton, New Jersey, Princeton University Press. p. 137-185.
- Bernard, H. A., Major, C. F., Parrott, B. S., and LeBlanc, R. J. Sr., 1970, Recent Sediments of Southeast Texas: Field Guide to the Brazos Alluvial-Deltaic Plain and the Galveston Barrier Island Complex: Guidebook 11, Bureau of Economic Geology. The University of Texas at Austin. Austin, Tx.

- Blum, M. D., 1994, Genesis and architecture of incised valley fill sequences: a Late Quaternary example from the Colorado River, Gulf Coastal Plain of Texas, *in* P. Weimer and H. W. Posamentier, eds., *Siliciclastic Sequence Stratigraphy: Recent Developments and Applications*: American Association of Petroleum Geologists Memoir 58. p. 259-283.
- Blum, M. D. and Valastro, S. Jr., 1994, Late Quaternary sedimentation, Lower Colorado River, Gulf Coastal Plain of Texas: *Geological Society of America Bulletin*. v. 106, pp. 1002-1016.
- Blum, M. D., Toomey, R. S. III, and Valastro, S. Jr., 1994, Fluvial response to Late Quaternary climatic and environmental change, Edwards Plateau of Texas: *Paleogeography, Paleoclimatology, and Paleoecology*. v. 108, pp. 1-21.
- Blum, M. D. and Price, D. M., 1994, Glacio-eustatic and climatic controls on Pleistocene alluvial plain deposition, Texas Coastal Plain: *Gulf Coast Association of Geological Societies Transactions*, v. 44, p. 85-92.
- Blum, M. D. and Price, D. M., in press, Pleistocene alluvial plain deposition in response to interacting glacio-eustatic and climatic controls, Gulf Coastal Plain of Texas. *in* Shanley, K. and McCabe, P., eds., *Relative Role of Eustasy, Climate, and Tectonism in Continental Rocks*: SEPM Special Publication.
- Brackenridge, G. R., 1988, River flood regime and floodplain stratigraphy: p. 139-165 *in* Baker, V. R., Kochel, R. C., and Patton, P. C., eds., *Flood Geomorphology*: New York, John Wiley and Sons.
- Brown, L. F., Brewton, J. L., McGowen, J. H., Evans, T. J., Fisher, W. L., and Groat, C. G., 1976, *Environmental Geologic Atlas of the Texas Coastal Zone: Corpus Christi Area*: Bureau of Economic Geology, University of Texas at Austin.
- Carlston, C. W., 1965, Relation of free meander geometry to discharge and its geomorphic implications: *American Journal of Science*, v. 263, p. 864-885.
- Chappell, J. and Shackleton, N. J., 1986, Oxygen isotopes and sea level: *Nature*, v. 324, p. 137-140.
- Doering, J. A., 1935, Post-Fleming surface formations of southeast Texas and south Louisiana: *American Association of Petroleum Geologists Bulletin*, v. 19, p. 651-688.

- Doering, J. A., 1956, Review of Quaternary surface formations of the Gulf Coast Region: American Association of Petroleum Geologists Bulletin, v. 40, p. 1816-1862.
- DuBar, J. R., Ewing, T. E., Lundelius, E. L., Otvos, E. G., and Winker, C. D., 1991, Quaternary geology of the Gulf of Mexico Coastal Plain, *in* R. B. Morrison, ed., Quaternary Non-Glacial Geology of the Conterminous United States: Boulder, Colorado, Geology of North America Volume K-2, Geological Society of America. p. 583-610.
- Duessan, A., 1914, Geology and Underground Waters of the Southeastern Part of the Texas Coastal Plain, United States Geological Survey Water Supply Paper 335, Washington.
- Duessan, A., 1924, Geology of the Coastal Plain of Texas west of Brazos River: United States Geological Survey Professional Paper 126, Washington.
- Dury, G. H., 1965, Principles of Underfit Streams: Professional Paper 452-A, United States Geological Survey, Washington.
- Fisher, W. L., McGowen, J. H., Brown, L. F. Jr., and Groat, C. G., 1972. Environmental Geologic Atlas of the Texas Coastal Zone: Galveston - Houston Area: Bureau of Economic Geology, University of Texas at Austin.
- Fisk, H. N., 1944, Geological Investigations of the Alluvial Valley of the Lower Mississippi River: Mississippi River Commission, US Army Corps of Engineers, Vicksburg, Mississippi.
- Gagliano, S. M and Thom, B. G., 1967, Deweyville terrace, Gulf and Atlantic coasts: Coastal Studies Bulletin 1, Louisiana State University, p. 23-41.
- Gagliano, S. M., 1991, Late Quaternary Deweyville interval superfloods: Gulf Coast Association of Geological Societies Transactions, v. 41, p. 298.
- Galloway, W. E., 1981, Depositional architecture of Cenozoic Gulf Coastal Plain fluvial systems. pp. 127-156 *in* Ethridge, F. G. and Flores, R. M., eds., Recent and Ancient Non-Marine Depositional Environments: Special Publication 31, Society of Economic Paleontologists and Mineralogists. Tulsa, Oklahoma.
- Hayes, C. W. and Kennedy, W., 1903, Oil Fields of the Texas-Louisiana Gulf Coastal Plain: United States Geological Survey Bulletin 213, Washington. D. C.

- Hill, R. T. and Vaughn, T. W., 1897, Geology of the Edwards Plateau and Rio Grande Plain Adjacent to Austin and San Antonio, Texas, with Reference to the Occurrence of Groundwaters: Annual Report 18, United States Geological Survey, Washington, D. C.
- Hill, R. T. and Vaughn, T. W., 1902, Description of the Austin Quadrangle: Atlas Folio 76. United States Geological Survey, Washington, D. C.
- Hobgood, J. S. and Cervený, R. S., 1988, Ice-age hurricanes and tropical storms: *Nature*, v. 333, p. 243-245.
- Knox, J. C., 1983, Responses of river systems to Holocene climates. *in* H. E. Wright and S. C. Porter, eds., Late Quaternary Environments of the United States: Volume 2, The Holocene. Minneapolis. University of Minnesota Press. p. 26-41.
- McGowen, J. H., Brown, L. F., Evans, T. J., Fisher, W. L., and Groat, C. G., 1975, Environmental Geologic Atlas of the Texas Coastal Zone: Bay City-Freeport Area: Bureau of Economic Geology, University of Texas at Austin.
- McGowen, J. H., Proctor, C. V., Brown, L. F., Evans, T. J., Fisher, W. L., and Groat, C. G., 1976, Environmental Geologic Atlas of the Texas Coastal Zone: Port Lavaca Area: Bureau of Economic Geology, University of Texas at Austin.
- Morton, R. A. and McGowen, J. H., 1980, Modern Depositional Environments of the Texas Coast: Guidebook 20, Bureau of Economic Geology, University of Texas at Austin.
- Morton, R. A. and Price, W. A., 1987, Late Quaternary sea-level fluctuations and sedimentary phases of the Texas Coastal Plain and shelf, *in* D. Nummedal and O. H. Pilkey, eds., Sea Level Fluctuations and Coastal Evolution: SEPM Special Publication No. 15, p.181-198.
- North American Commission on Stratigraphic Nomenclature, 1983, The North American Stratigraphic Code: American Association of Petroleum Geologists Bulletin, v. 67, p. 841-875.
- Pearson, C. E., Kelley, D. B., Weinstein, R. A., and Gagliano, S. M., 1986, Archaeological Investigations on the Outer Continental Shelf: A Study within the Sabine River Valley, Offshore Louisiana and Texas: Coastal Environments Inc., Report to the Minerals Management Service. United States Department of the Interior.

- Porter, S. C., 1989, Some geological implications of average Quaternary glacial conditions. *Quaternary Research*, v. 32, p. 245-262.
- Price, W. A., 1933, Role of diastrophism in topography of Corpus Christi area, Texas: *American Association of Petroleum Geologists Bulletin*, v. 17, p. 205-250.
- Price, W. A., 1958, Sedimentology and Quaternary geomorphology of South Texas: *Gulf Coast Association of Geological Societies Transactions*, v. 8, p. 43-75.
- Saucier, R. T. and Fleetwood, A. R., 1970, Origin and chronologic significance of Late Quaternary terraces, Quachita River, Arkansas and Louisiana: *Geological Society of America Bulletin*, v. 81, p. 869-890.
- Schumm, S. A., 1960, The Shape of Alluvial Channels in Relation to Sediment Type: Professional Paper 352-B, United States Geological Survey, Washington, D. C.
- Schumm, S. A., 1969, River metamorphosis: *Proceedings of the Journal of the Hydraulics Division, American Society of Civil Engineers*, v. 95, p. 255-273.
- Thomas, M. A., 1990, The Impact of Long-Term and Short-Term Sea Level Change on the Evolution of the Wisconsinan-Holocene Trinity/Sabine Incised Valley System, Texas Continental Shelf: Unpublished Ph.D. Dissertation, Rice University, Houston, TX.
- Thomas, M. A. and Anderson, J. B., 1994, Sea level controls on the facies architecture of the Trinity/Sabine incised valley system, Texas Continental Shelf. *in* R. M. Dalrymple, R. Boyd, and B. A. Zaitlin, eds., *Incised Valley Systems: Origins and Sedimentary Sequences: SEPM Special Publication 51*, p. 63-82.
- Toomey, R. S. III, Blum, M. D., and Valastro, S. Jr., 1993, Late Quaternary climates and environments of the Edwards Plateau, Texas: *Global and Planetary Change*, v. 7, p. 299-320.
- Waters, M. R. and Nordt, L. C., 1995, Late Quaternary floodplain history of the Brazos River in east-central Texas: *Quaternary Research*, v. 43, p. 311-319.
- Wendland, W. M., 1977, Tropical storm frequencies related to sea-surface temperatures: *Journal of Applied Meteorology*, v. 16, p. 477-481.

- White, K. L. and Wiegand, K. C., 1989, Geomorphic analysis of floodplain sand mounds, Navasota River, Texas: Bulletin of the Association of Engineering Geologists, v. 26, p. 477-500.
- Williams, D. F., Thunnell, R. C., Tappa, E., Rio, D., and Raffi, I., 1988, Chronology of the Pleistocene oxygen isotope record, 0-1.88 million years before present: Paleogeography, Paleoclimatology, and Paleoecology, v. 64, p. 221-240.
- Winker, C. D., 1979, Late Pleistocene Fluvial-Deltaic Deposition on the Texas Coastal Plain and Shelf: Unpublished MA Thesis, University of Texas at Austin, Austin, Texas.
- Wolman, M. G. and Miller, J. P., 1960, Magnitude and frequency of forces in geomorphic processes: Journal of Geology, v. 68, p. 54-74.
- Wolman, M. G. and Gerson, R., 1978, Relative scales of time and effectiveness of climate in watershed geomorphology: Earth Surface Processes, v. 3, p. 189-208.

FIGURE CAPTIONS

Figure 1. Geologic map of the Texas Coastal Plain between Sabine and Nueces Rivers, illustrating principal fluvial axes, the distribution of Lissie and Beaumont alluvial plain strata, and post-Beaumont valleys (simplified from DuBar et al., 1991).

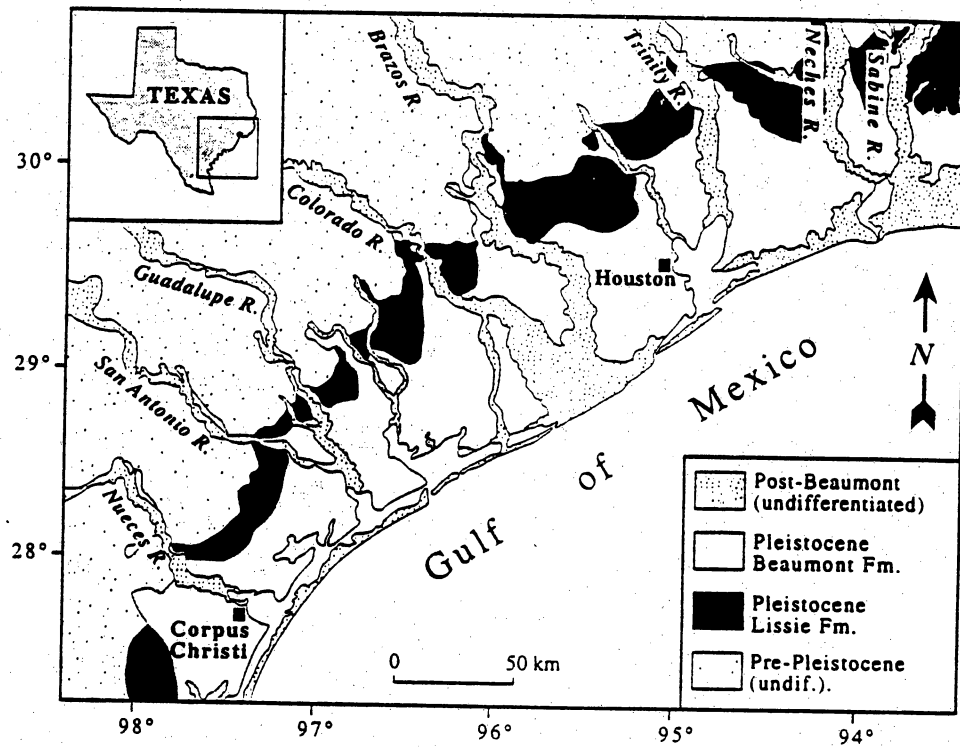
Figure 2. (a) Surficial geologic map of the lower Trinity valley. (b) Surficial geologic map of the lower Nueces valley. Maps illustrate distribution of high, intermediate, and low Deweyville terraces, plus low Deweyville channel scars (LD) now covered by thin veneers of Holocene floodplain or delta plain facies (Trinity valley). (c) Longitudinal profiles for the basin fringe Sabine, Neches, Trinity, and Nueces Rivers. B = Pleistocene Beaumont surface, HD = highest "Deweyville" terrace, ID = intermediate "Deweyville" terrace, LD = lowest "Deweyville" terrace, and HF = Holocene floodplain. For the Sabine, Neches, and Trinity, the lowest "Deweyville" profile coincides with, or dips below, the Holocene floodplain, and is not plotted separately.

Figure 3. (a) Surficial geologic map of the lower Colorado valley between Columbus and Garwood, TX., illustrating distribution of Beaumont, "Deweyville", and Holocene landforms and deposits. Note that different "Deweyville" terraces have not been differentiated. (b) Long profiles of depositional surfaces in Colorado valley between Ellinger and Wharton, TX., illustrating onlap of "Deweyville" surfaces by deposits of Holocene age between towns of Eagle Lake and Garwood. Adapted from Blum and Valastro (1994).

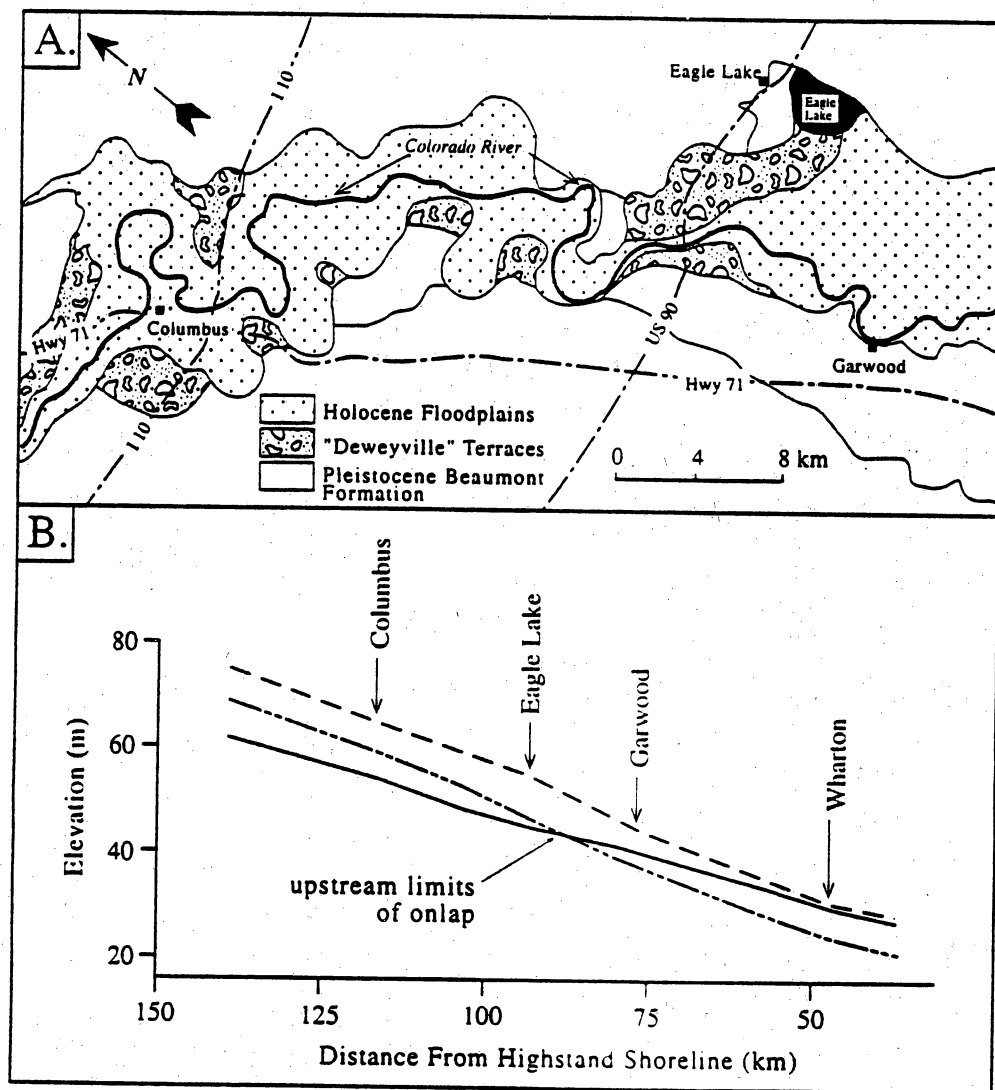
Figure 4. Schematic valley cross-sections contrasting "Deweyville allostratigraphy" in different geomorphic settings along the Texas Coastal Plain, at similar distances updip from modern highstand shorelines. (a) Low-gradient basin fringe fluvial axis, where high and intermediate Deweyville surfaces remain as terraces, but low Deweyville surfaces occur at the same elevation as modern floodplains, and are veneered by floodplain / delta plain strata. (b) Steep-gradient basin fringe fluvial

axis, where low Deweyville surfaces remain as a terrace above modern floodplains until overlapped at modern bay-head deltas. (c) Extrabasinal fluvial axes, where all "Deweyville" surfaces have been overlapped and buried by Holocene strata, and post-Beaumont valleys are nearly filled. Relative scale of valley fill sequences as indicated. "Deweyville" allostratigraphic units are shown occurring on one side of the valley for illustration purposes only.

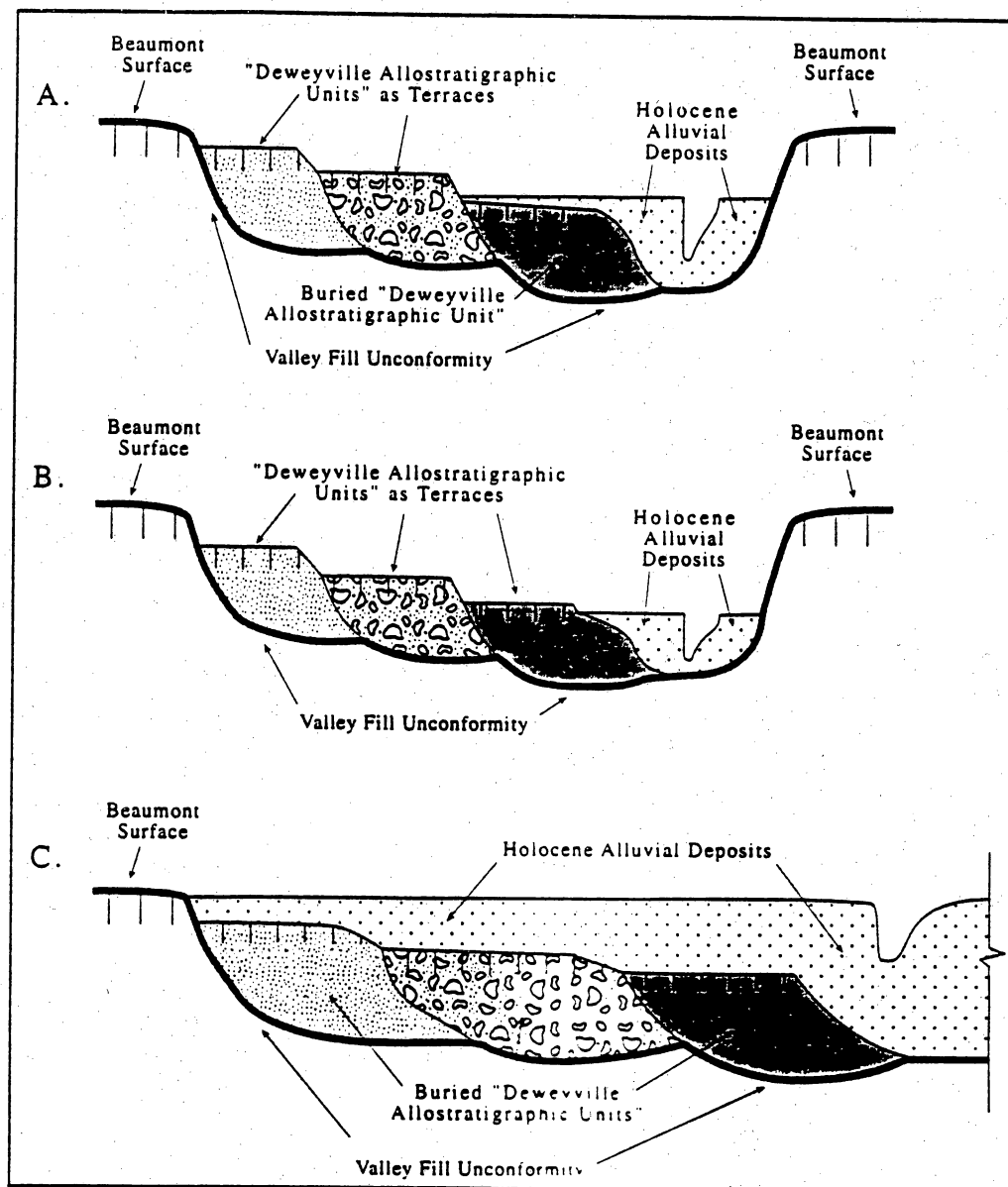
Figure 5. (a) Eustatic sea level curve inferred from oxygen isotopes for last 125 ky (adapted from Chappell and Shackleton, 1986), with shaded area representing inferred depths of -15 to -65 m below present. (b) Schematic illustration of differences between interglacial highstand, intermediate glacial period, and full-glacial lowstand shoreline positions. As in Figure 5a, shaded area represent depths of -15 to -65 m below present. Based in part on J. R. Suter (pers. communication, 1995).



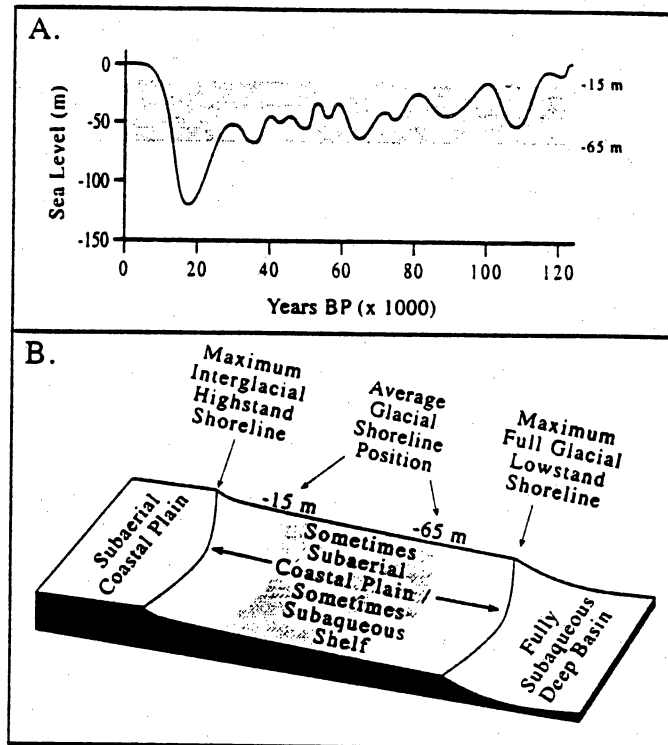
Blum et al. - Fig. 1



Blum et al. - Fig. 3



Blum et al. - Fig. 4



Blum et al. - Fig. 5

Addendum 7. Descriptions of Vibracores, Sabine Lake

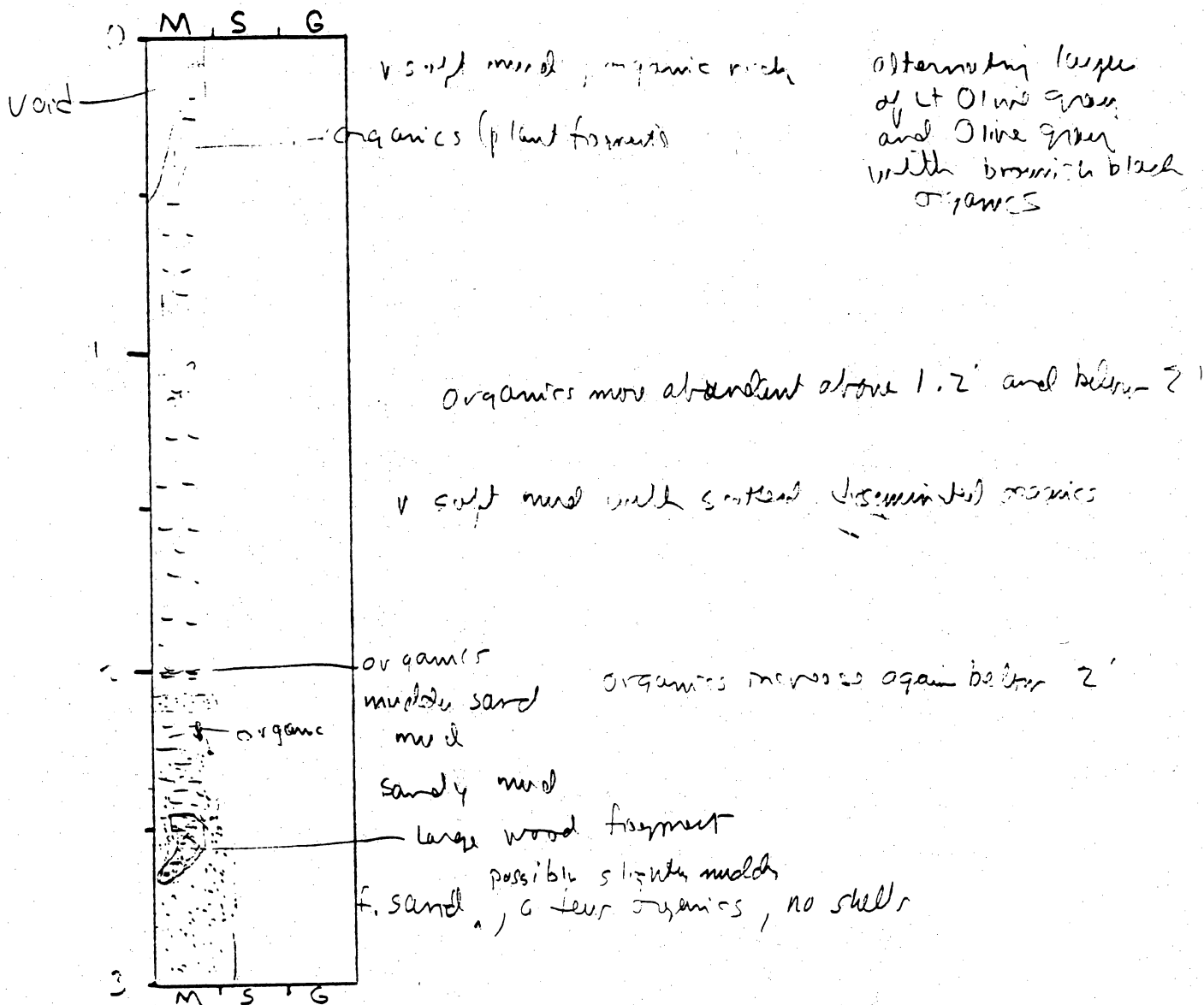
CORE LOG

CORE # SLV-11A TYPE Vibrocore LOCATION Sabine Lake - East Pass & Black Bayou
 LATITUDE 29° 54' 00" LONGITUDE 90° 45' 12" SURFACE ELEVATION -51'
 DEPTH PENETRATED ? LENGTH RECOVERED 16' 9" % COMPACTION ?

OBTAINED BY C. B. B. - R. H. K. Jones
 DESCRIBED BY W. H. B.

DATE 10-17-92
 DATE 11-1-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



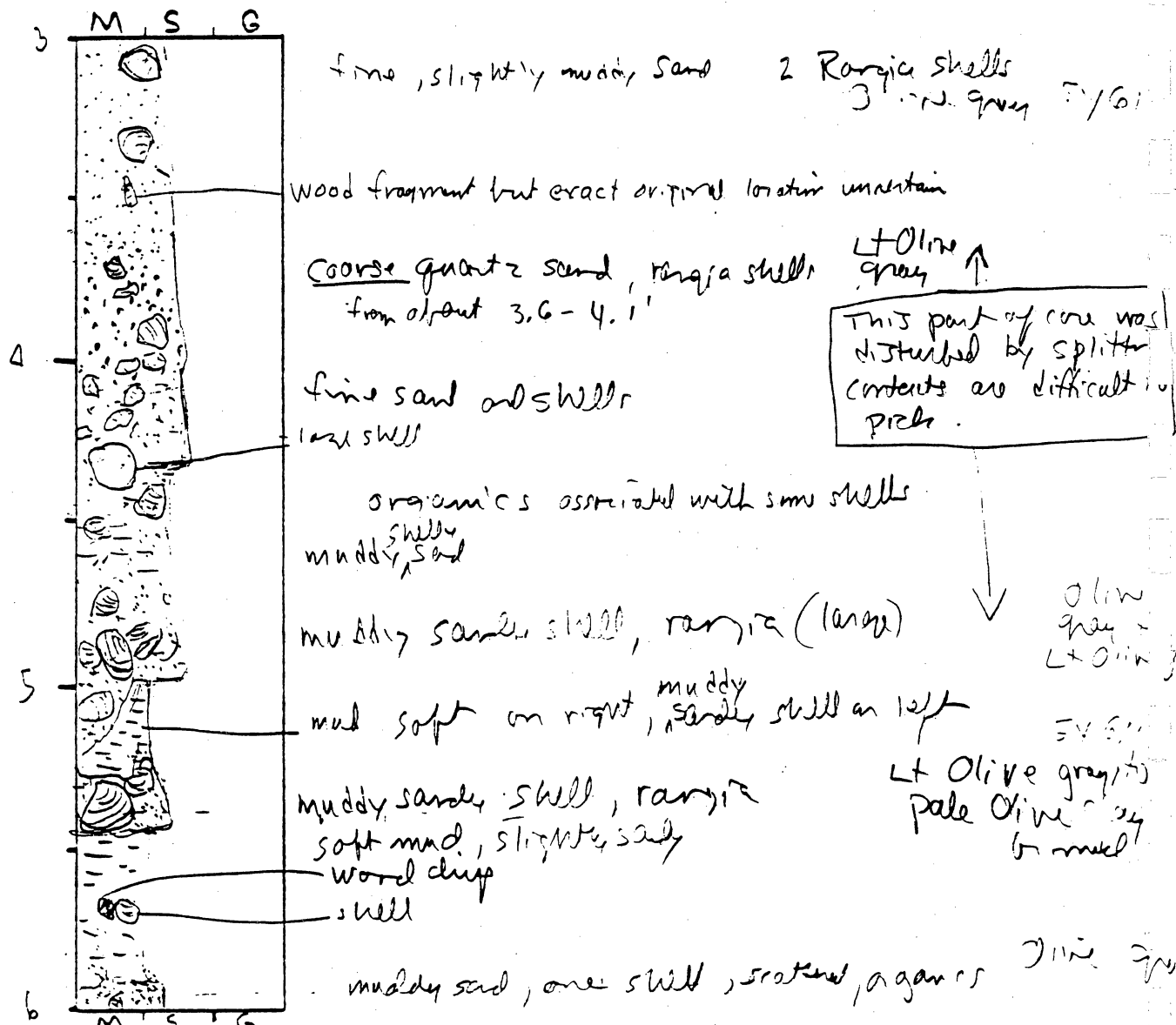
General Comments:

CORE LOG

CORE # SLV-1 (3) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



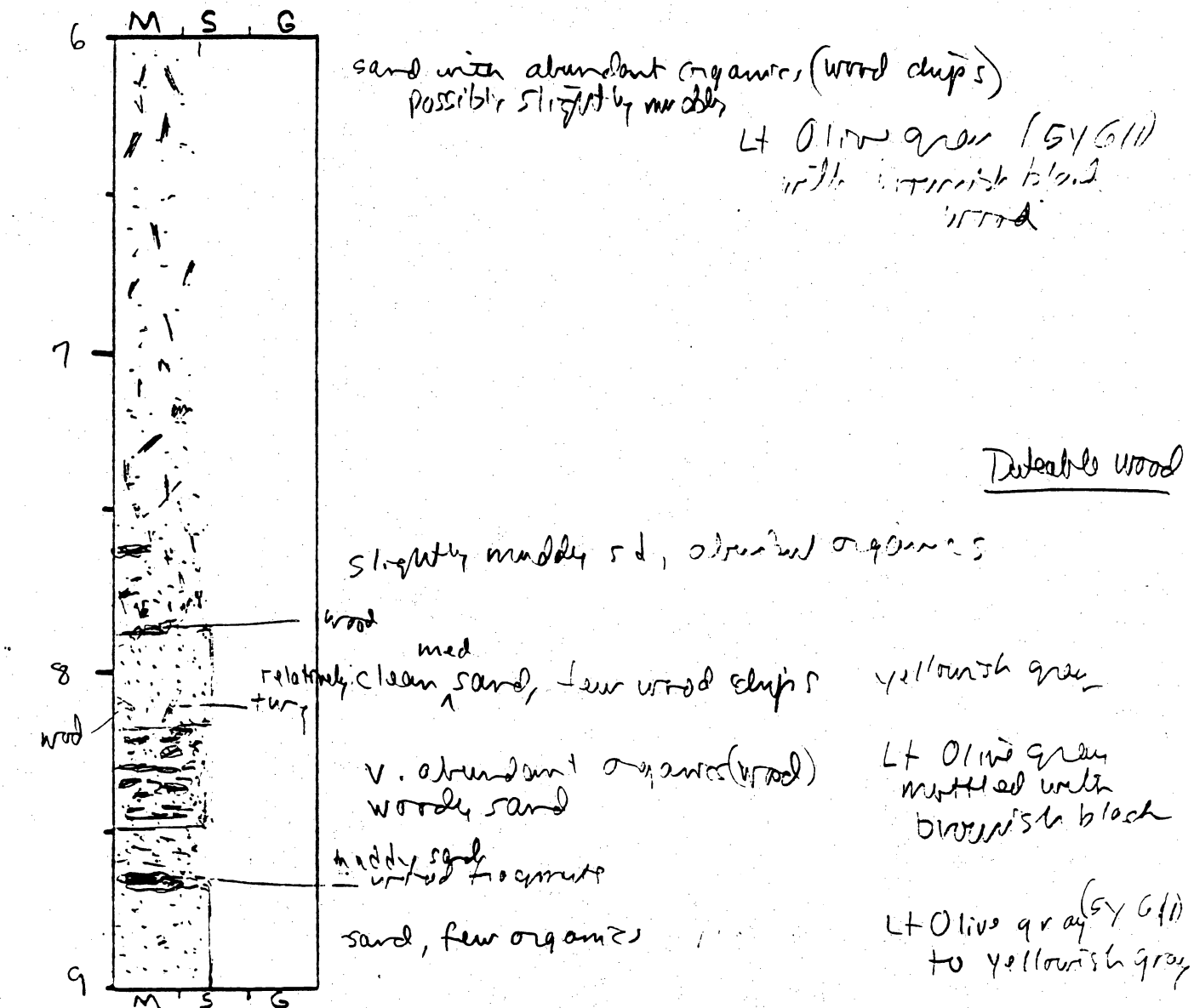
General Comments:

CORE LOG

CORE # SLV-1 (C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



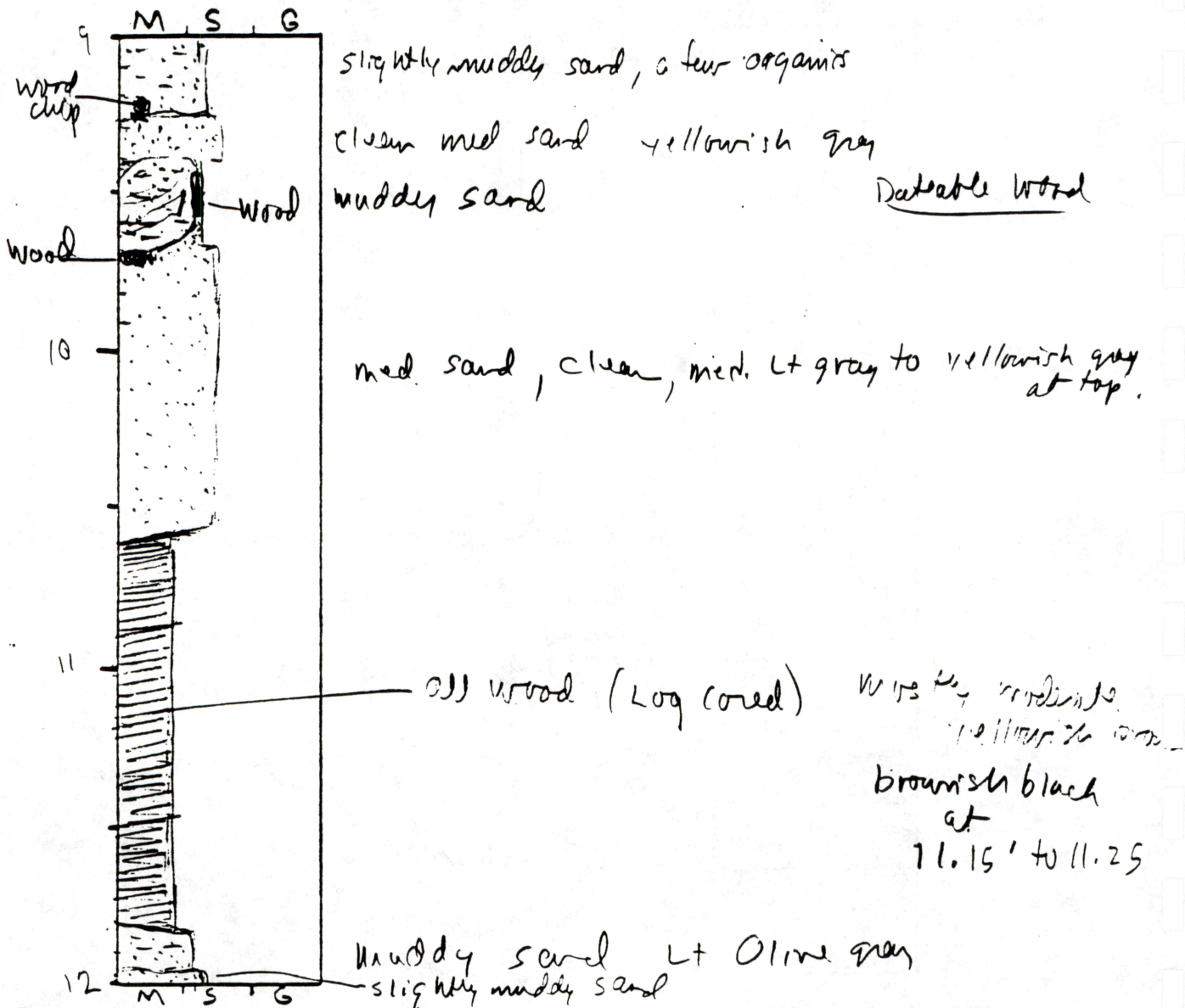
General Comments:

CORE LOG

CORE # SLV-11D TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft. m) SKETCH LITHOLOGY STRUCTURE REMARKS



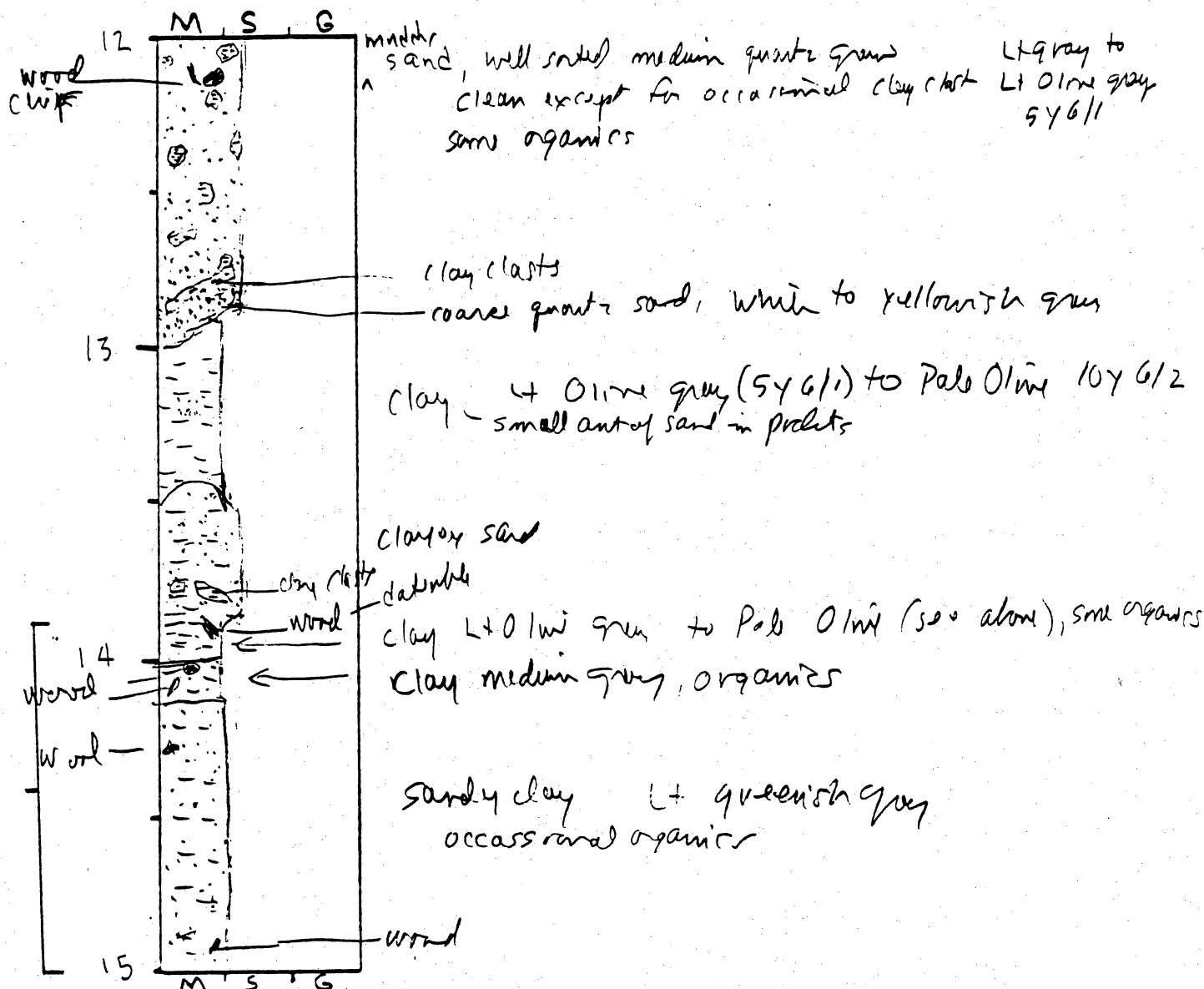
General Comments:

CORE LOG

CORE # SLV-1 (E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft. m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



General Comments:

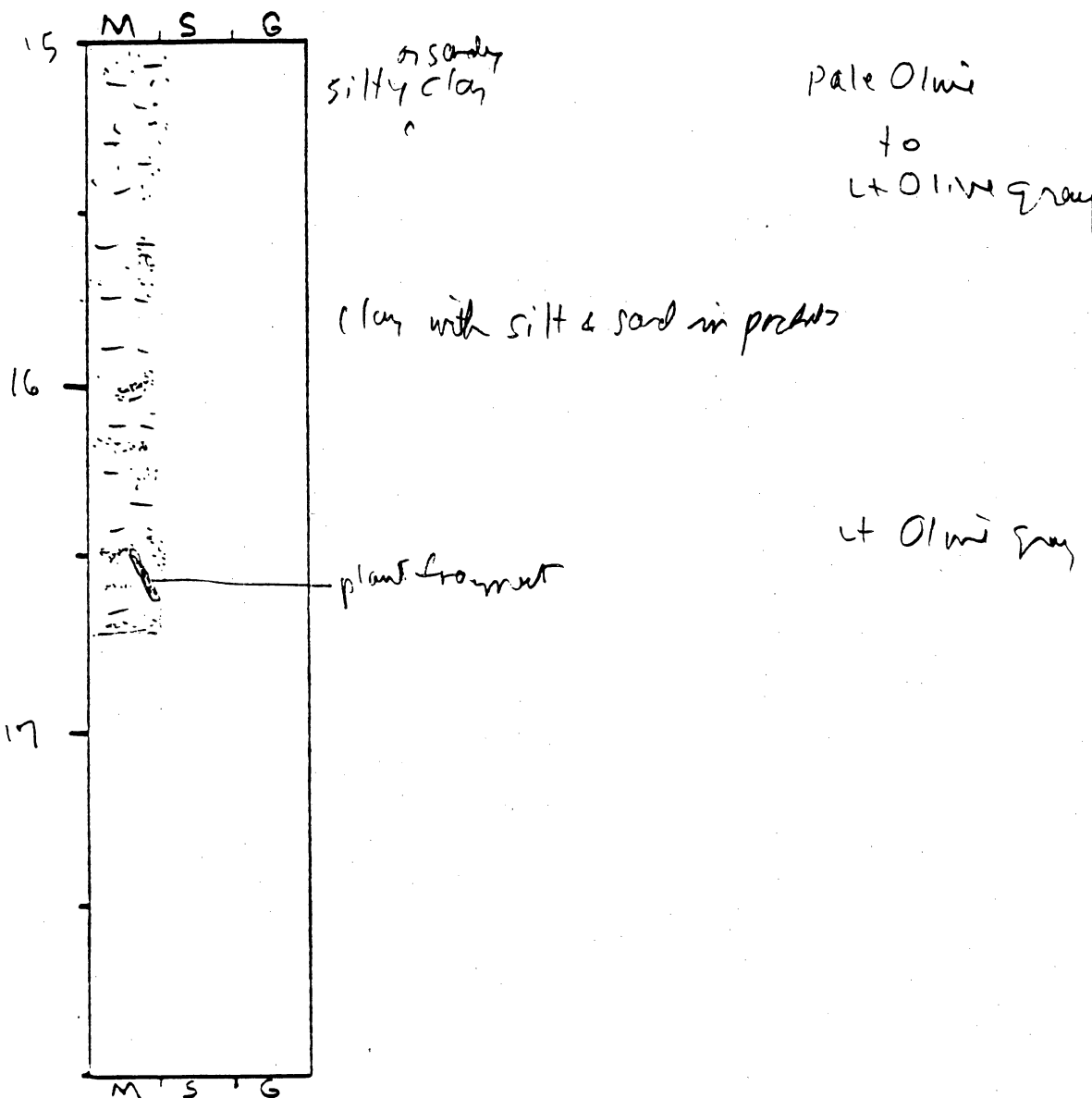
6980
years
B.P.

CORE LOG

CORE # SLV-1 (F) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft. m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



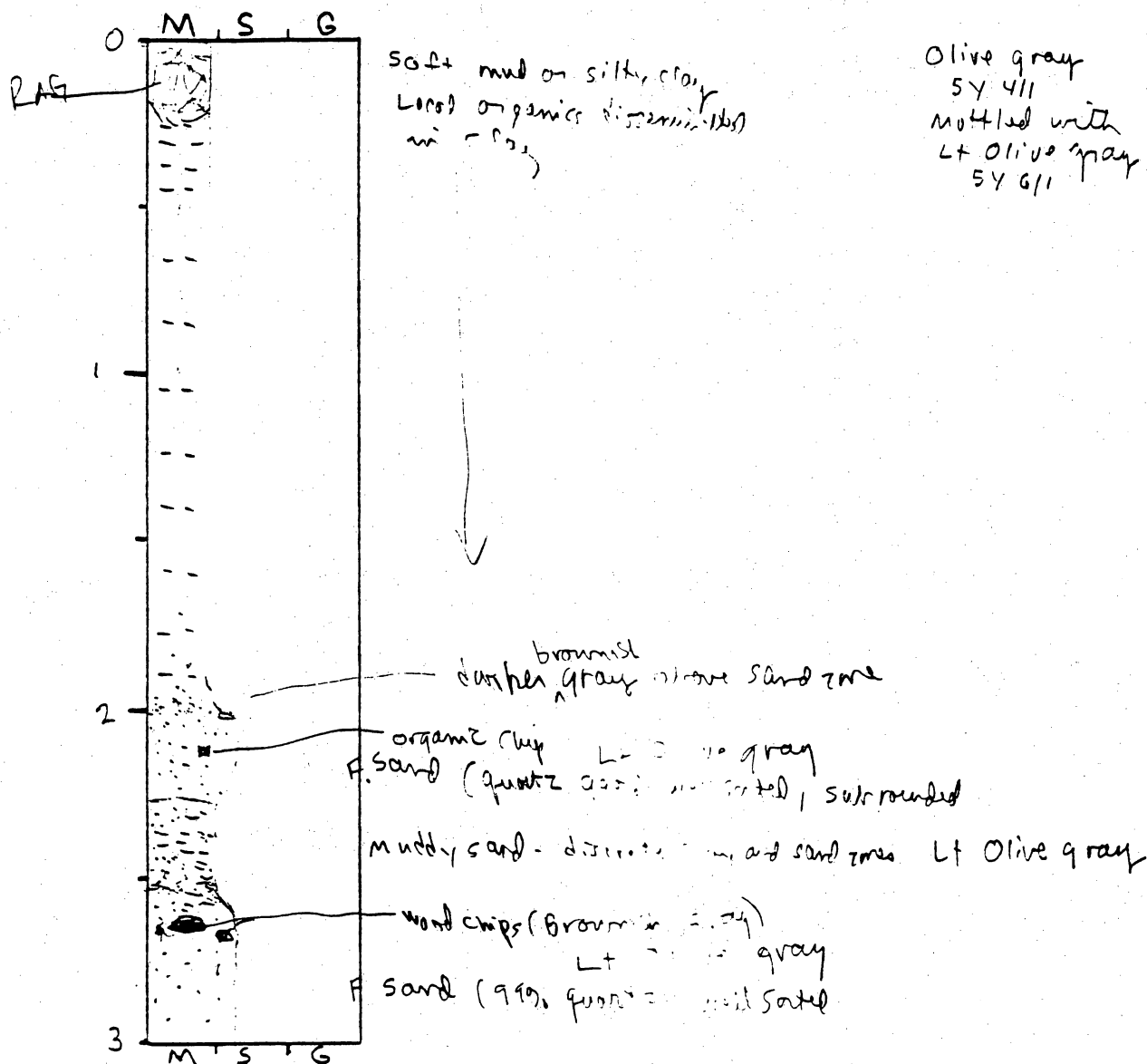
General Comments:

CORE LOG

CORE # SLV-2(A) TYPE Vibracore LOCATION Sabine Lake
 LATITUDE 29° 52.980 LONGITUDE 93° 46.00 SURFACE ELEVATION -19.5'
 DEPTH PENETRATED ? LENGTH RECOVERED 17'0" % COMPACTION ?

OBTAINED BY Gibeault - R/V Kit Jones DATE 10-8-94
 DESCRIBED BY White DATE

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



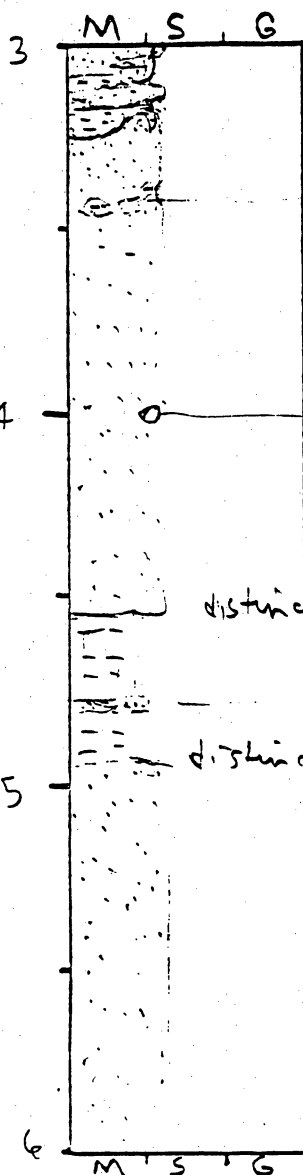
General Comments:

CORE LOG

CORE # SLV-2(B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft. m) SKETCH LITHOLOGY STRUCTURE REMARKS



Interbedded sand & clay
 but possible, flattened clasts

Fine sand, quartz, well sorted, subrounded
 clay clasts

Lt Olive gray 5y 6/1
 to yellowish gray in sand

4 shell (only one well worn (uncertain if this is proper depth because of disturbance of core along split margin))

distinct contour clay Lt Olive gray with dark organic specks

muddy sand layer

distinct contour

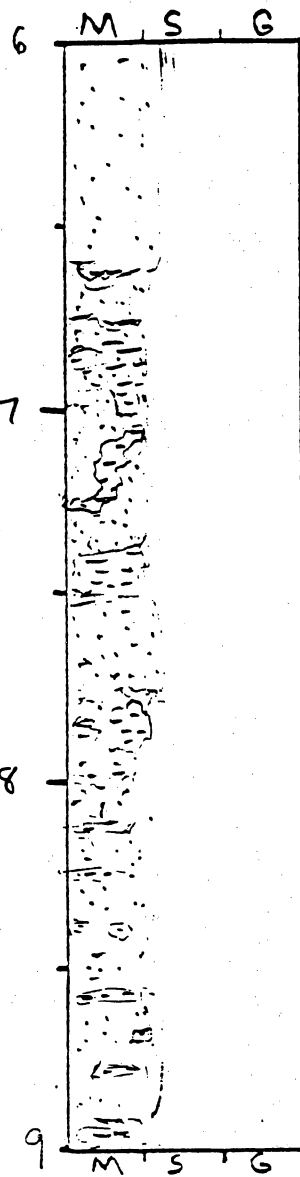
Fine well sorted quartz sand
 Lt Olive gray (5y 6/1) to yellowish gray

General Comments:

CORE LOG

CORE # SLV-2(C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



sand

Lt olive grey sand 5y 6/1

some thin interbedding of clay & sand or possibly
clattered clasts

clayey sand (common abundant from below)

clay clast, some questionable layers

clay color is pale olive

sand slightly muddy

muddy clayey sand

discrete clay clasts

Lt Olive grey sand

5y 6/1

Pale Olive clay

10Y 6/2

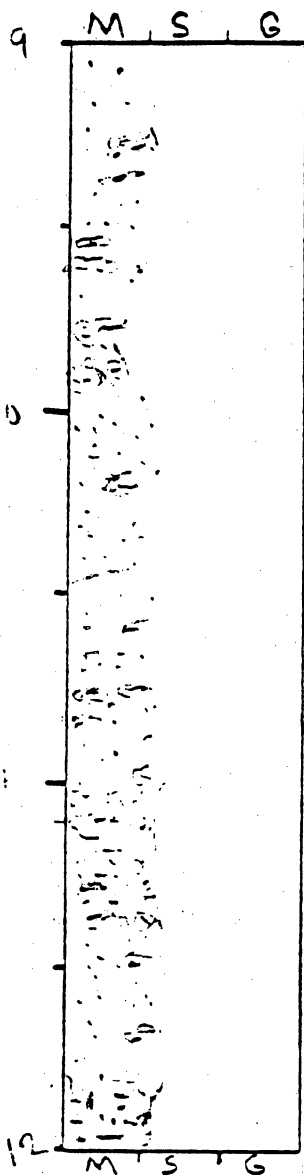
General Comments:

CORE LOG

CORE # SLV-2(1D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



muddy or clayey sand
 (with distinct clasts
 of clay)

lt olive green
 sand, clay
 slightly darker

clay
 sandy mud in muddy sand

sandy clay or mud

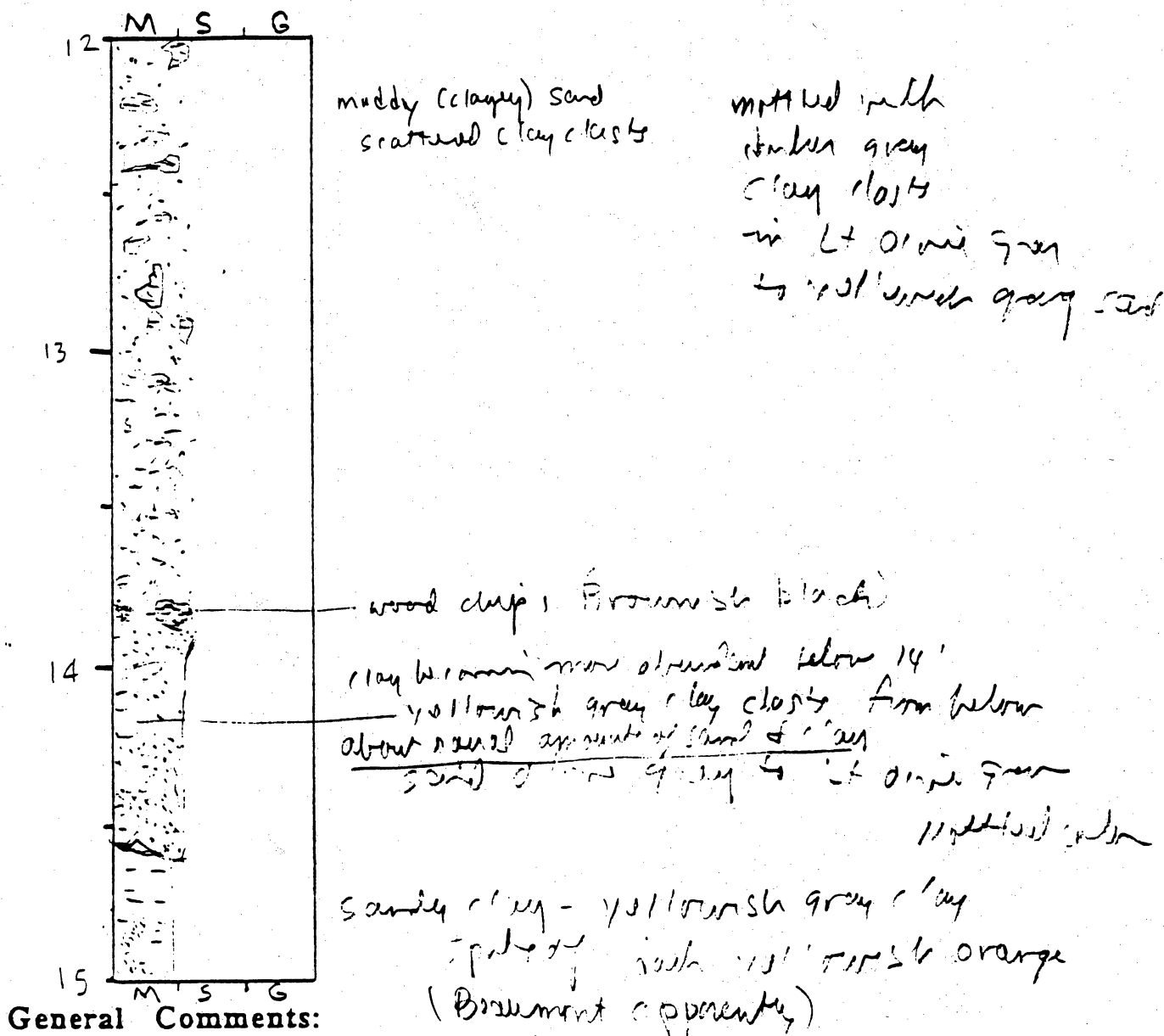
General Comments:

CORE LOG

CORE # SLV-25 TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS

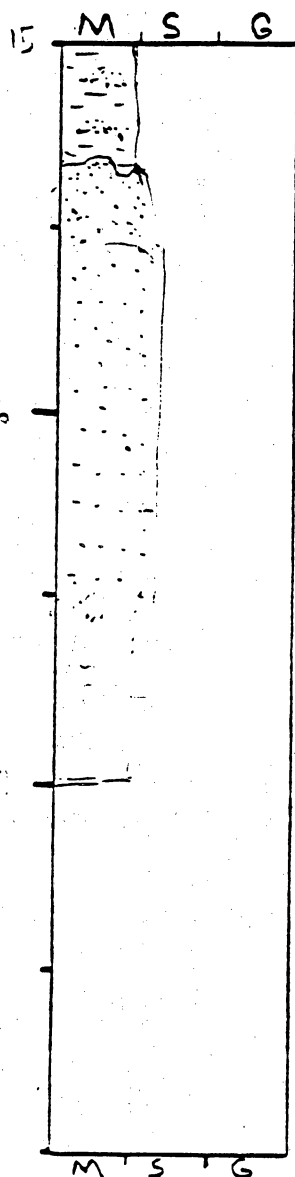


CORE LOG

CORE # SLV-2(F) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



Sandy clay

Slightly muddy sand
 sand Lt Olive gray
 5Y 6/11
 to Olive gray (5Y 4/11)

Medium sand, clean
 well sorted

yellowish gray (5Y 8/1)

Some silt
 fine

Mottled
 Clay pale olive 10Y 6/2
 to yellowish gray
 dark olive gray sand pebbles

some silt
 organics

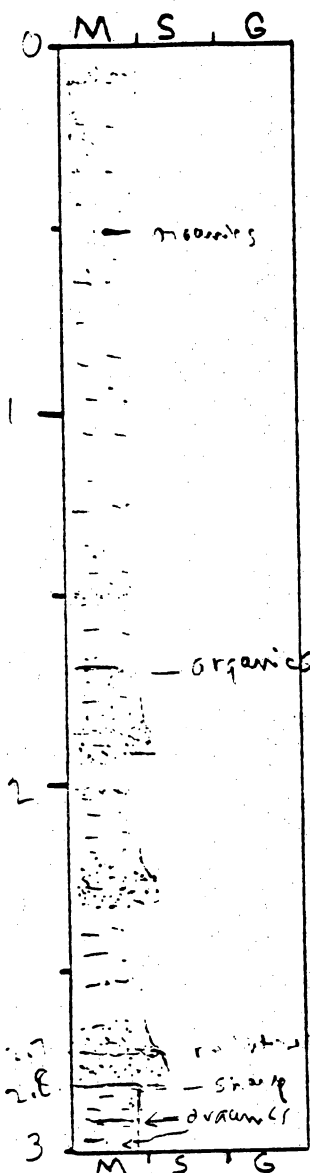
General Comments:

CORE LOG

CORE # SLV-3 (A) TYPE Vibromore LOCATION Sabine Lake
 LATITUDE 29° 59.002' LONGITUDE 93° 46.617' SURFACE ELEVATION -6'
 DEPTH PENETRATED ? LENGTH RECOVERED 17' 9 1/2" COMPACTION ?

OBTAINED BY Gibeaut - R/V Kit Jones DATE 10-8-94
 DESCRIBED BY John F. DATE 2-17-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



Primarily mud to sand, mud
 abundant organic pecks
 some thin discontinuous organic
 inclusions

Alternating layers of
 Dark yellowish brown
 brownish gray and
 pale yellowish brown.

Distorted horizontal
 structures

Sand, muddy

Sand, muddy

sharp contact at top and gradually muddy sand to
 sand, clean, light gray, in color
 mud, organics

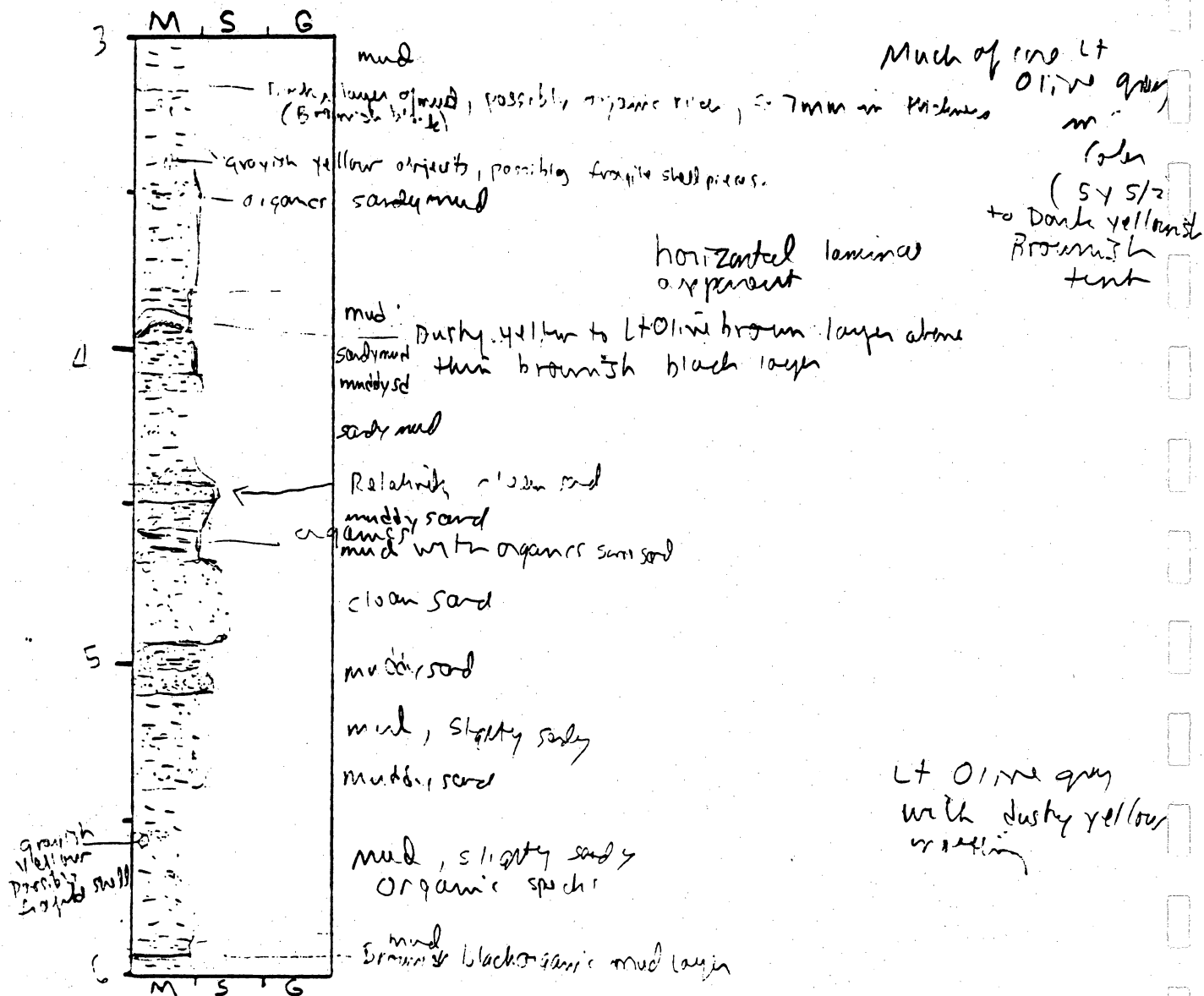
General Comments:

CORE LOG

CORE # SLV-31B TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

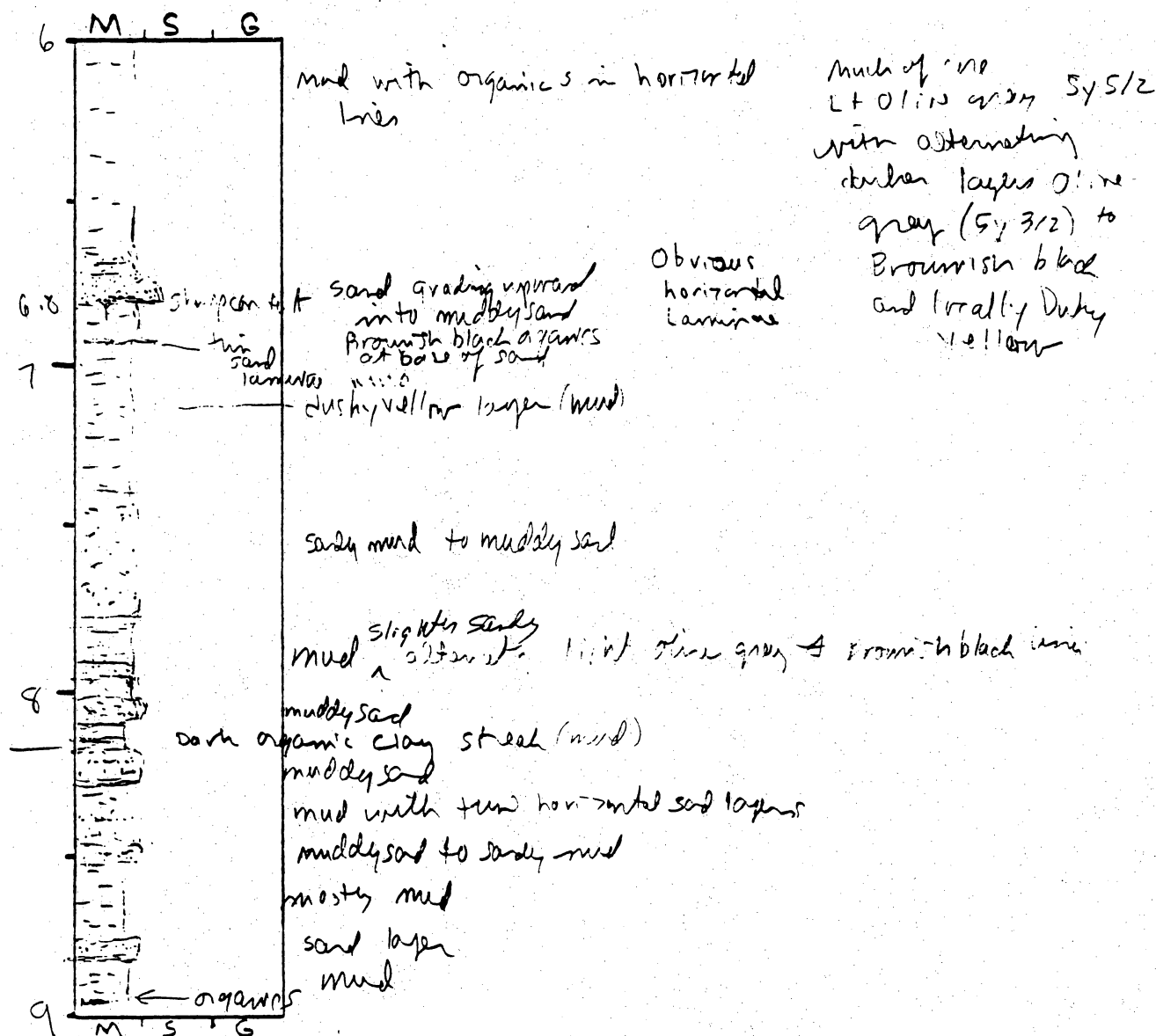


General Comments:

CORE LOG

CORE # SLV-3(C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



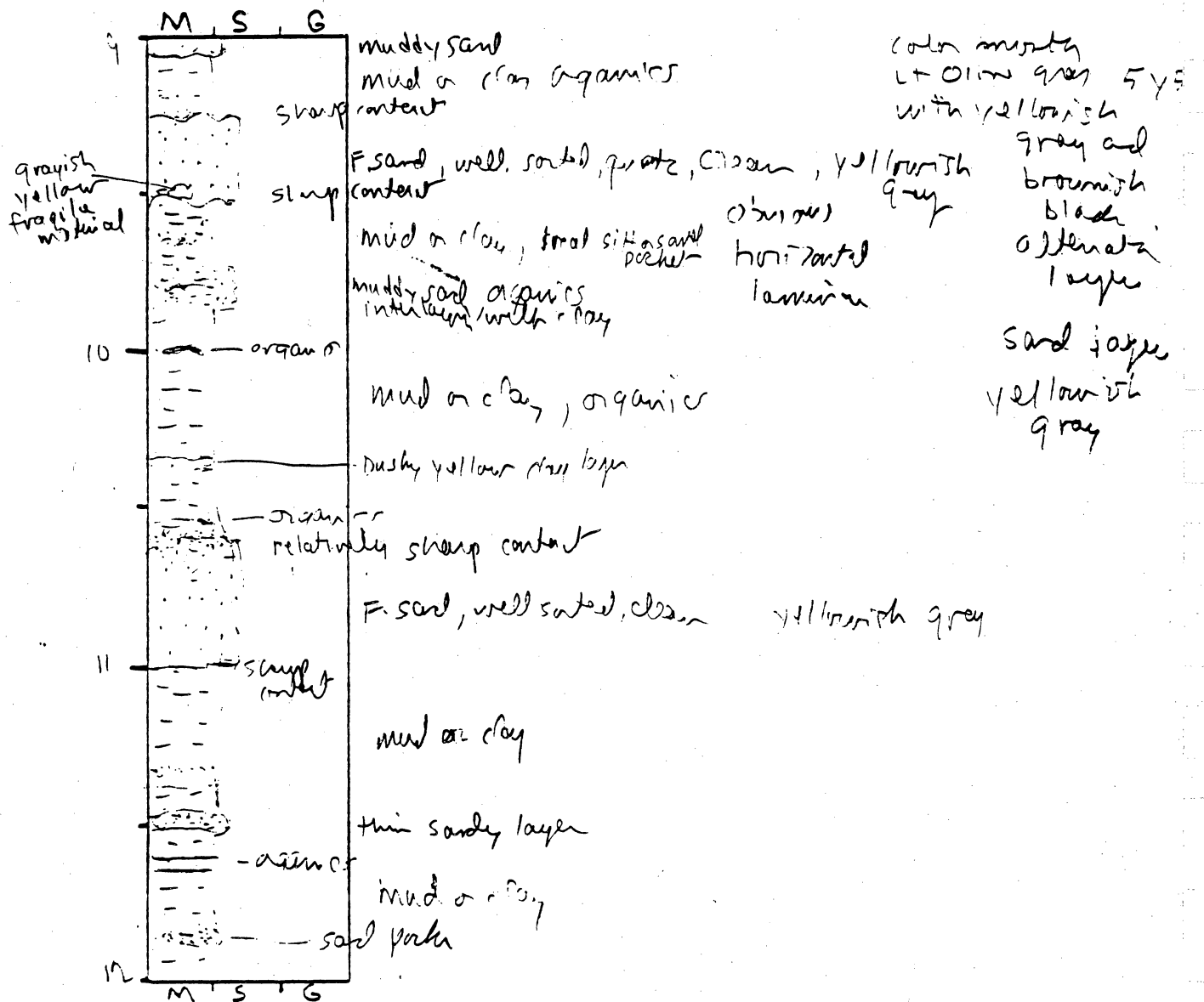
General Comments:

CORE LOG

CORE # LV-3(D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS

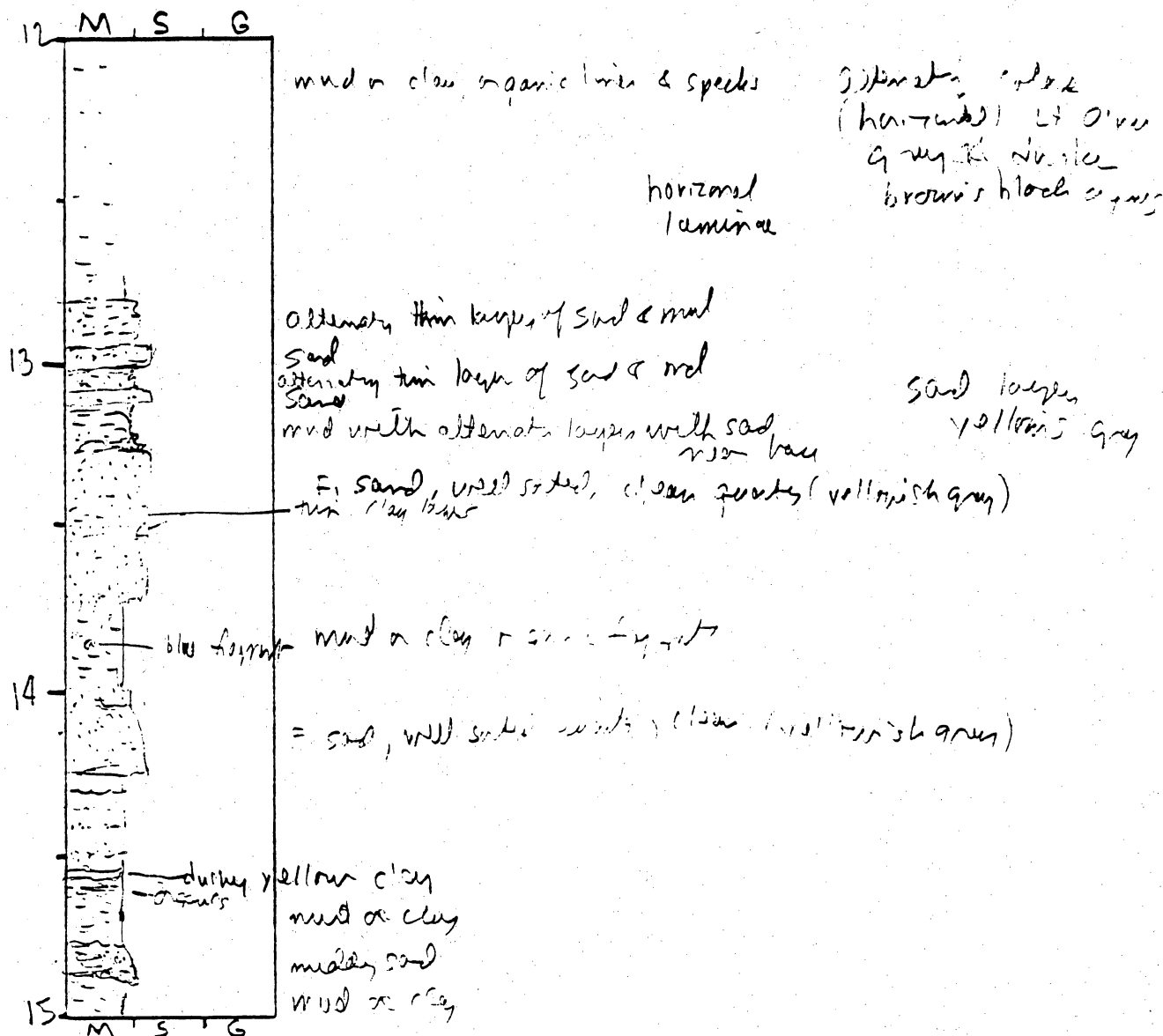


General Comments:

CORE LOG

CORE # SLV-3(E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



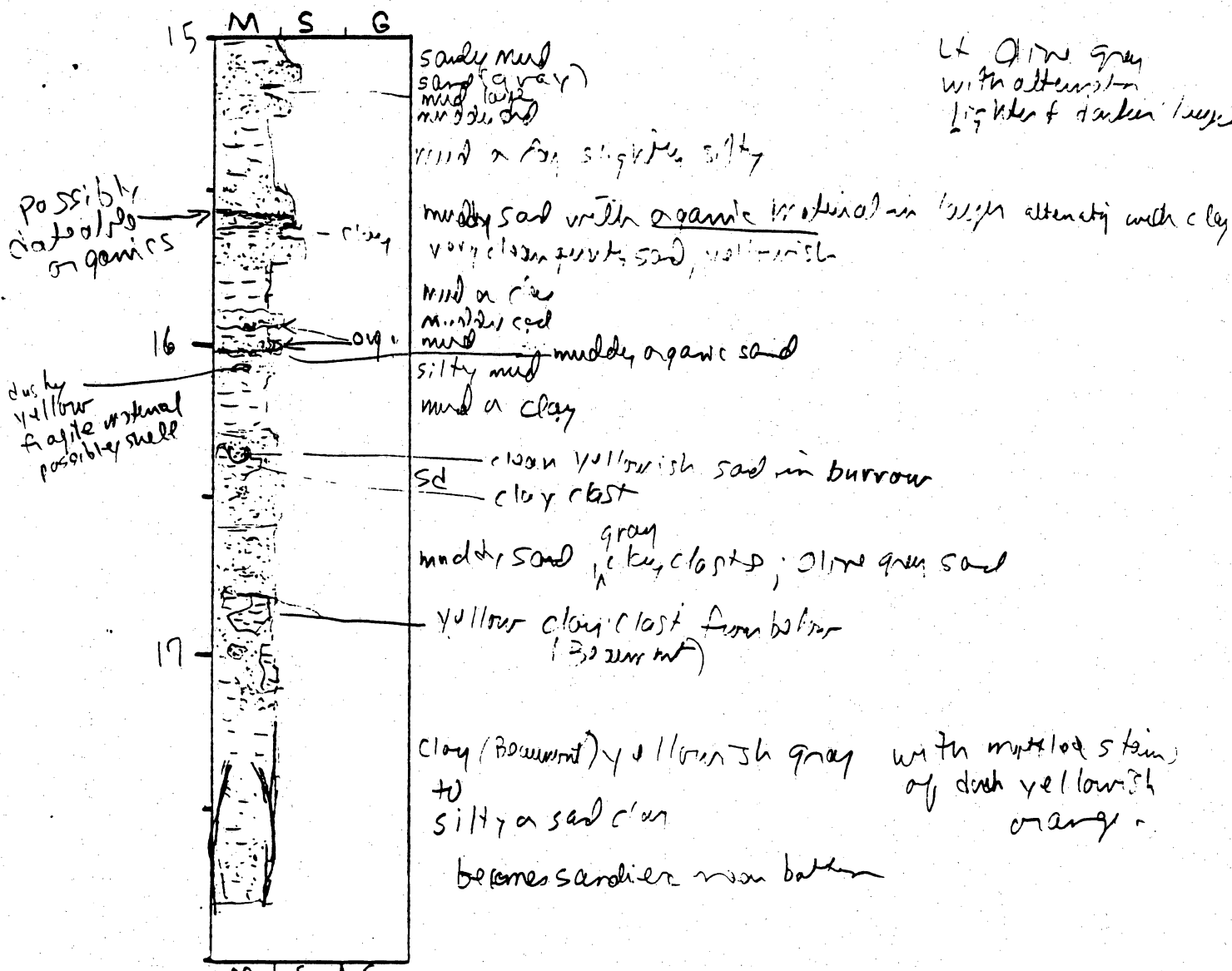
General Comments:

CORE LOG

CORE # SLV-3(F) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



General Comments:

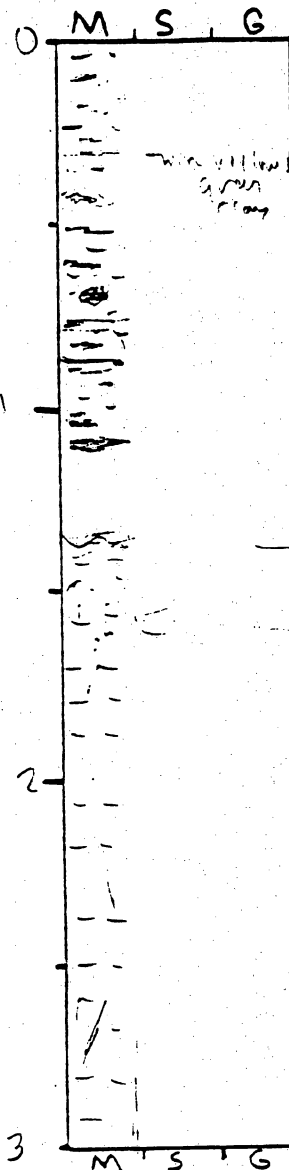
CORE LOG

CORE # SLV-4(A) TYPE Vibrocore LOCATION Sabine Lake - Poyon Plant Channel
 LATITUDE 29° 59.372' LONGITUDE 93° 53.990' SURFACE ELEVATION 5' 6"
 DEPTH PENETRATED ? LENGTH RECOVERED 19' 1 1/2" % COMPACTION ?

OBTAINED BY Gibeault - R/V K. Jones
 DESCRIBED BY (J) W. B.

DATE 10-8-94
 DATE 2-17-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



soft
 organic rich mud
 red dubriat
 various bryozoa

horizontal
 laminated

mostly
 brownish black
 organic
 material
 yellowish gray - G

reddish gray clay from agent

near base of organic rich mud
 Lt Olive gray clay becomes dominant
 decreasing organic material

homogeneous

soft
 clay on mud
 scattered plant material
 (roots)

Lt Olive green
 sand yellowish gray

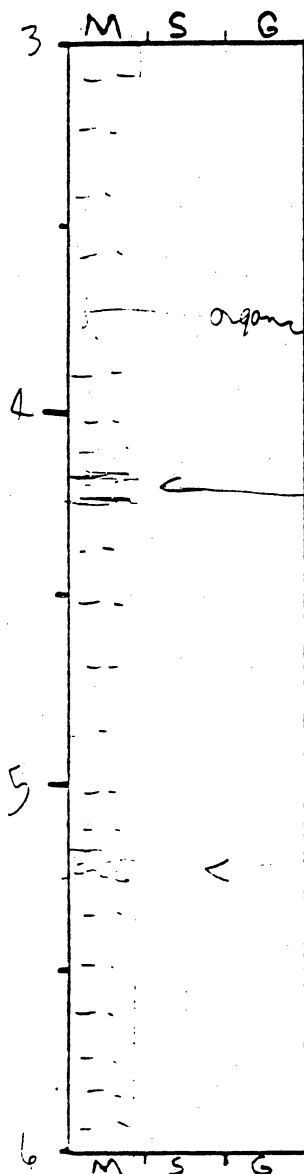
General Comments:

CORE LOG

CORE # SLV-4 (3) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



relatively homogeneous
 Lt olive green mud
 or silt clay

Lt olive gray
 5-16/1

organic (plant frag)

semi horizontal
 laminae

yellowish gray clay layer
 thin silt laminae

yellowish green clay layer
 (appear to have been affected by micro fault)

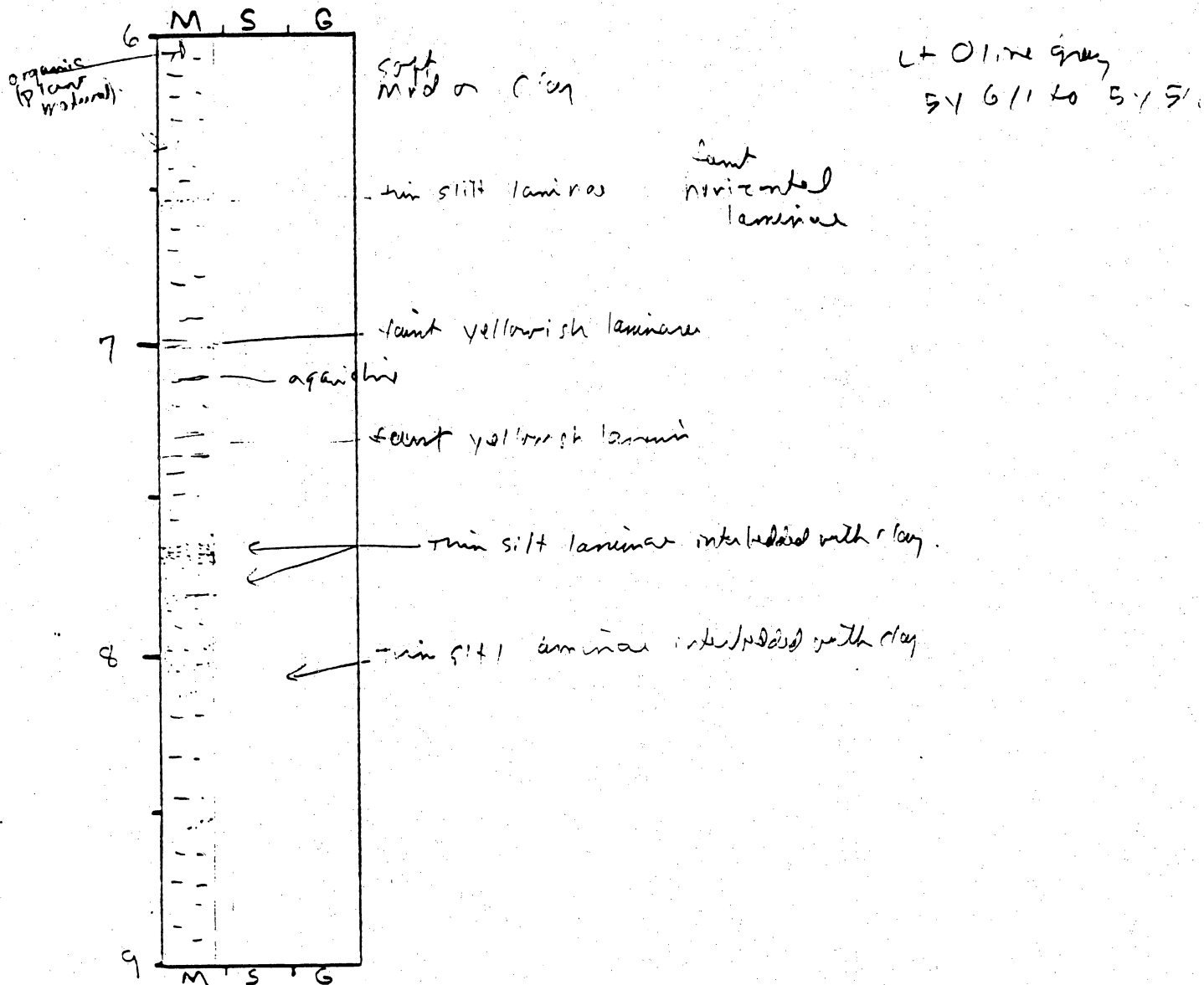
General Comments:

CORE LOG

CORE # SLV-4(2) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



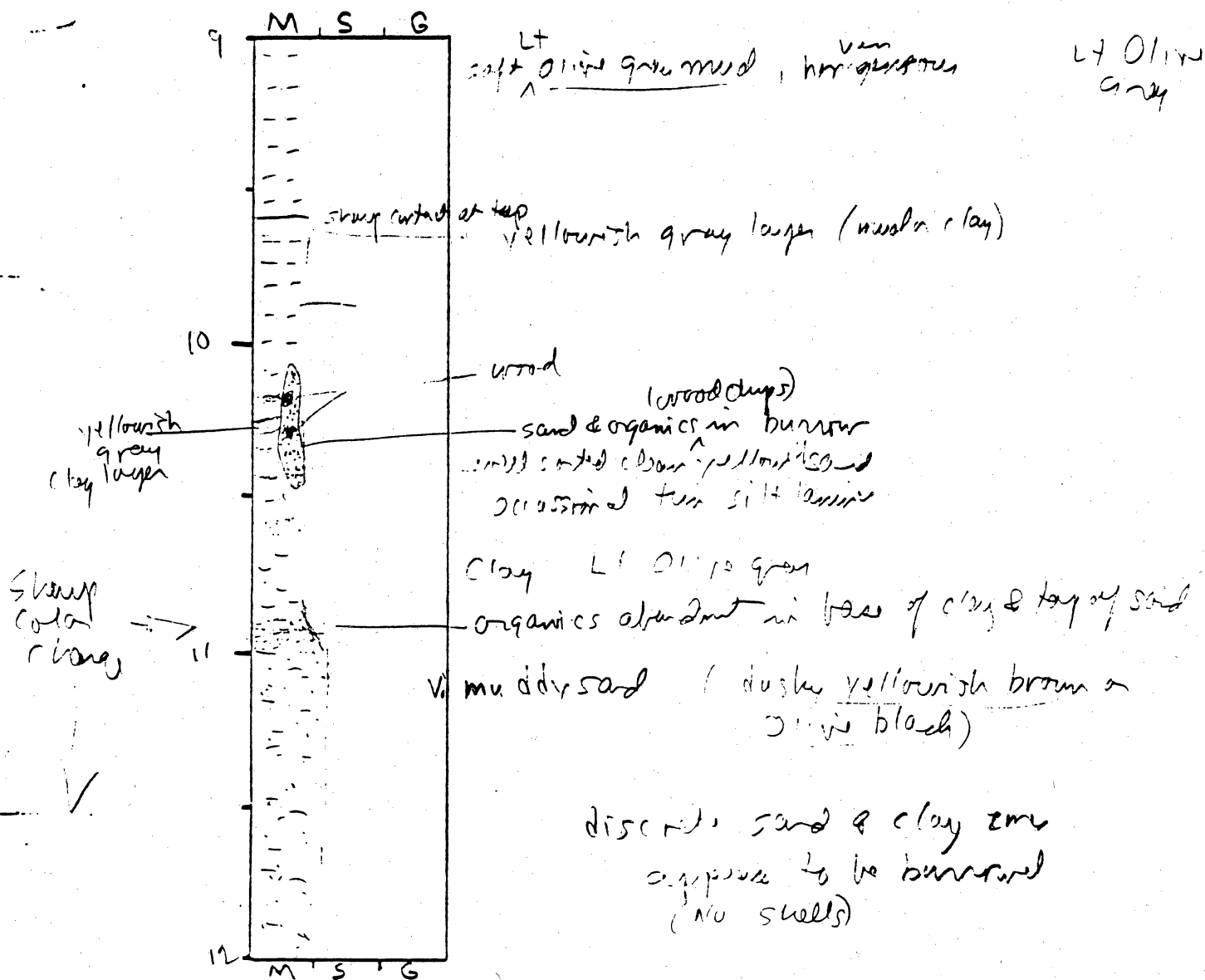
General Comments:

CORE LOG

CORE # SLV-4(D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS

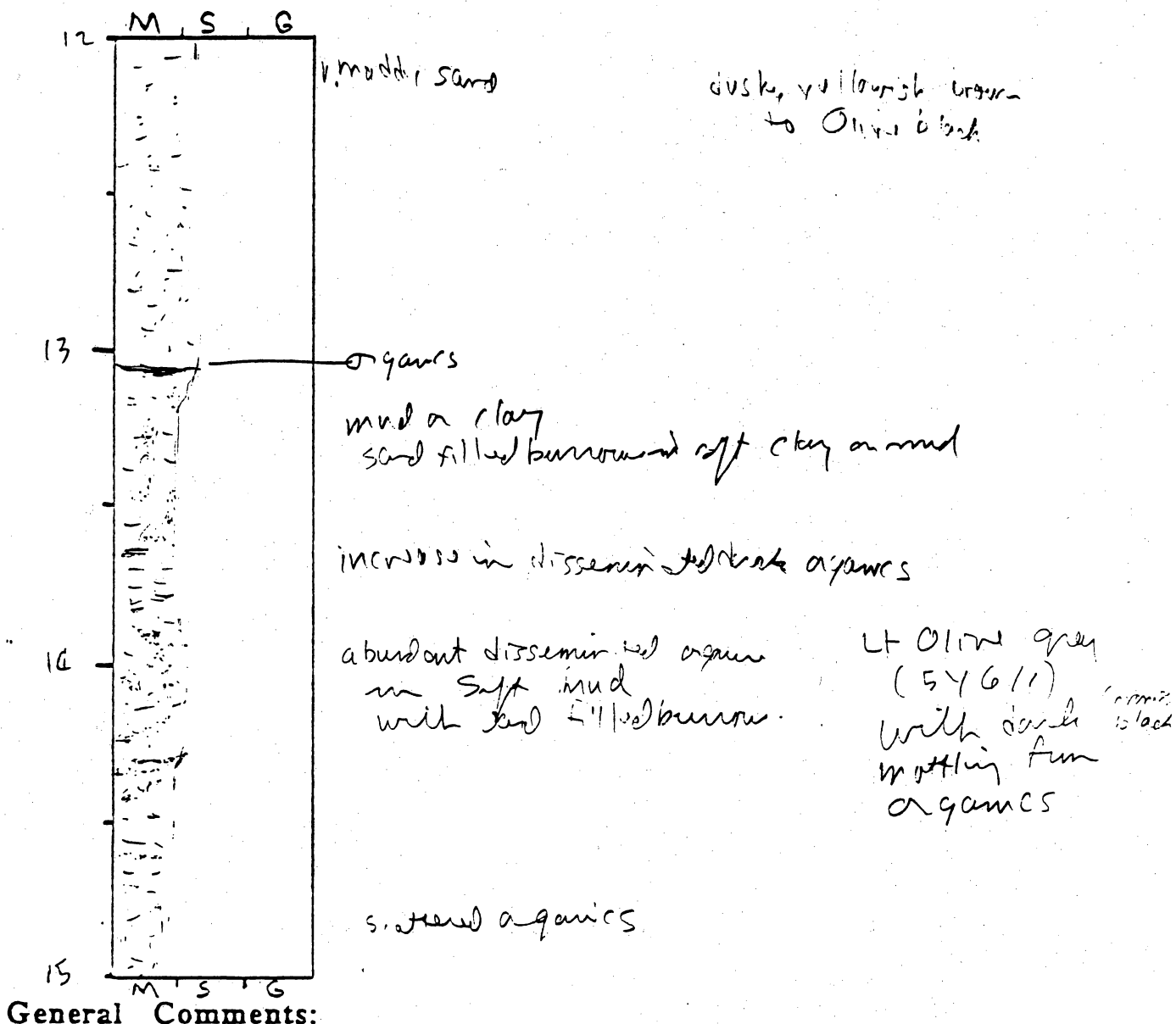


General Comments:

CORE LOG

CORE # SLV-4(E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

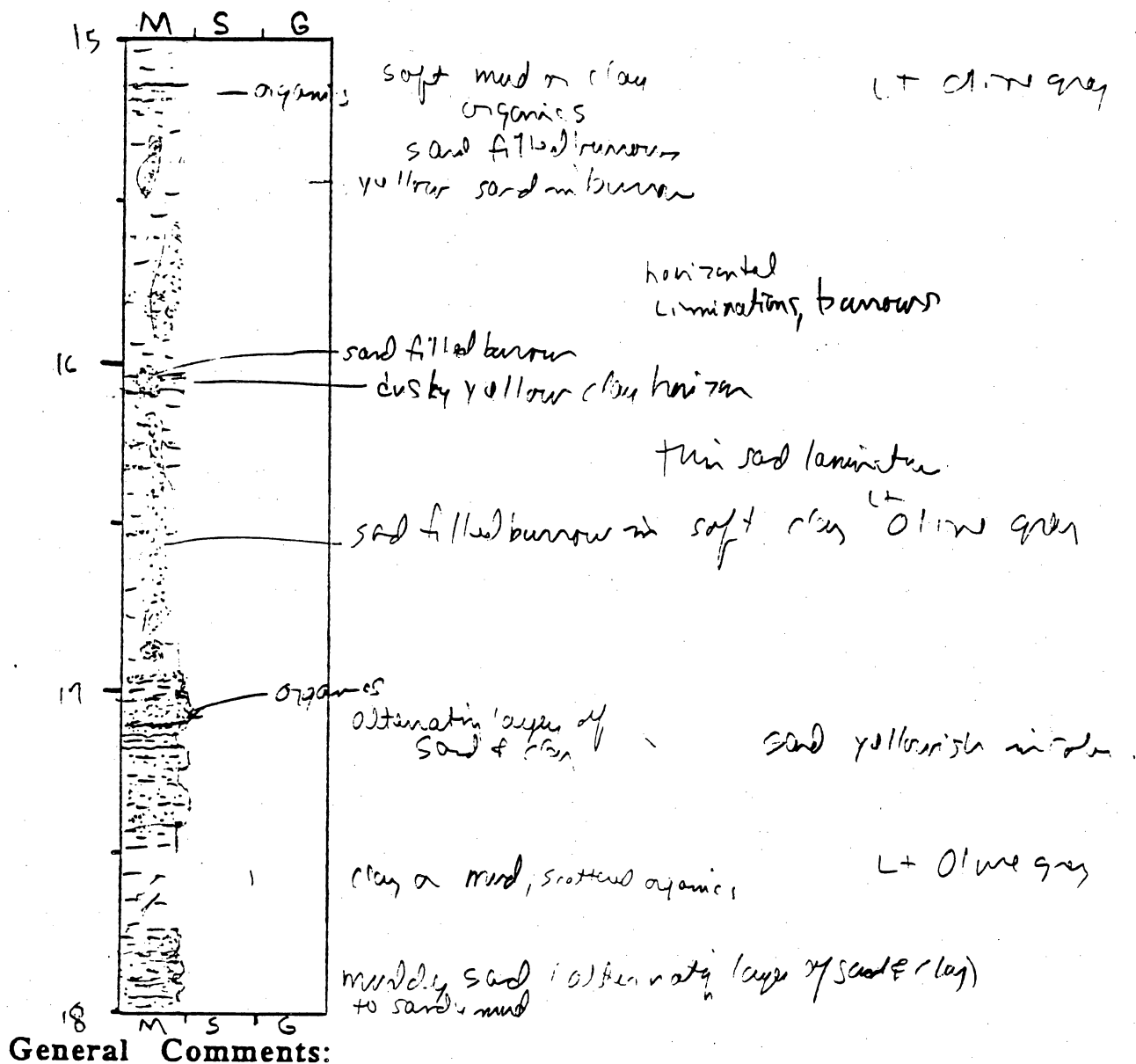


CORE LOG

CORE # SLV-41E TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH
 (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS

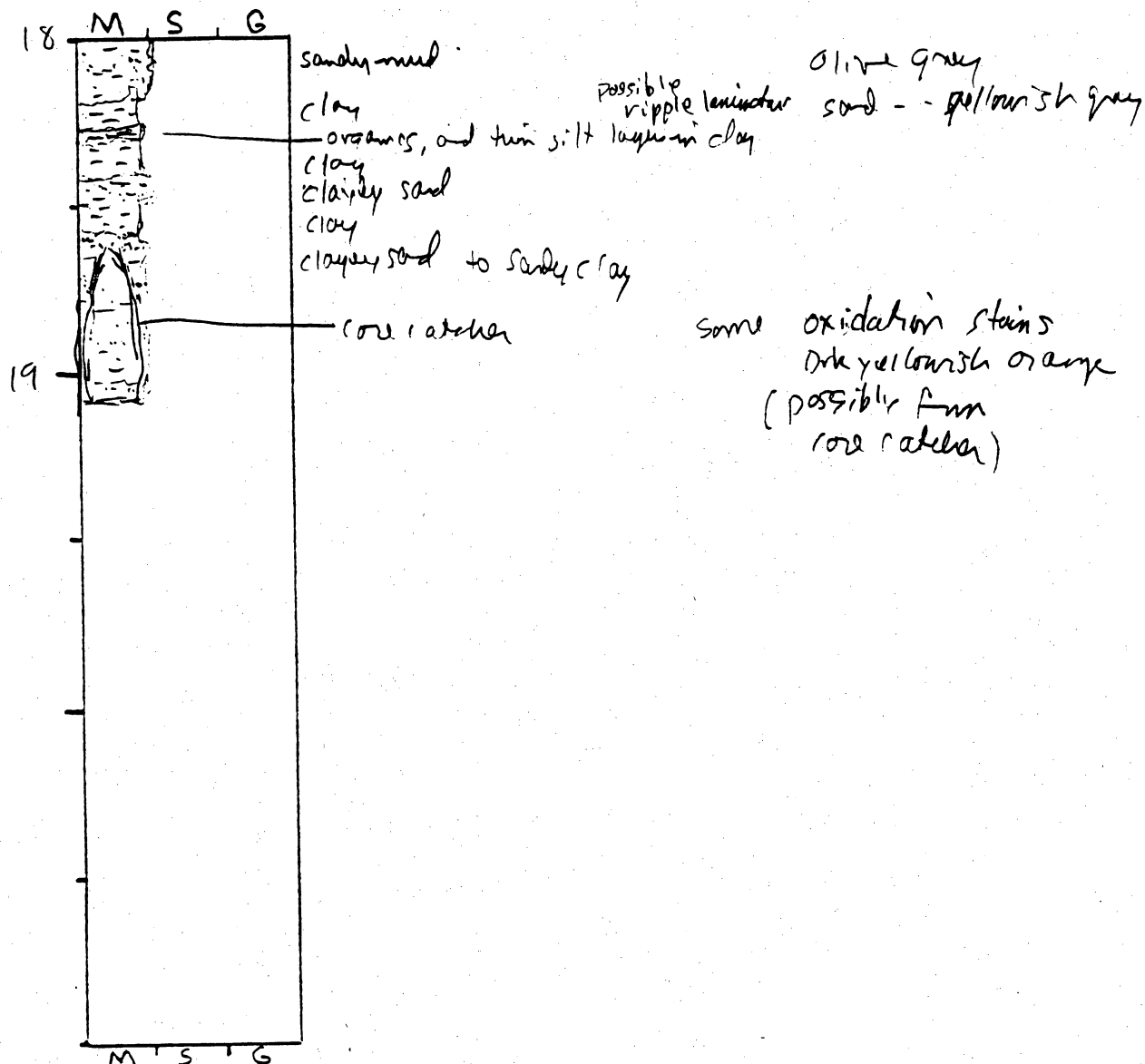


CORE LOG

CORE # SLV-4 (G) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



General Comments:

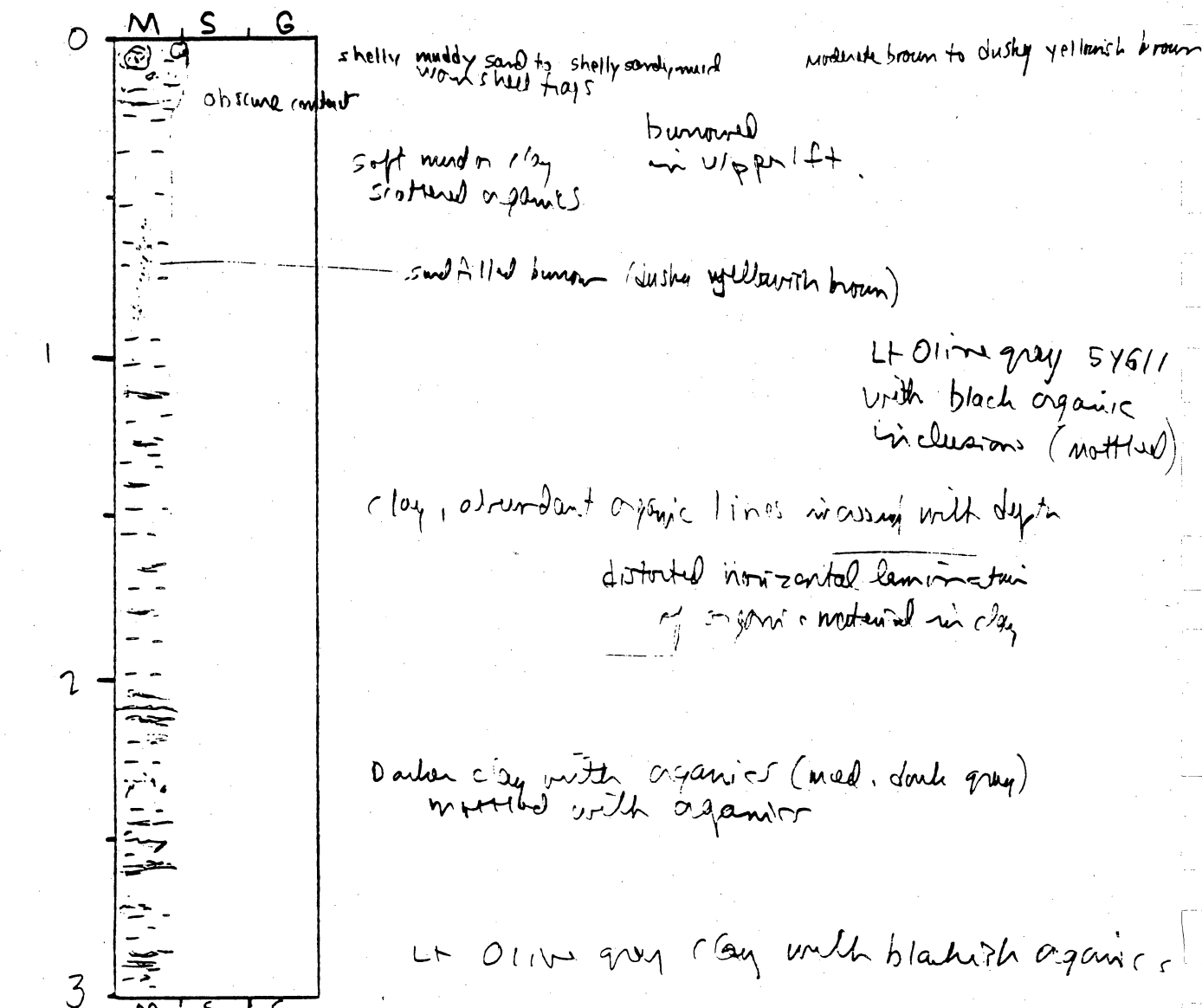
CORE LOG

CORE # SLV-5(A) TYPE V. biocore LOCATION Sabrin Lake - canal
 LATITUDE 29° 54.957' LONGITUDE 93° 54.016' SURFACE ELEVATION -15'
 DEPTH PENETRATED ? LENGTH RECOVERED 17' 3 3/4' % COMPACTION ?

OBTAINED BY Gibeault - R/V Kit Jones
 DESCRIBED BY White

DATE 10-8-94DATE 2-20-94

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



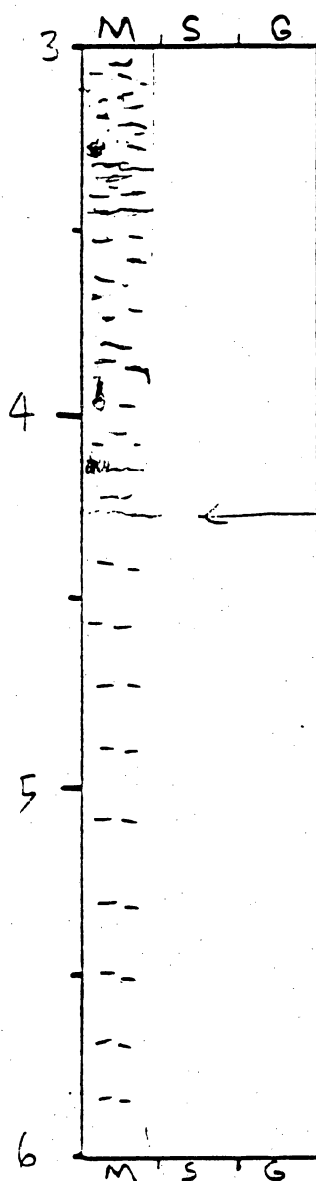
General Comments:

CORE LOG

CORE # SLV-5 (13) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



soft mud or clay with distorted laminations of
 black organics

5Y 6/1
 Lt Olive gr
 with black org.

← Organics much less abundant below 4.3'

(5Y 6/1)
 Lt. olive gray clay with scattered
 black organic specks

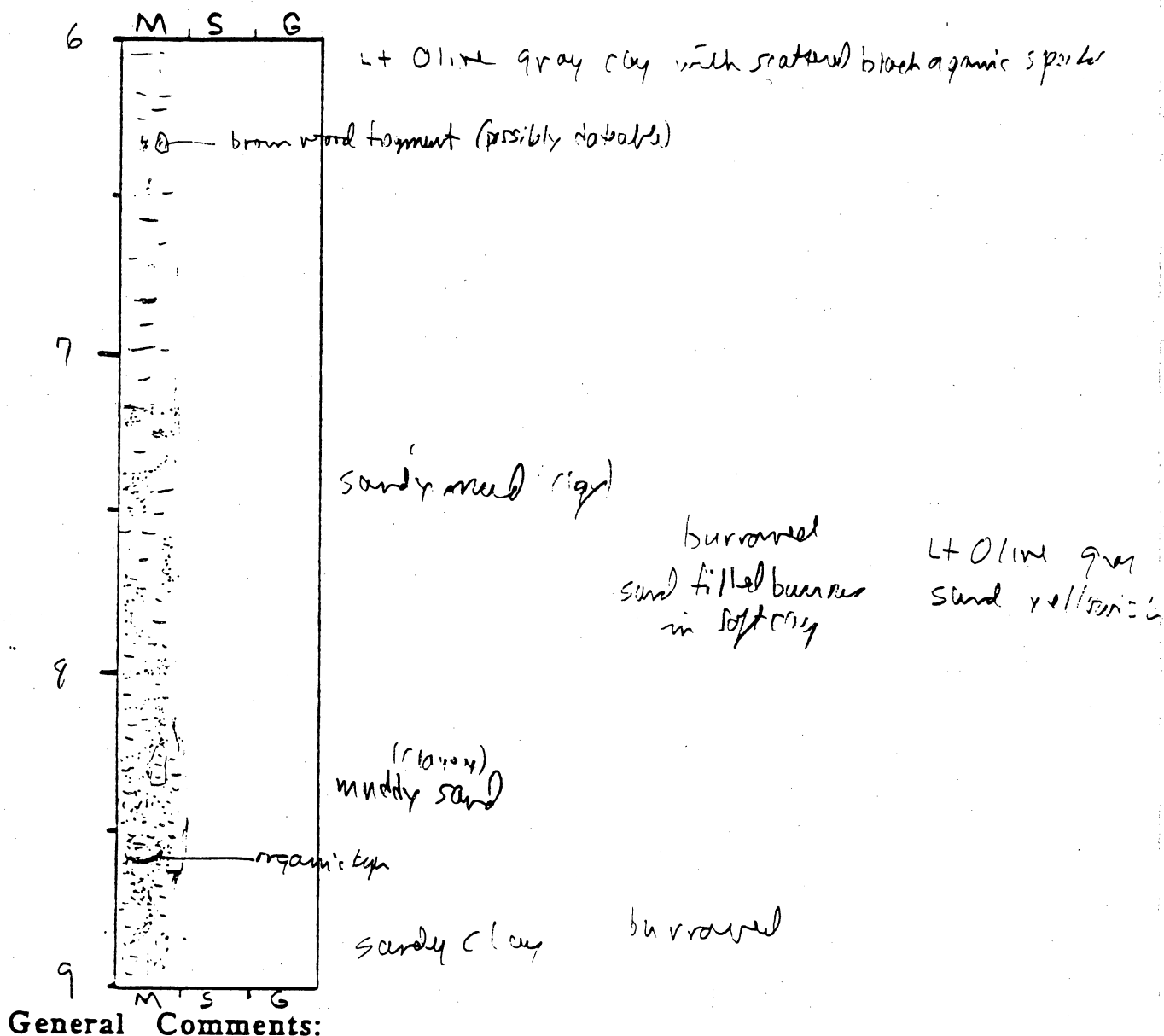
General Comments:

CORE LOG

CORE # SLV-5 (C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft. m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

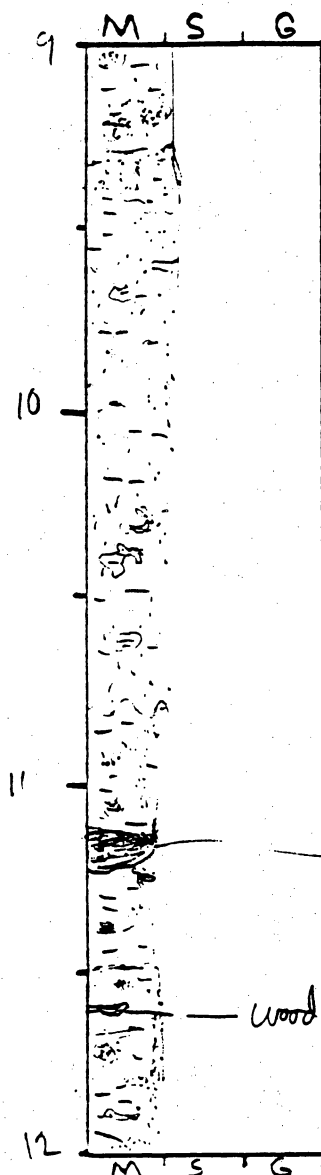


CORE LOG

CORE # CLV-510 TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft. m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



sandy clay burrowed Lt Olive gray (5Y 6/1)

clumpy sand (mostly sand)
 diatoms clay clasts

some scattered organics

Lt Olive gray
 (5Y 5/2)

burrowed

sandy clay

6730
 years
 B.P.

organic concentration brownish block,
 slightly silty clay - Lt Olive gray (5Y 6/1)

wood chip

burrowed, organics
 Dark gray sandy clay (sand in burrows, yellowish gray)

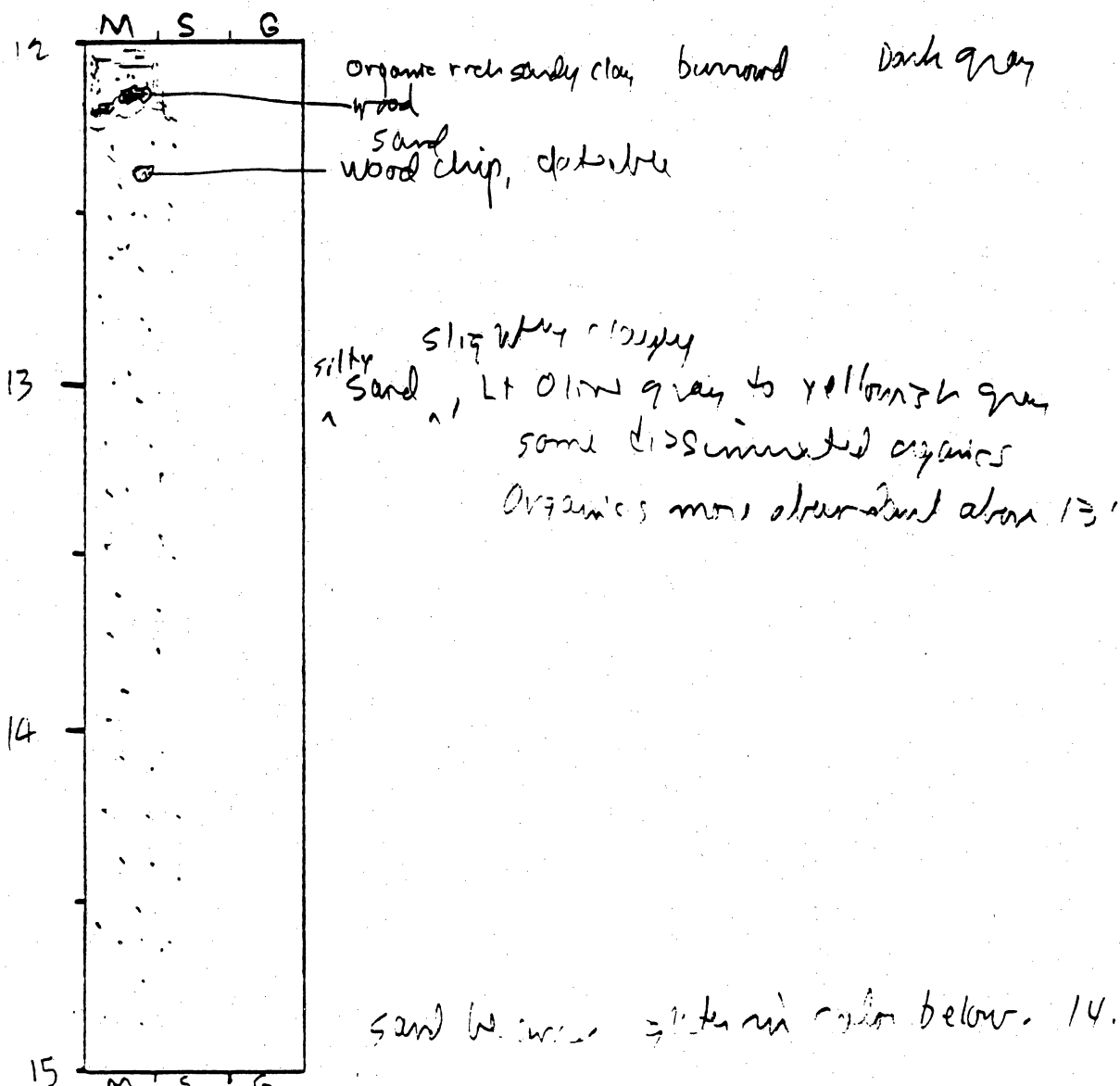
General Comments:

CORE LOG

CORE # SLV-5 (E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



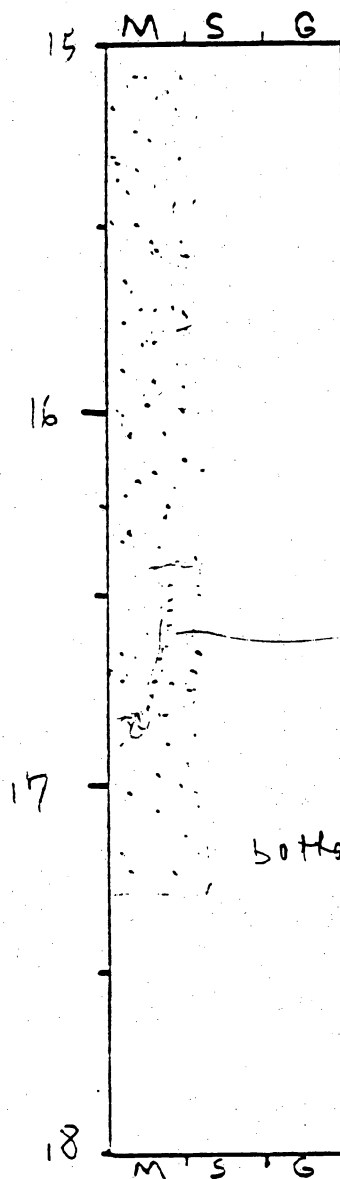
General Comments:

CORE LOG

CORE # SLV-5(F) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft. m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



sand some siltstone specks to about 15.5
 mottled Lt Olive gray to
 yellowish gray sand

Med dark gray muddy sand filled corner
 in Lt Olive brown sand
 Some oxidation stains at 16.5'

mottled dark yellowish orange (oxidized)
 really begins approx 16.8'
 bottom (no core taken)

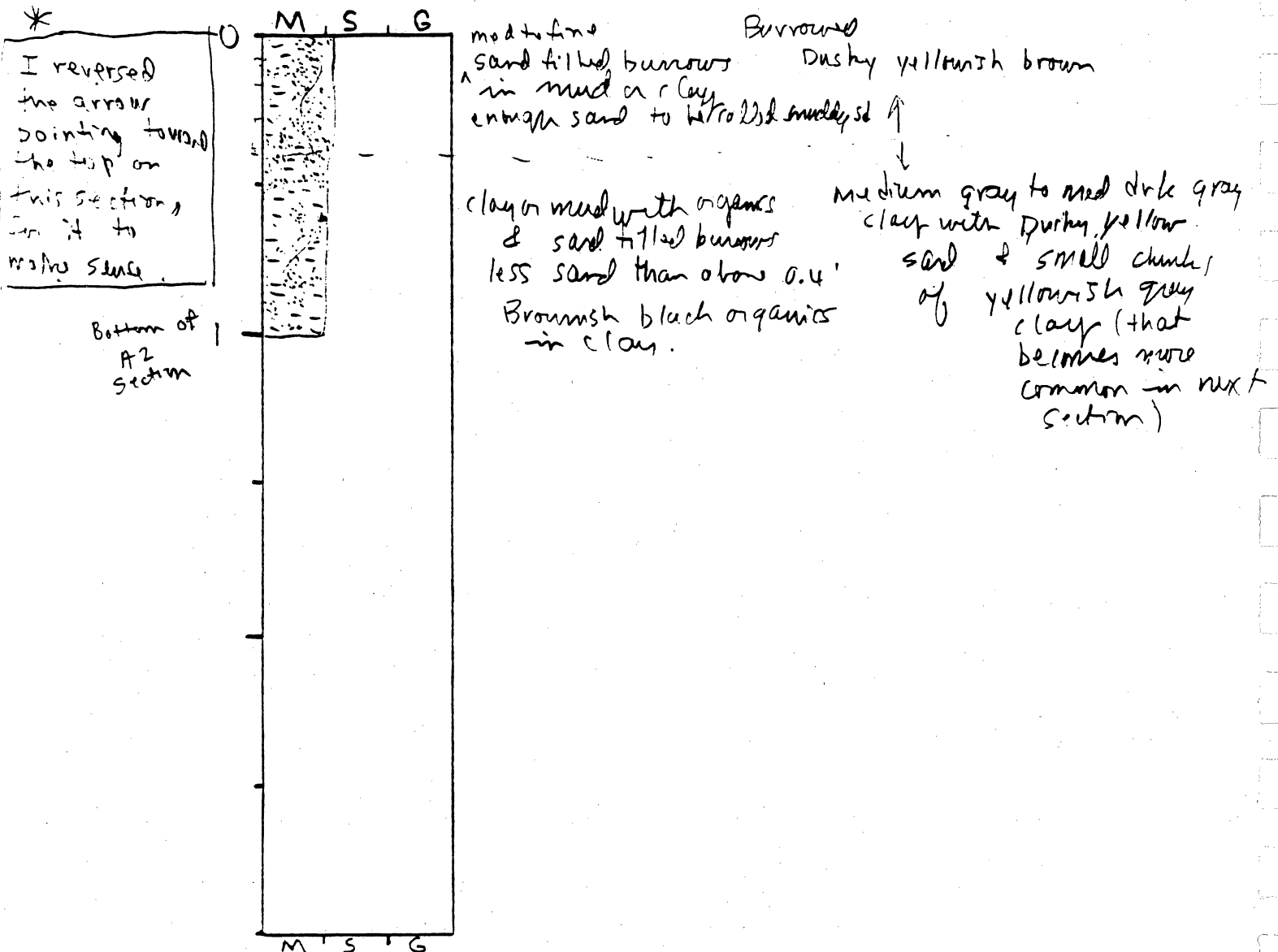
General Comments:

CORE LOG

CORE # SLV-6(A2) TYPE Vibrocore LOCATION Sabine Lake - Bessie Canal
 LATITUDE 30° 01.076 LONGITUDE 93° 57.445 SURFACE ELEVATION -14.5'
 DEPTH PENETRATED ? LENGTH RECOVERED 19' 6 1/2" COMPACTION ?

OBTAINED BY Gibson - R/V Kit Jones DATE 10-8-94
 DESCRIBED BY U. W. J. DATE 2-23-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

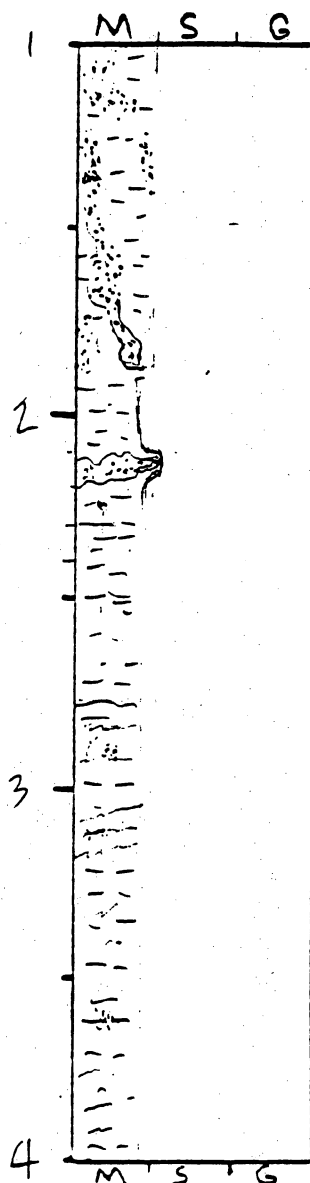


General Comments:

CORE LOG

CORE # SLV-6(A1) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



Burrowed
 mud or clay with sand filled burrows. medium dark gray

clay on mud, organics
 - sand, yellowish gray

clay on mud, organic rich
 local silty partings
 on thin layers

Disturbed
 horizontal
 laminae
 of black
 organics

Mottled layer of medium dark
 gray clay with yellowish
 gray clay dominated
 color below 1.5'
 sand in burrows - dusky
 yellowish brown to
 local spots of grayish orange

mottled layer of
~~brownish~~ black organics
 in yellowish gray to
 to medium gray clay

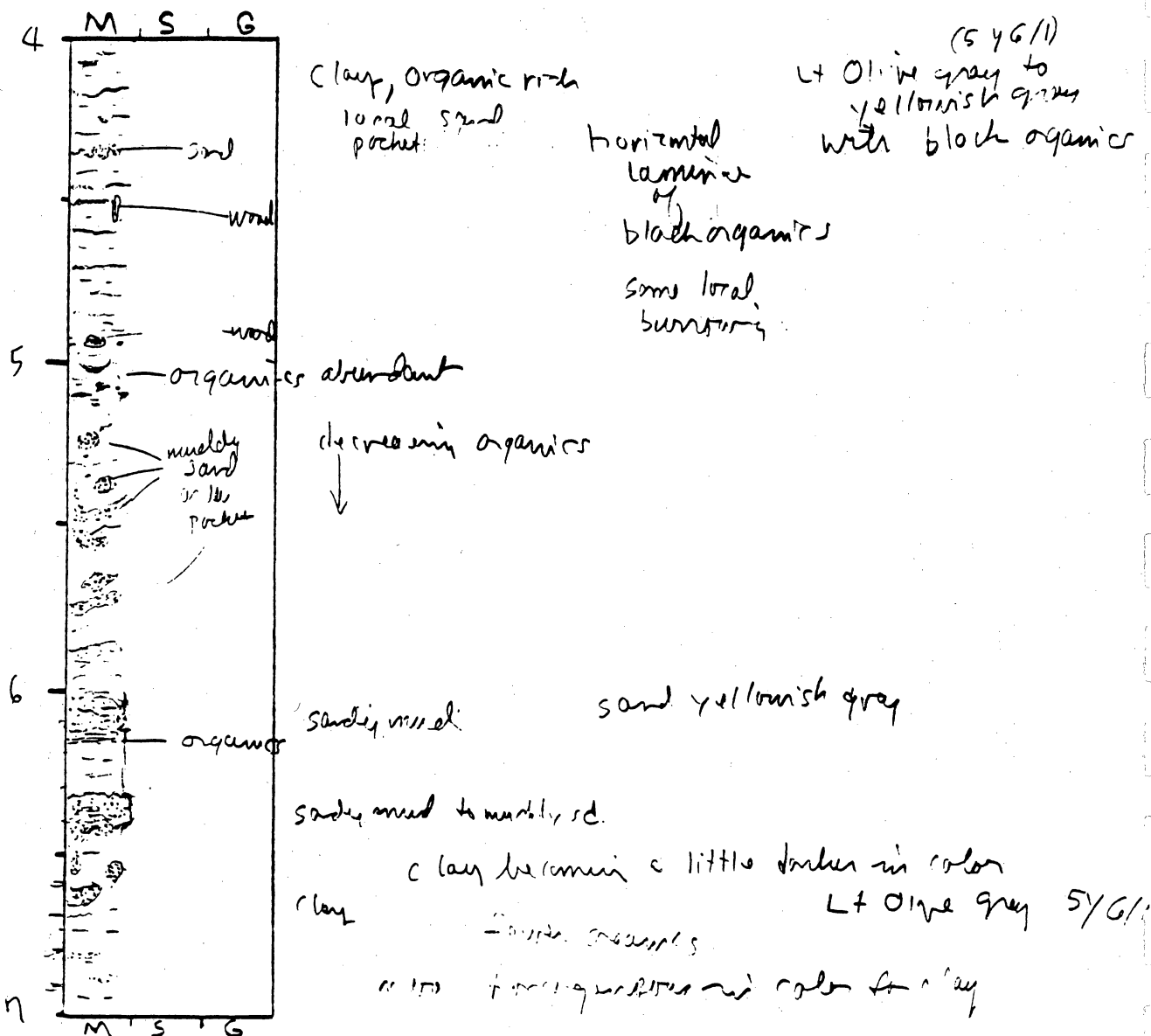
General Comments:

CORE LOG

CORE # SLV-6(B1) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft. m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



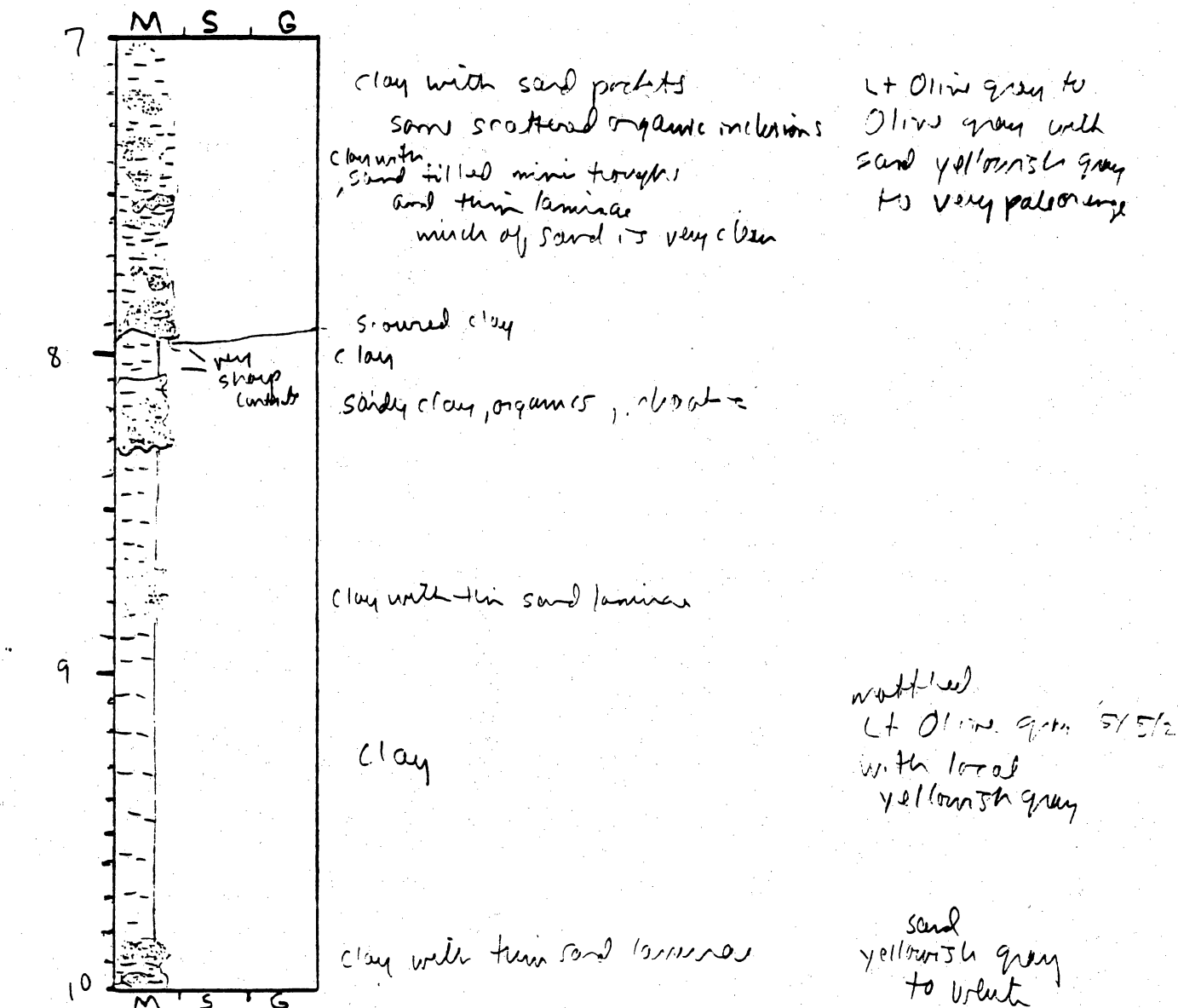
General Comments:

CORE LOG

CORE # SLV-6 (B2) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



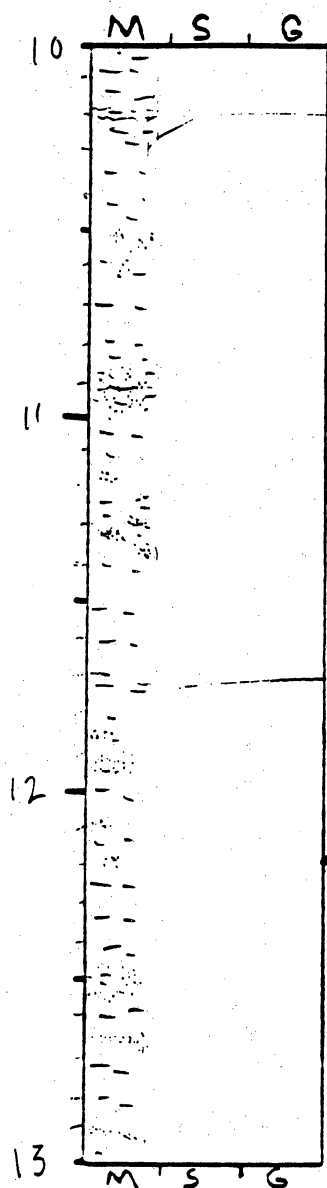
General Comments:

CORE LOG

CORE # SLV-6 (B3) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



clay
 dusky yellow clay layer
 very scattered small traces of organics
 traces of sand in clay

mottled color
 in clay
 Lt Olive green to
 olive green
 sy 6/1 to sy 4/1

traces of sand in clay

Dusky yellow clay horizon
 traces of sand in clay

traces of sand in clay
 very thin sand laminae
 traces of sand in clay

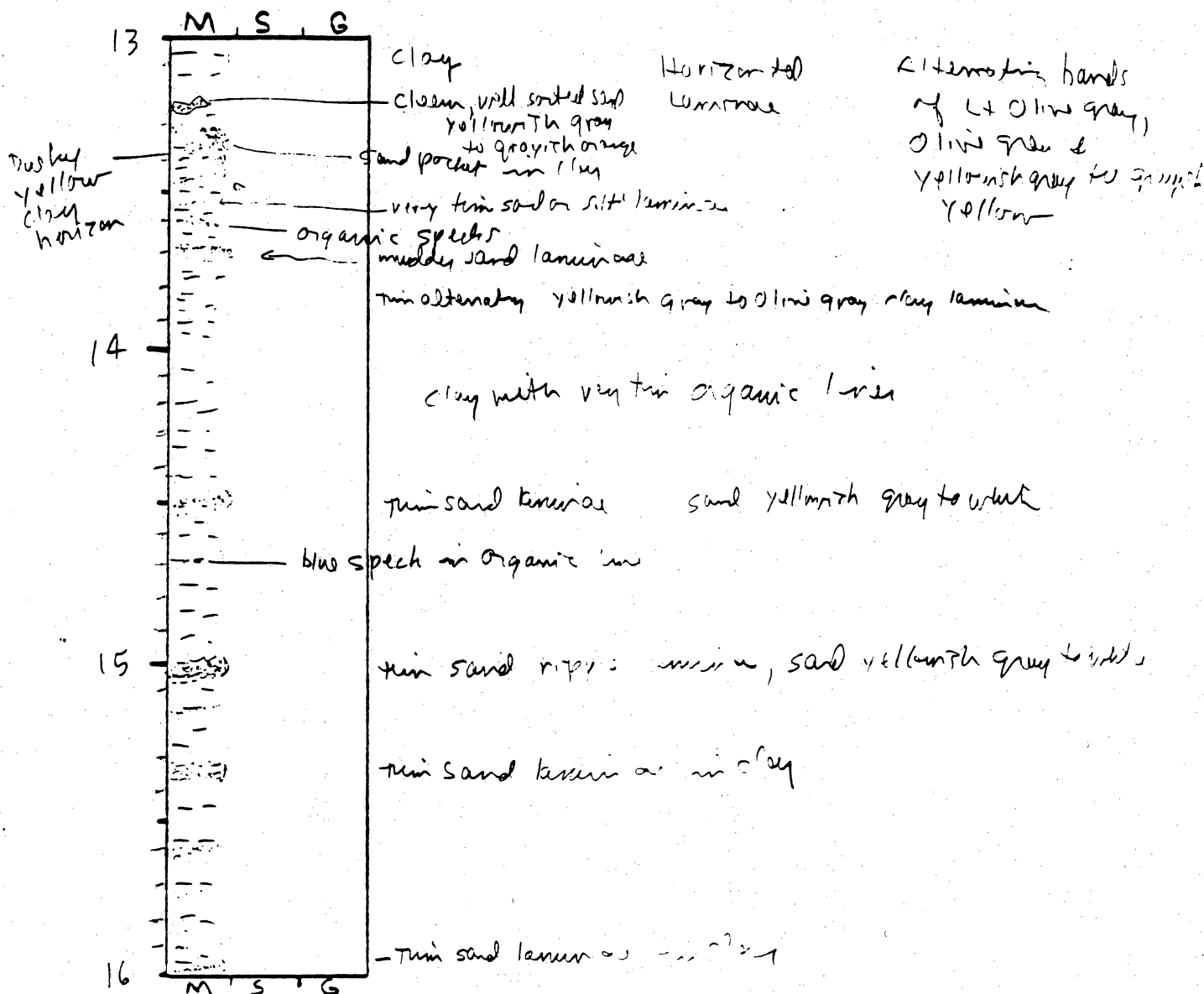
General Comments:

CORE LOG

CORE # SLV-6 (C1) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



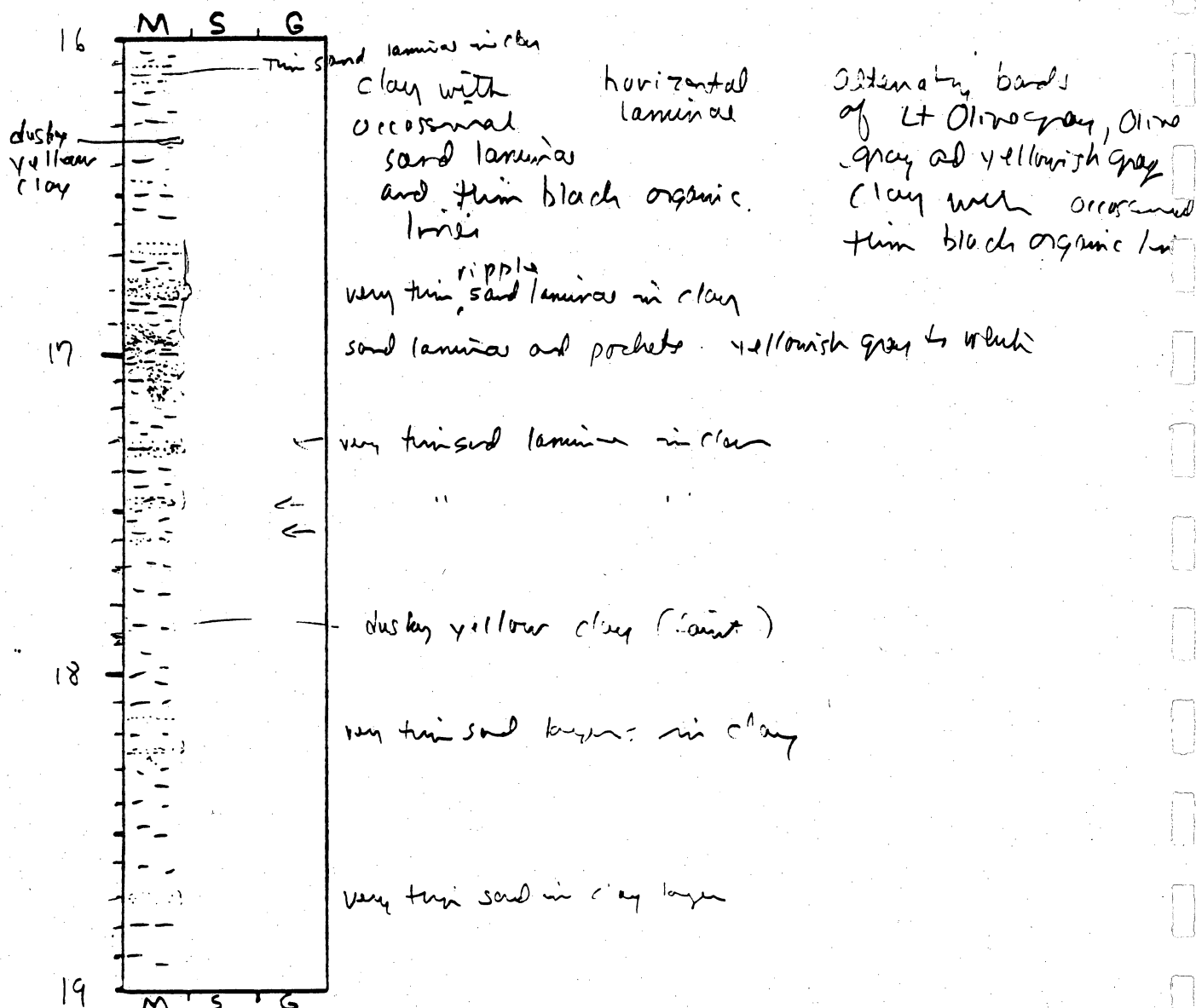
General Comments:

CORE LOG

CORE # SLN-6 (C2) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft. m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



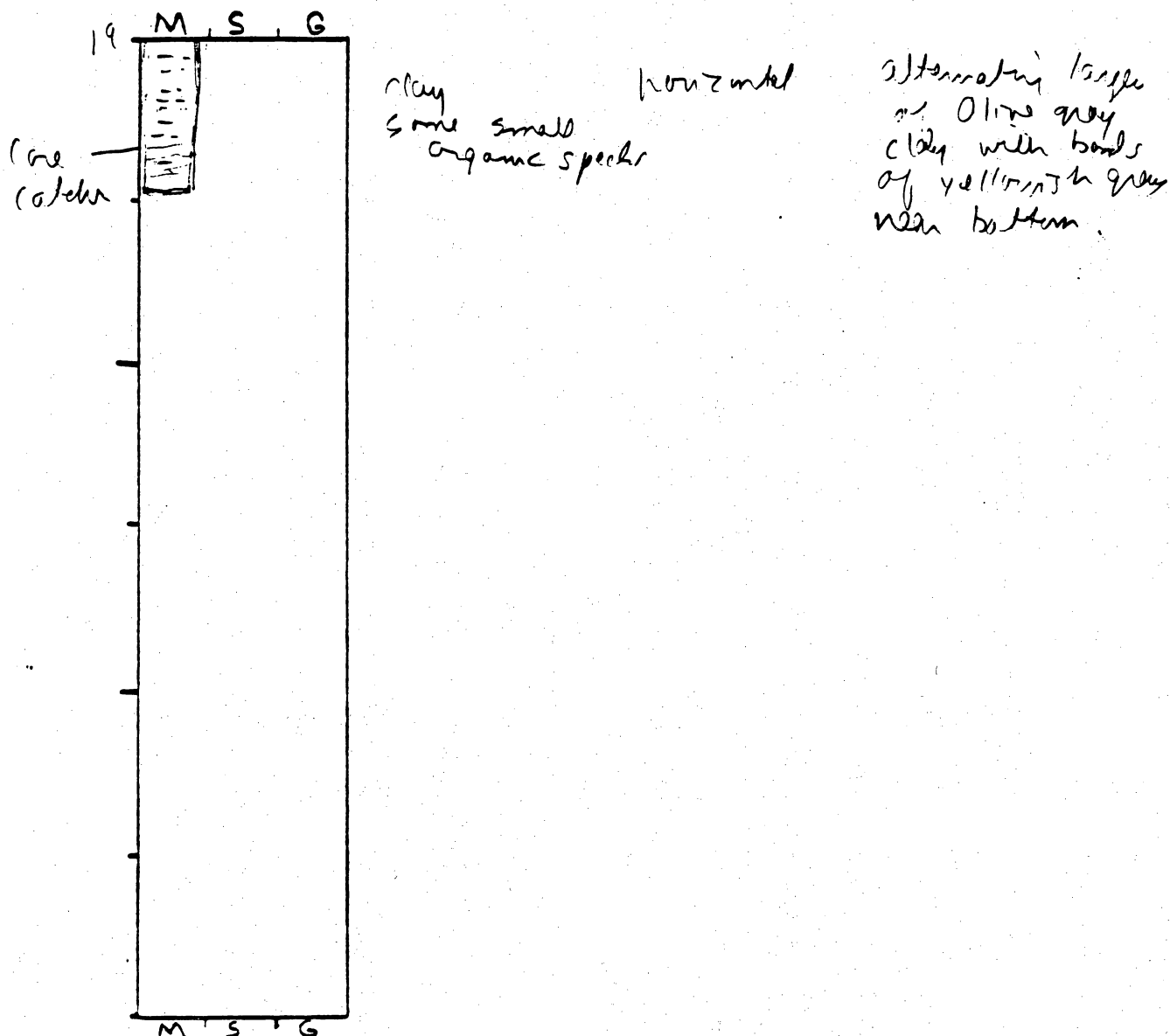
General Comments:

CORE LOG

CORE # SLV-6(C3) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



General Comments:

Formerly SLV-1

CORE LOG

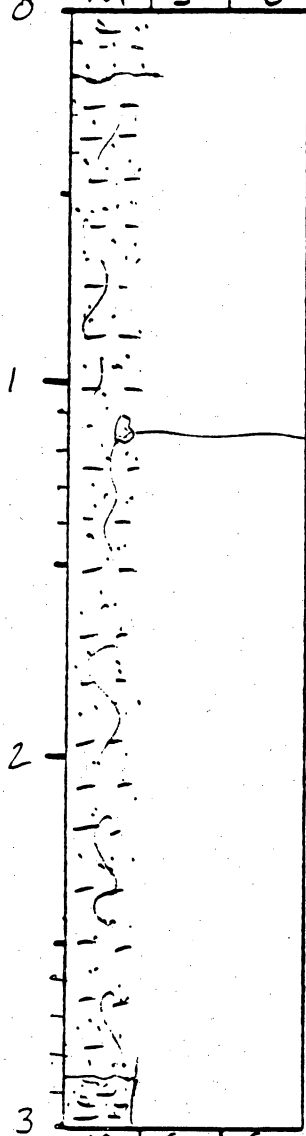
CORE # SLV-7(A) TYPE Vibrona LOCATION Sabine Lake, near mouth
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED 7.6 % COMPACTION _____

OBTAINED BY Shaw / Gilbert
 DESCRIBED BY Wilke

DATE _____
 DATE 2-28-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

0 M S G

Sandy mud
to muddy sandOlive gray with layer of moderate yellowish brown
at about 0.2'very muddy sand to
sandy mud
discrete mud & sand
componentsIntensely
burrowedOlive gray
(5Y 3/2)

Only shell frag in this section of core

mud appears more abundant than above
sandy mud

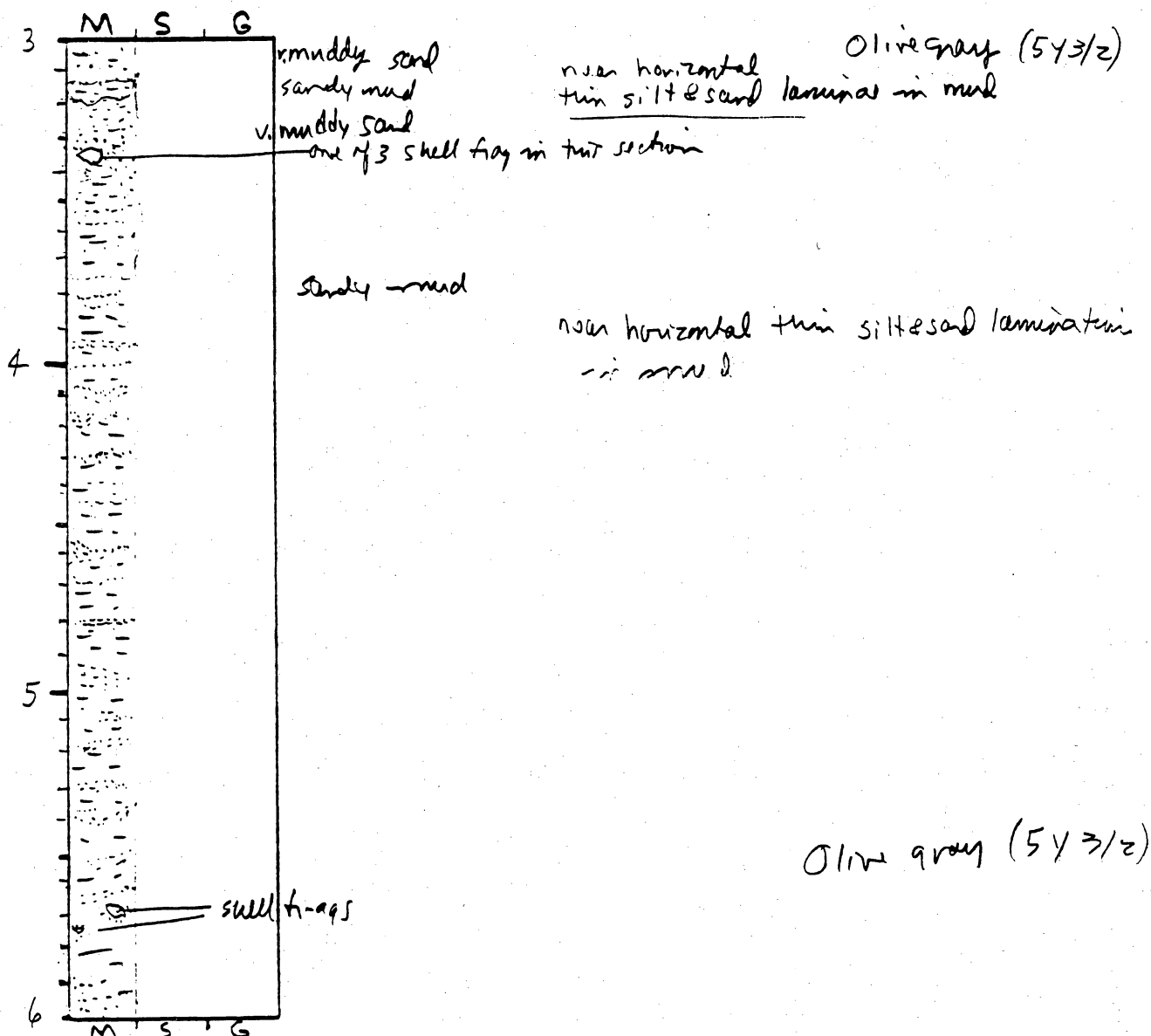
General Comments:

CORE LOG

CORE # SLV-7 (B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



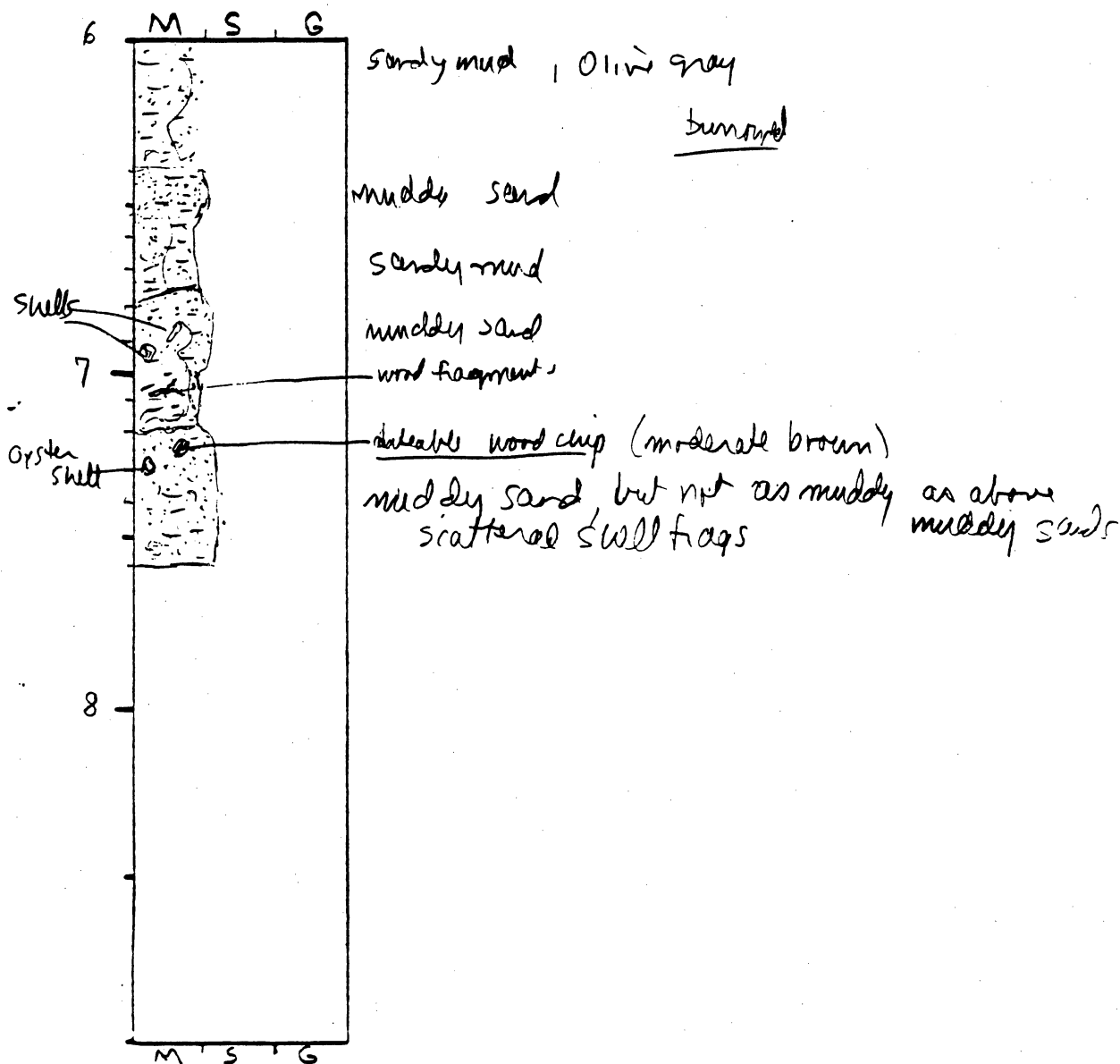
General Comments:

CORE LOG

CORE # SLV-7 (C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft. m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



General Comments:

Formerly SLV-2

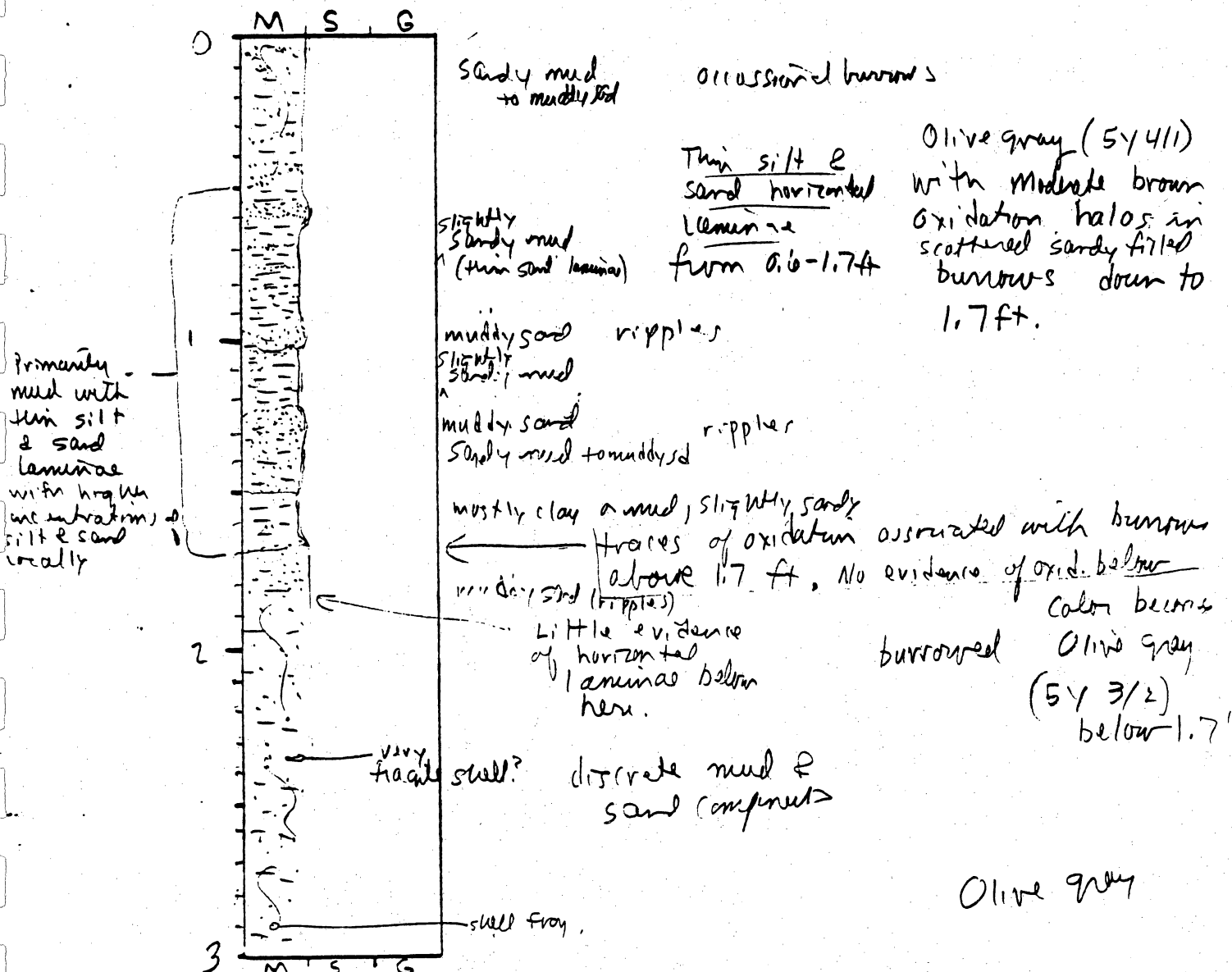
CORE LOG

CORE # SLV-8 (A) TYPE Vibracore LOCATION Sabine Lake near mouth
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED ? LENGTH RECOVERED 11.3 ft % COMPACTION ?

OBTAINED BY G. Hunt / Gilbert
 DESCRIBED BY V. Hunt

DATE _____
 DATE 2-28-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



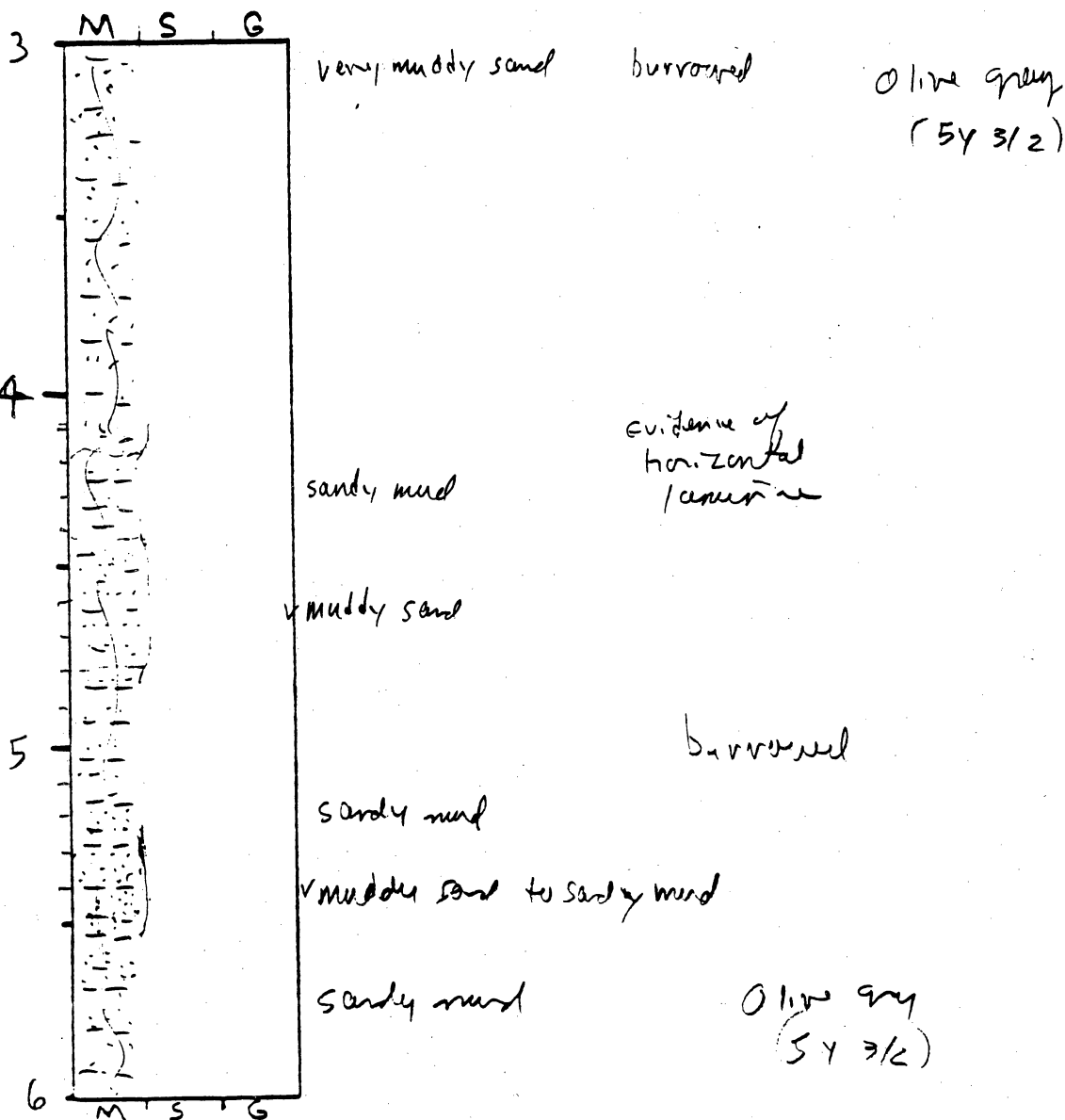
General Comments:

CORE LOG

CORE # SLV-8 (B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



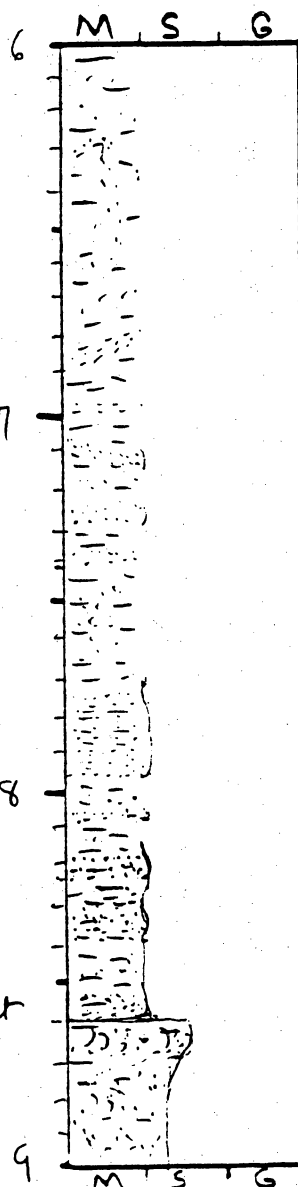
General Comments:

CORE LOG

CORE # SLV-8 (C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft. m) SKETCH LITHOLOGY STRUCTURE REMARKS



sandy mud

burrowed

Olive gray (5Y 3/2)

occasional

horizontal laminae

& starved

ripple laminae

ripples & cross beds of thin sand laminae in mud
 at 7.1' sand laminae dipping in opposite directions
 from those at 6.75'.

muddy sand, alternating thin layers of sand & mud.

sandy mud

muddy sand

sandy mud

muddy sand

sandy mud

muddy sand

muddy sandy shell to muddy shelly sand

sand, muddy siltstone shell

Olive gray
 (5Y 3/2)
 to
 (5Y 4/1)

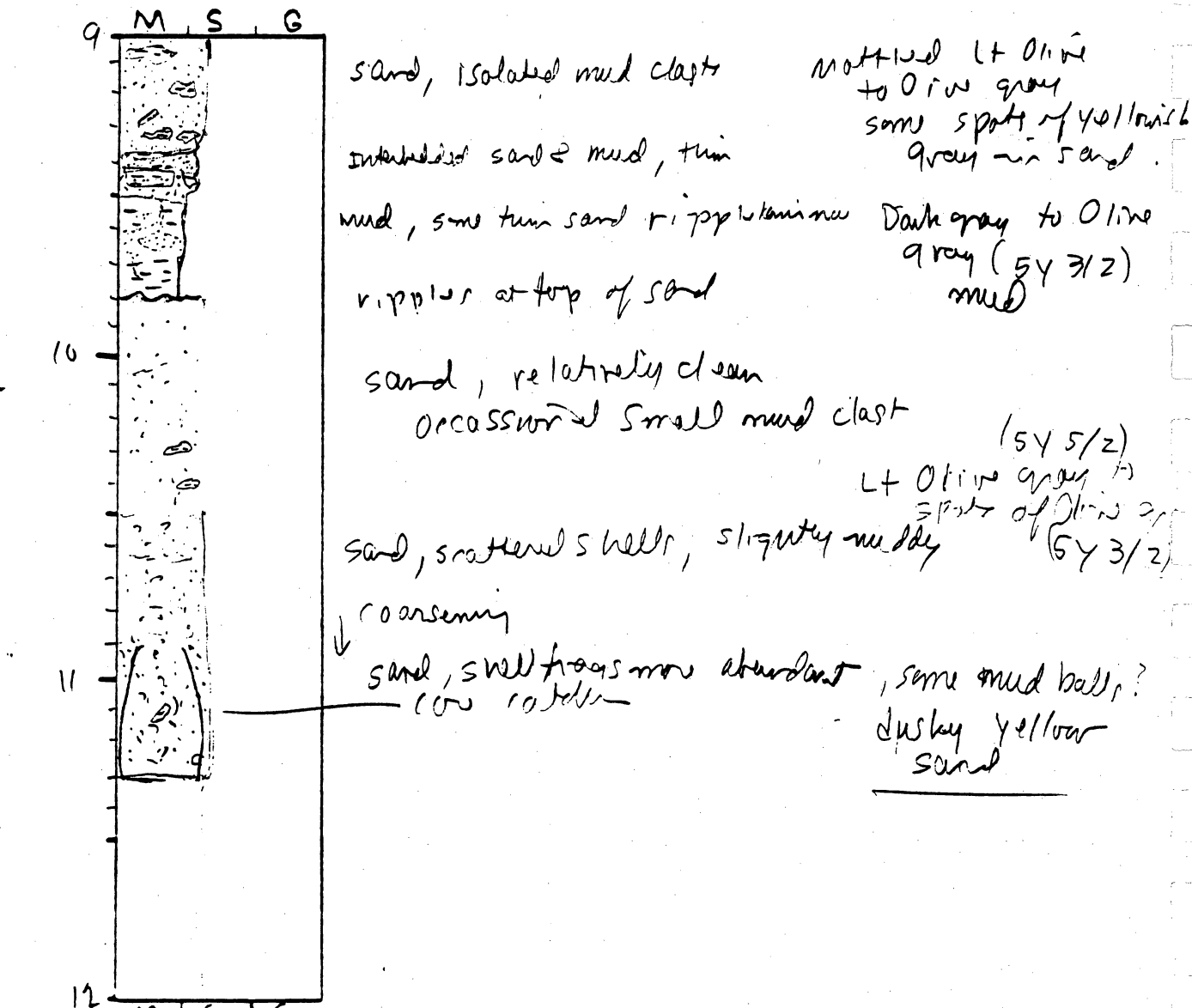
General Comments:

CORE LOG

CORE # SLV-8(D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft. m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



General Comments:

CORE LOG

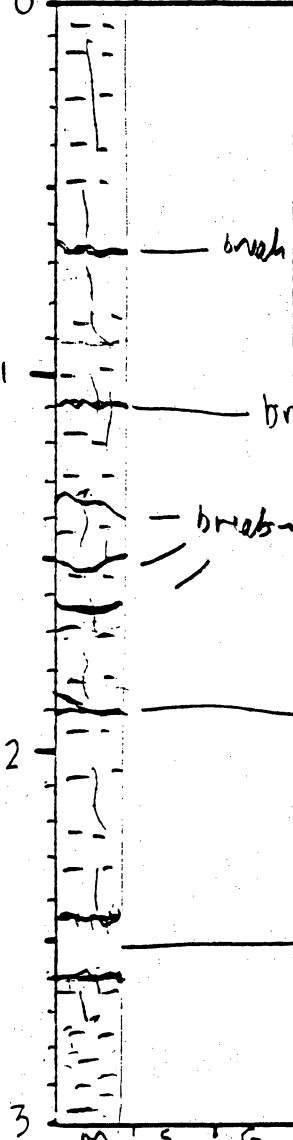
Soy R. in State Park Easting

CORE # Mc FV-2(A) TYPE Vibrom LOCATION Mc Fadden NWR
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED 10.95' % COMPACTION _____

OBTAINED BY Morgan / White DATE 5-5-92
 DESCRIBED BY White DATE 2-28-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

0 M S G



Organic rich mud or clay
 roots down to cat least
 2.7'

Core is dried out
 Brownish black

break in core

Brownish black

break in core

Mottled Olive gray to
 Olive black

break in core

break in core & color change

Brownish black

Mud on clay, organic (roots)
 loss clay content

Mottled
 Lt Olive gray
 to dark gray

destruction zone

brownish black
 organic in clay

Some dark
 yellowish orange
 stain down center
 below 2.7'

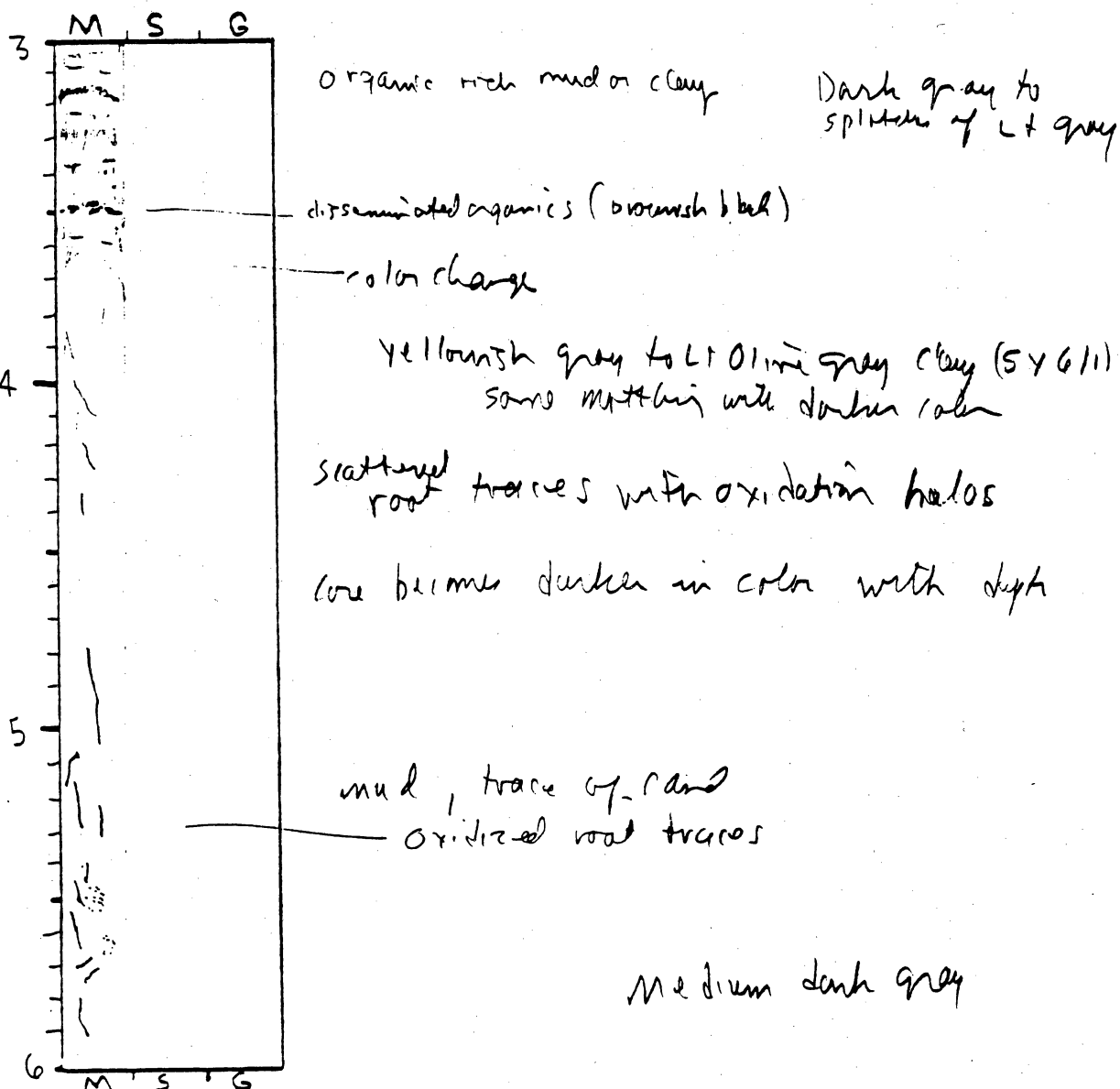
General Comments:

CORE LOG

CORE # MCV-2(B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS

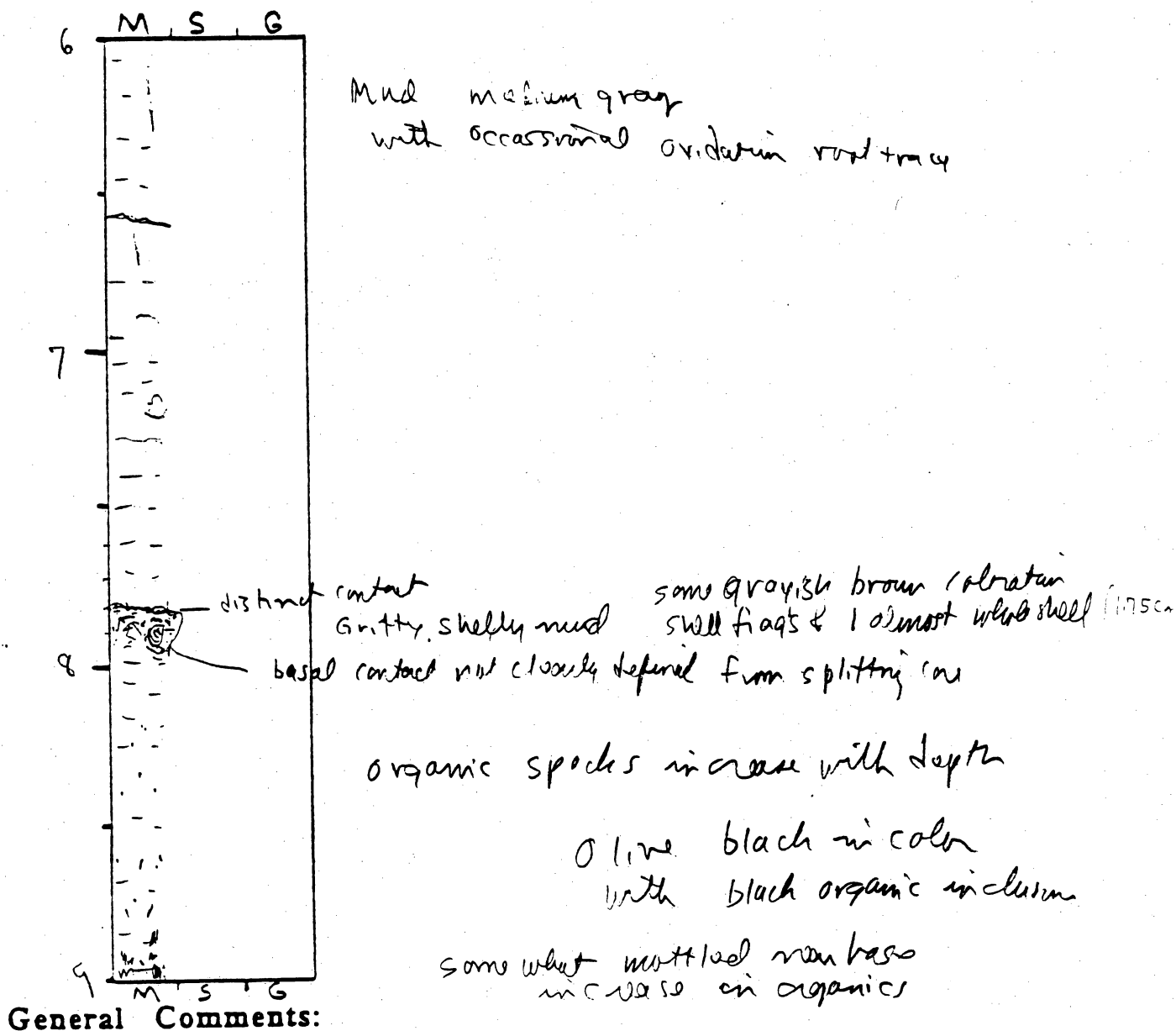


General Comments:

CORE LOG

CORE # MCV-2(C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft. m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

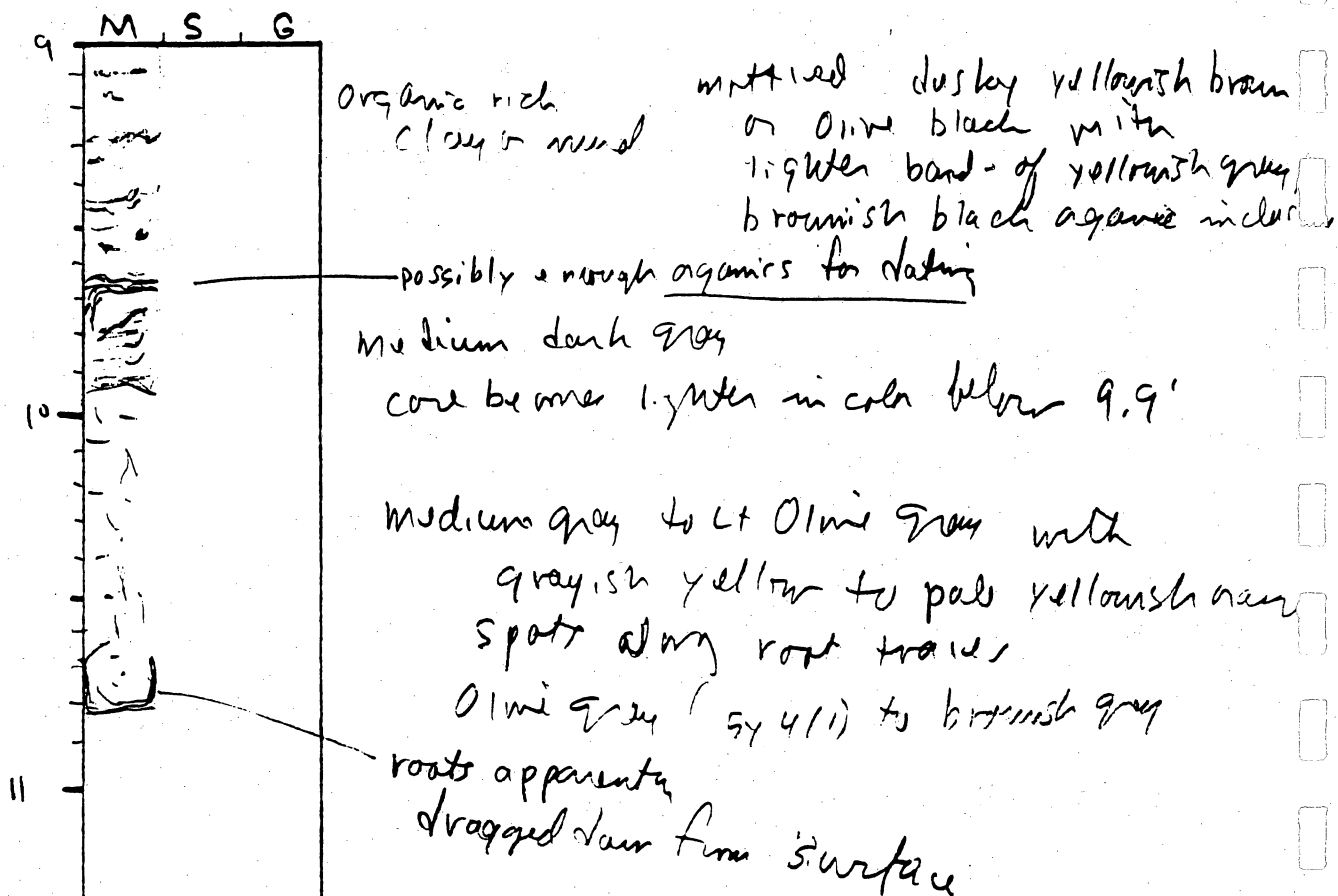


CORE LOG

CORE # MCEV-2(D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH
 (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



General Comments:

CORE LOG

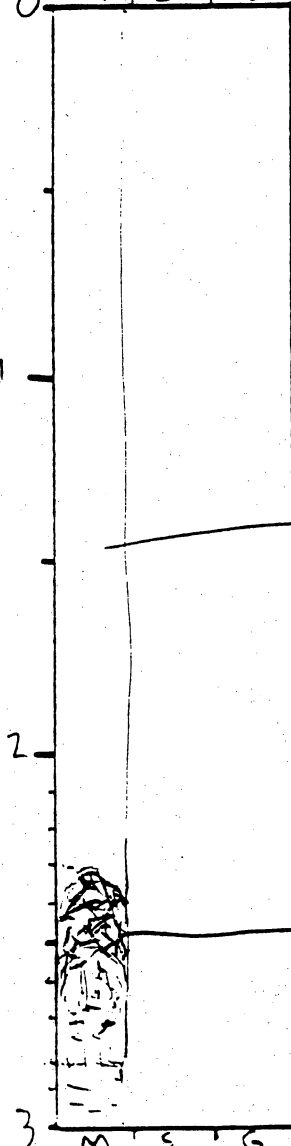
CORE # Mc FV-3(A) TYPE Vibrocore LOCATION McEddin NW 1/4, North Exxon Office
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED 2 ft % COMPACTION 5

OBTAINED BY Mark / Whit
 DESCRIBED BY W. J. H.

DATE 5-6-92
 DATE 2-28-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

0 M S G



General Comments:

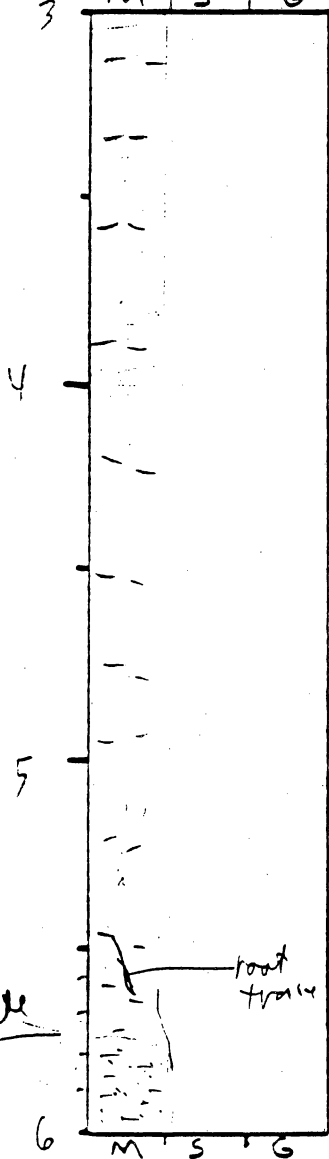
CORE LOG

CORE # McFV3(B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft. m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

3 M S G



Organic rich mud on clay

material,
 Dark gray, with
 lighter colored areas
 of light olive
 gray to light greenish
 gray. Dark
 black organics.
 Spots of Dusky yellow
 some halos around
 root traces

mud on clay

oxidation. spots of dark yellowish orange
 in mottled areas of med dark
 and med light gray

↓
 mottled

color becomes lighter

Lt Olive gray with some oxidation

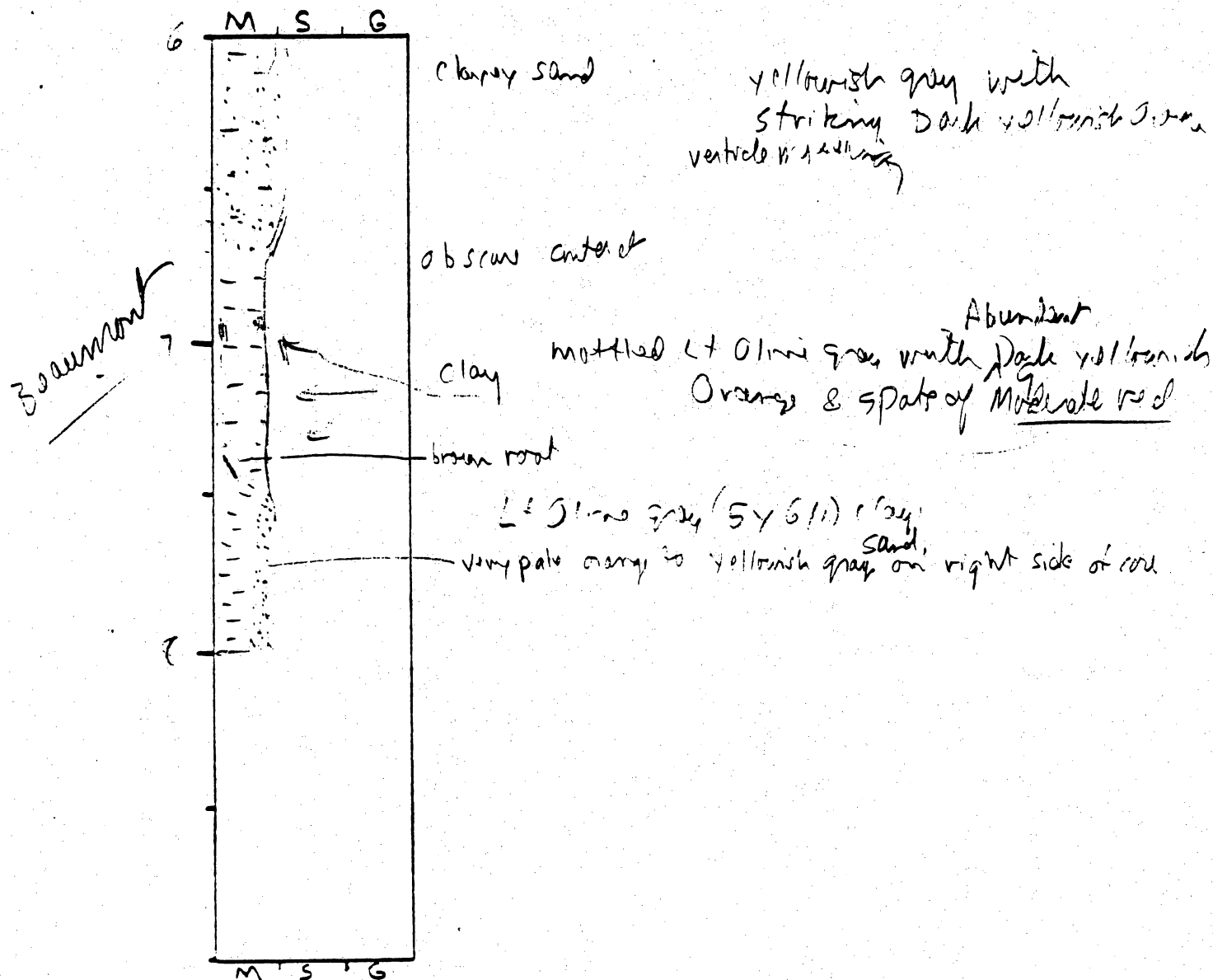
clayey sand to sandy clay
 yellowish gray with Drk yellowish areas,
 stains

General Comments:

CORE LOG

CORE # M. = 1-3(c) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft. m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

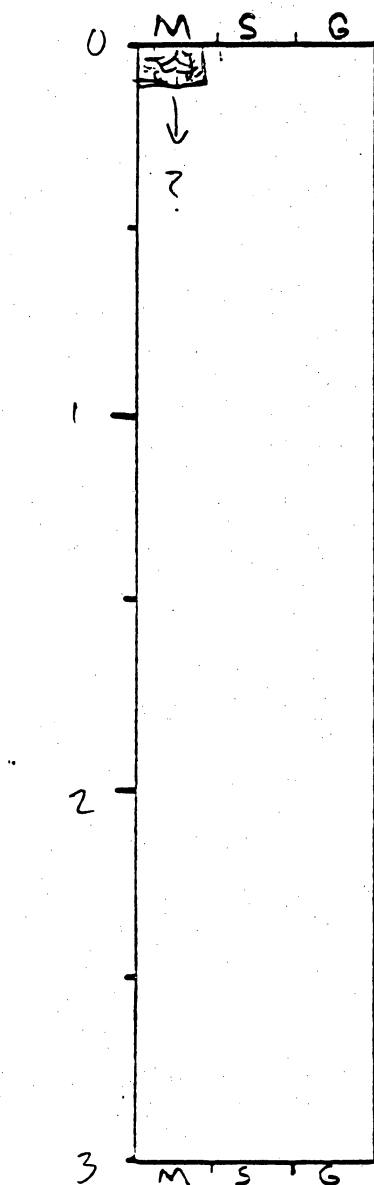


CORE LOG

CORE # McFV 5(A) TYPE 1/2" core LOCATION McFadden NW/R
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED 12 FT LENGTH RECOVERED 9.2 FT COMPACTION ?

OBTAINED BY M. L. & V. P. DATE 5-6-62
 DESCRIBED BY W. L. H. H. DATE 2-23-95

| DEPTH (ft. m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



Blackish red organic plant mass only 0.2' recovered
 exact location unknown

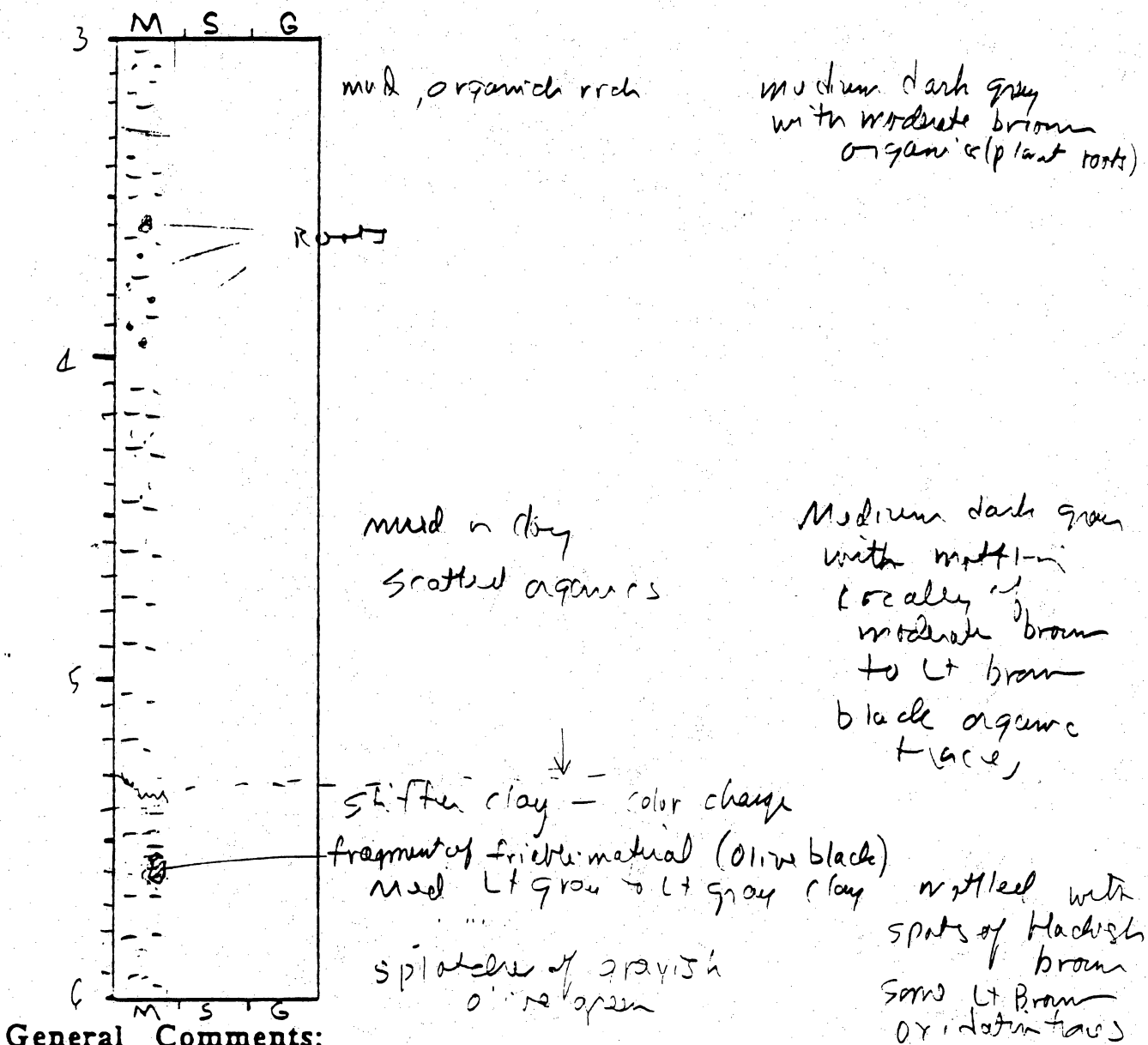
General Comments:

CORE LOG

CORE # McEV-5(B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

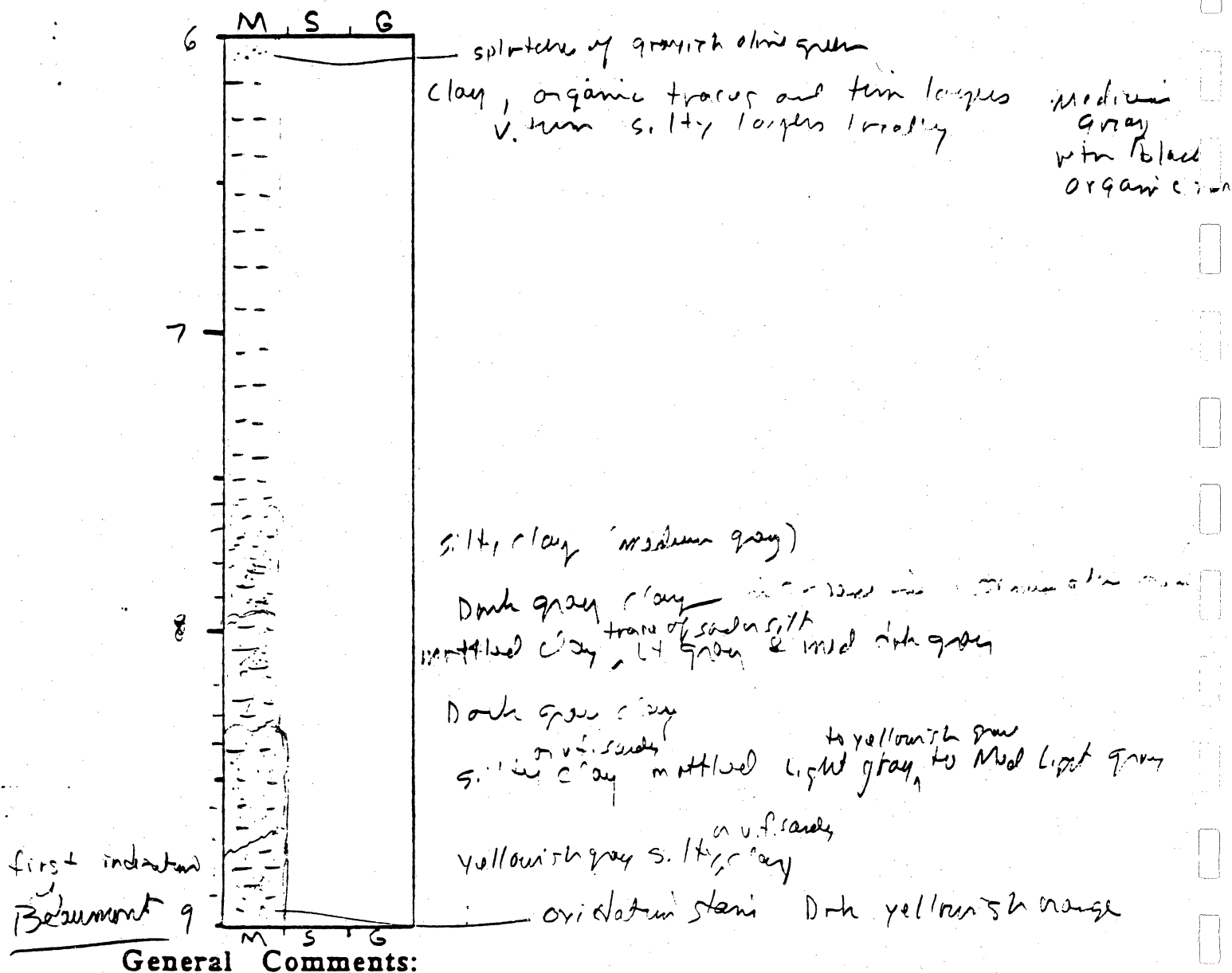


CORE LOG

CORE # McFV-5C TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

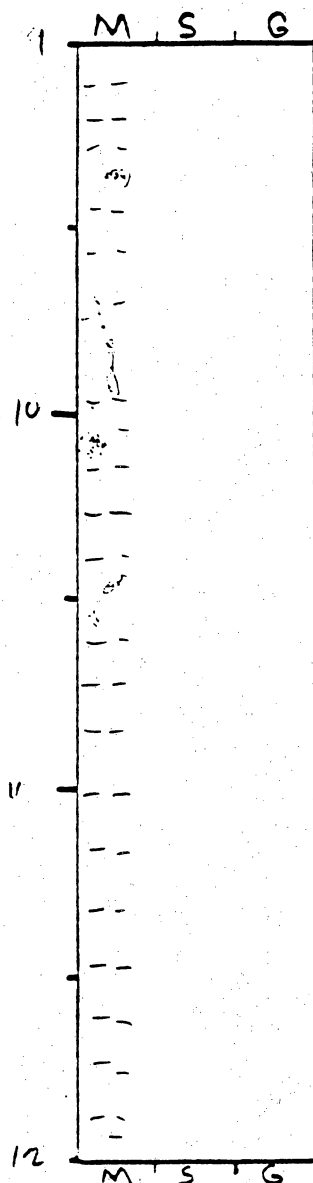
DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



CORE LOG

CORE # Mc EV-5(d) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



Beaumont Clay
 SH ft

Local Lt Olive gray
 silty and sandy clay
 fractured

Lt Gray to yellowish
 gray
 mottled with
 dark yellowish orange
 splashes

General Comments:

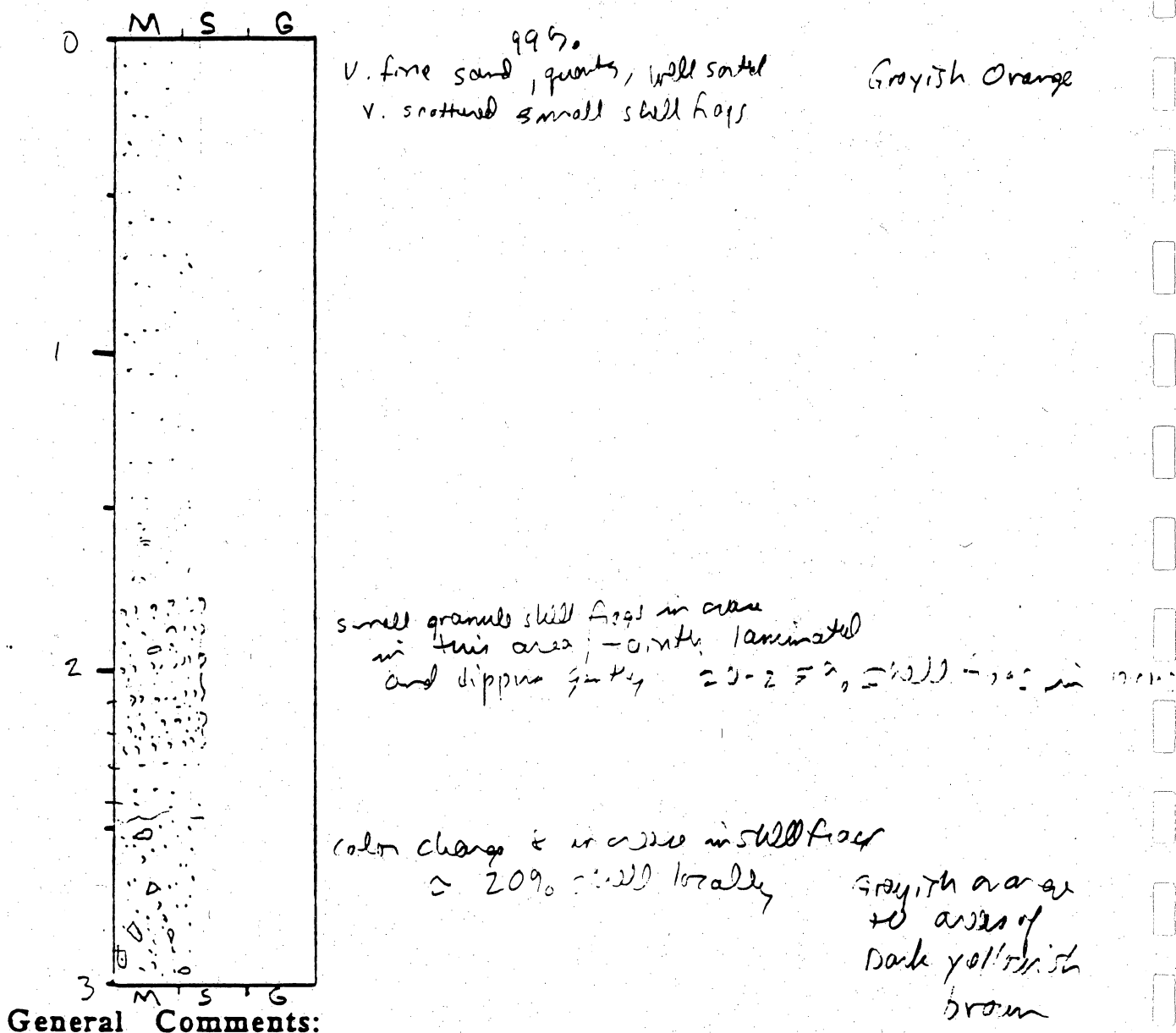
CORE LOG

CORE # McEV-7(A) TYPE Vibracore LOCATION McFadden NWR Gull Beach (Back bldg)
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED ? LENGTH RECOVERED 3.4 ft COMPACTION ?

OBTAINED BY Morton & White
 DESCRIBED BY UW

DATE 5-6-92
 DATE 7-23-95

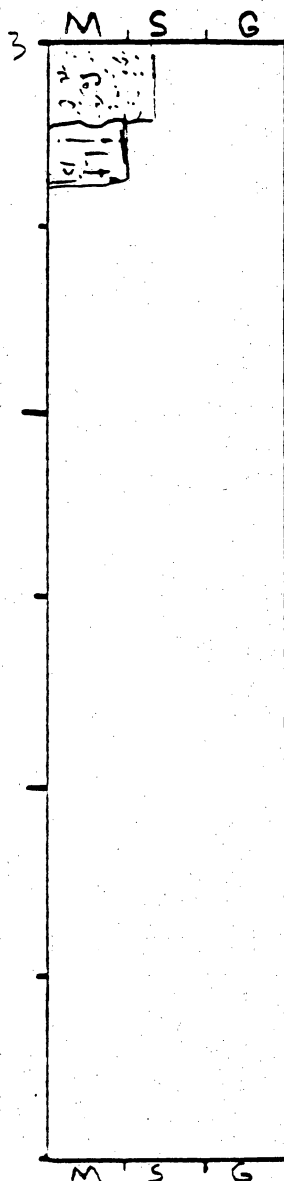
| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



CORE LOG

CORE # McEv (78) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



Sand scattered } grayish gray, splatters of Lt brown
 small shell frags 10-20%
 relatively stiff clay, organic s near base
 some moderate brown splatters.

Grayish brown
 to brownish
 gray
 blackish
 spots near
 base.

General Comments:

**Addendum 8. Site Dependency of Shallow Seismic Data Quality in Saturated,
Unconsolidated Coastal Sediments**

SITE DEPENDENCY OF SHALLOW SEISMIC DATA QUALITY IN SATURATED, UNCONSOLIDATED COASTAL SEDIMENTS

Paine, Jeffrey G., Morton, Robert A., and Garner, L. Edwin, Bureau of Economic Geology, The University of Texas at Austin, University Station, Box X, Austin, Texas 78713.

ABSTRACT

Shallow seismic reflection profiling using small sources is a viable method of imaging near-surface late Quaternary strata along the Texas coast. Seismic testing was completed at three representative coastal sites to determine the usefulness of land-based shallow seismic reflection profiling, to examine the dependence of data quality on environment, to evaluate compressional-wave sources for shallow profiling, and to determine the exploration depth range of shallow seismic reflection methods.

Tests in three environments, including unvegetated beach sands at High Island, Holocene marsh deposits at Sabine Pass, and a vegetated floodplain along the Neches River, show that near-surface sediment characteristics strongly influence data quality. A modified soil probe hammer, which is a low energy, broad frequency range seismic source, was used for the short reflection profiles at each site. Highest quality data were collected at the beach, where reflections were recorded as shallow as 7 m and as deep as 200 m. Data quality in the marsh at Sabine Pass and the vegetated floodplain along the Neches River was not as good. At these sites, surface wave velocities were higher, peak frequencies were lower, and exploration depths were limited.

Despite similar target depths and near-surface water tables at each site, optimum acquisition parameters varied. At High Island, one shot per shotpoint and a relatively low filter setting of 16 Hz produced good data. At the Sabine Pass marsh, where subsurface gases may have reduced data quality, a low-cut filter setting of 32 Hz improved data by reducing surface wave noise. At the Neches River site, a higher low-cut filter setting of 64 Hz diminished traffic noise, source-related surface waves, and bridge vibrations.

Similar shallow reflection surveys should be useful in a variety of coastal environments. Potential applications include studies of late Quaternary stratigraphy, reactivated near-surface faults, and buried archeological sites. On-land surveys can also augment borehole data, guide borehole placement, and extend offshore surveys across the shoreline and onto the coastal plain.

INTRODUCTION

Preliminary seismic tests were conducted along the upper Texas coast to (1) determine the usefulness of land-based shallow seismic reflection profiling of Pleistocene and Holocene strata in three representative environments, (2) examine the dependence of data quality on ground characteristics, (3) evaluate several compressional-wave seismic sources for ultra-shallow reflection profiling, and (4) determine the effective depth range of shallow seismic reflection methods in these environments.

Three sites were chosen for the tests between Galveston Bay and Sabine Pass (fig. 1). Tests at High Island were completed on the barren, sandy beach near the high tide line. Core from a nearby borehole drilled on the beach by the Bureau of Economic Geology (BEG) to a depth of 6 m shows that a 2-m thick veneer of Holocene beach and washover sand overlies Holocene marsh mud to a depth of 4 m, which in turn overlies upper Pleistocene fluvial and deltaic deposits of the Beaumont Formation at a depth of between 4 and 5.5 m.

The Sabine Pass site, located 4 km north of Sabine Pass (fig. 1), is in a muddy marsh environment between sandier Holocene chenier beach ridge deposits (Aronow and Barnes, 1982; Fisher and others, 1973). Two cores were acquired by BEG from boreholes located southeast and northwest of the test site to depths of 10 and 30 m, respectively. The interpreted erosional Holocene-Pleistocene contact deepens from 8 m southeast of the test site to 26 m northwest of the site into an erosional valley feeding into the ancestral Sabine River valley. Near-surface sediments (upper 6 to 8 m) are shelly sand

and sandy mud deposited in Holocene marsh and beach ridge and swale environments. A thick section (6 to 26 m depth) of estuarine and deltaic muds underlies the beach ridge and swale deposits in the northwestern core.

At the Neches River site (fig. 1), located along a bridge over the Neches River 2 km upstream from Sabine Lake, seismic tests were conducted on the vegetated Neches River floodplain within the modern Neches River valley (Aronow and Barnes, 1982; Fisher and others, 1973). BEG borehole samples and foundation boring descriptions from as deep as 35 m indicate that soft, organic-rich, clayey sediments, probably deposited in a floodplain environment, are present to a depth of about 10 m at the test site. These deposits are underlain by interpreted late Pleistocene or early Holocene Deweyville fluvial sands to a depth of about 17 m. Below 17 m are stiff upper Pleistocene clay and sandy clay of the Beaumont Formation.

METHODS

Seismic Tests

Seismic tests performed at the High Island, Sabine Pass, and Neches River sites included noise, filter, and source tests that were used to optimize acquisition geometry and recording settings for short reflection surveys. For these tests, the seismograph was connected to a spread of 48 high-frequency geophones spaced at 1 m intervals (table 1). For the noise test, the seismograph recorded background seismic noise with no source activated. This test and observations made during the surveys revealed that important sources of noise were wind (at each site), breaking waves (at the High Island site), vehicle noise (at the Sabine Pass and Neches River sites), and bridge vibrations (at the Neches River site). Wind noise was largely unavoidable, as was constant vehicle noise across Rainbow Bridge over the Neches River. Noise from breaking waves and bridge vibrations was reduced by using low-cut filters during data acquisition and vehicle noise

was avoided at the Sabine Pass site by recording only when no vehicles were near the site.

Filter tests were conducted to determine the optimum setting for the analog low-cut filter. The intent was to raise the filter as high as possible to reduce low frequency surface wave noise, but keep it low enough to allow a wide frequency range and to allow the deepest events of interest to be recorded. Tests using the chosen acquisition geometry and low-cut filter settings of 4, 8, 16, 32, 64, 96, 128, and 192 Hz showed that the optimum filter setting was 16 Hz for the High Island site, 32 Hz for the Sabine Pass site, and 64 Hz for the Neches River site (table 2).

Compressional wave sources that were to be evaluated at the site included a sledgehammer, a modified soil probe hammer, and a Betsy Seisgun (table 1). The sledgehammer was struck on an aluminum plate resting on the ground. The soil probe hammer, originally manufactured to collect small diameter soil cores, consists of a sliding 3.6 kg weight mounted on a metal rod. The weight is driven downward by hand over a 45 cm stroke and strikes the top of a rod. A 225 cm² steel plate welded to the base of the rod delivers the seismic energy to the ground. This source produces less seismic energy than does the sledgehammer, but is easy to use and provides a consistent seismic pulse. Electronic switches mounted to the sources provided time breaks for the seismograph. We also planned to test a Betsy Seisgun using 0.410 gauge shotgun shells with 20 g shot and 12-gauge shells with 28 g slugs, but the unit was inoperable.

Stacking tests were conducted using the source-receiver geometry selected for the reflection lines. The soil probe hammer was fired repeatedly into the geophone spread in an attempt to increase the signal-to-noise ratio by partly canceling random noise. One shot per shotpoint was chosen to keep minor discrepancies in shot times from degrading the high frequency part of the source spectrum.

Other acquisition parameters chosen based on these tests included a seismograph sampling interval of 0.0005 to 0.001 s and a record length of 0.25 to 1 s (table 2). A Global Positioning System receiver was used to locate survey end points.

Acquisition Geometry

Three short seismic reflection lines were acquired at High Island, Sabine Pass, and the Neches River (fig. 1) in January 1995 using the common depth point method adapted to the shallow subsurface (Mayne, 1962; Steeples and Miller, 1990; Miller and others, 1990). Because we were interested in the shallowest reflections visible, the minimum source-receiver distance was 1 m (table 2). The farthest offset generally should be equal to or greater than the depth of the deepest target. Using 1-m shotpoint and geophone spacing, the maximum source-receiver offset was 24 m at the Neches River site and 48 m at the High Island and Sabine Pass sites (table 2). Source-receiver geometries were symmetric (split spread geometry with 24 geophones on each side of the shotpoint) at the Neches River site and were asymmetric (end-on geometry with the source trailing the geophone spread) at the High Island and Sabine Pass sites. One 40-Hz geophone was used at each geophone location for each line.

Processing

After the field work was completed, the seismic data were processed at BEG using the software SPW on a Macintosh computer. Processing procedures were those common to many types of reflection processing (Yilmaz, 1987).

The first processing step was to convert the data files to SPW format. Next, trace headers were created that combined the seismic data with acquisition geometry information. Dead or excessively noisy traces were then deleted from the data set. Automatic gain control was applied to amplify weak arrivals at late times or far offsets. A mute function was designed to delete the first arrivals from each shot gather to prevent

them from stacking as a false reflector. Another mute function was designed to remove the air wave, or the sound of the source traveling through the air, from each shot gather. Bandpass filtering removed unwanted low- and high-frequency noise from Sabine Pass and Neches River data. Velocity analysis was conducted by fitting reflection hyperbolas to events on common midpoint (CMP) gathers (all traces that have the same source-receiver midpoint, but differing offsets). For 24-fold data, there are 24 traces in a CMP gather.

The velocity function derived from the CMP gathers was used to correct each trace in the gather for normal moveout (the delay in arrival time caused by increasing source-receiver offset) and to simulate zero offset for all traces. Each velocity-corrected trace in a CMP gather was summed to produce a single composite trace. A stacked seismic section is a display of these composite traces.

RESULTS

Gulf Beach at High Island

Of the three test sites, the highest quality data were recorded at the High Island test site. A sample field record (HIRL1003) from the short reflection survey at this site (fig. 2), recorded with one shot from the soil probe hammer and a 16-Hz low-cut filter, shows several types of seismic energy. Visible phases (fig. 2a) include (1) high amplitude, low frequency, and slowly propagating surface waves (lower left of field record, less than 80 m/s propagation velocity), (2) an air wave, or the sound of the hammer blow traveling in air (high frequency, 330 m/s propagation velocity), (3) a critically refracted arrival from the near-surface water table (1600 m/s propagation velocity), and (4) a few hyperbolic reflectors between 0 and 0.080 s two-way time. With automatic gain control applied (fig. 2b), later reflectors are visible (to 0.200 s), as is the hyperbolic signature of a Gulf of Mexico wave breaking on the shoreface at about 30 m offset.

The strongest events on these field records are the low frequency surface waves (figs. 2, 3a), which commonly obscure shallow reflectors in reflection surveys. At High Island, near-surface compressional velocities are about 20 times higher than surface wave propagation velocities (fig. 2c). This allows early reflections (0.010 s and later) to arrive at the geophones before the surface waves at near-source distances. Power spectra of individual traces at High Island show a power peak at about 30 Hz and a secondary peak at about 150 Hz (fig. 3a). After muting the surface-wave dominated part of the field record, the remainder of the seismic energy on the 10 m trace is mostly reflected and refracted energy and has a band of significant power between 100 and 200 Hz and a peak at about 150 Hz (fig. 3b). This peak is one to two orders of magnitude weaker than that for the surface waves.

Velocities picked for hyperbolic reflectors visible on CMP gathers show that velocities increase with two-way time (fig. 4). Velocities increase rapidly from about 1300 m/s to 1500 m/s between 0.020 and 0.050 s, then increase more slowly to about 2250 m/s at 0.200 s. A best-fit velocity function calculated from least-squares regression of two-way times and stacking velocities can be used to convert time to depth for the seismic data (fig. 4). This function is:

$$\text{velocity} = \text{two-way time} \times 4913 \text{ m/s}^2 + 1337 \text{ m/s}$$

which has a correlation coefficient of 0.987. Calculated depths for the reflectors visible on High Island field records range from as shallow as about 7 m to as deep as 200 m (fig. 4). Velocities calculated for these reflectors yield new information on seismic velocities within the upper Pleistocene and Holocene strata. They allow actual measured velocities to be used in depth calculations rather than theoretical relationships between two-way time and depth (Lehner, 1969).

Velocity picks were also used to correct traces of differing source-receiver offsets for delays caused by increasing source-receiver distance (normal moveout). After correcting and stacking traces with the same source-receiver midpoint, a seismic section

was constructed (fig. 5a). Numerous major and minor reflectors are visible between about 0.010 and 0.250 s, the latest data processed. Major reflectors are visible near 0.050 s, 0.125 s, and 0.180 s. Though the section is only 70 m long, some geological information is present. There appears to be a narrow low in the 0.020 s reflector between CMP 32 and 38, a broad low in the 0.060 s reflector centered on CMP 30, and an increasing southwestward (leftward) apparent dip of reflectors later than 0.100 s. The earliest reflector has a calculated depth that is near that of the Pleistocene-Holocene contact in a nearby BEG borehole. Deeper reflectors arise from acoustic boundaries within upper Pleistocene and older strata.

Marsh at Sabine Pass

After source and noise tests at the chenier plain marsh at Sabine Pass, shallow reflection data were acquired employing one soil probe hammer pulse at each shotpoint (table 2). Data were acquired in an end-on configuration in both line directions, resulting in 96 traces per shotpoint. A relative amplitude display of a typical field record, in which the highest recorded amplitudes are equalized among the traces, reveals that low frequency surface waves, high frequency air waves, and random noise are all clearly recorded at the site (fig. 6). A few reflection hyperbolas are also visible, particularly at about 0.025 s, between 0.040 and 0.050 s, and at about 0.080 s. Other reflectors are either not present or are obscured by strong surface waves or noise. Data quality deteriorates with increasing offset and reflectors are difficult to see on the field record beyond about 35 m.

The propagation velocity of the surface waves is as high as 150 m/s, nearly twice as high as at the High Island site and stronger relative to the reflections. These faster surface waves increase the offset distance by which there is adequate separation between the arrival times of the reflected energy and the surface waves, which in turn increases the minimum exploration depth. Using a near-surface velocity of 1400 m/s and a zero offset

two-way time of the earliest observed reflection of 0.020 s, the shallowest visible reflector corresponds to a depth of 14 m. The deepest reflector visible on the field record arrives at about 0.130 s, which represents a depth of about 120 m.

A power spectrum calculated for a trace with a 10 m source-receiver separation shows that most of the recorded seismic signal is below 100 Hz (fig. 7a). Power peaks at 30 and 50 Hz are removed when the surface-wave dominated part of the shot record is muted, and are replaced by a 70 Hz peak that is about 15 times weaker than the low frequency surface wave peaks (fig. 7b). This probably represents the dominant frequency of the reflected energy.

After velocity analysis, normal moveout correction, and CMP stacking, the stacked section shows a few strong reflectors between 0 and 0.1 s and a few weaker reflectors later than 0.1 s (fig. 5b). Reflection peaks are broader (lower frequency) than those in the High Island section and reflections are obscured in some parts of the Sabine pass section (between CMP 1050 and 1075, for example). The strong reflector at 0.020 s, calculated to be at a depth of 14 m, falls in the expected depth range for the Pleistocene-Holocene erosional contact. This contact deepens from 8 m in a borehole southeast of the site to 26 m in a borehole northwest of the site. Earlier arrivals in the stacked section may represent a weak reflection off the interface between chenier plain deposits and underlying bay and bayhead delta muds.

In general, the Sabine Pass section has a lower signal-to-noise ratio than the High Island section. Because much of the noise appears to be random wind-related noise and because there is little significant transmitted energy above 100 Hz, the signal-to-noise ratio might be improved by stacking several shots at each shotpoint.

Neches River Floodplain

At the Neches River site, seismic tests and a short seismic reflection survey were completed on the vegetated floodplain in the right-of-way of a heavily-trafficked bridge

crossing the Neches River. Field records of low-cut filter tests using the soil probe hammer source show several types of recorded energy, including direct, critically refracted, and reflected compressional waves, surface waves, an air wave, bridge vibrations, and random wind-related noise (fig. 8). The direct wave, which travels from the source to the receiver without appreciable refraction, is visible as the first arrival at source-receiver offsets of 1 to 5 m. It propagates across the spread at 333 m/s, nearly the same speed as the air wave, and is distinguished from it by the direct wave's strong leftward (downward) deflection on the field record. Beyond 5 m offset, the first arrival is a compressional wave that propagates at 1565 m/s and is critically refracted at the shallow water table.

Bridge vibrations appear as low-frequency, high-amplitude, leftward-propagating waves on the field records (fig. 8a, b). With a dominant frequency of about 16 Hz, this noise source is diminished by applying a 16 Hz low-cut filter (fig. 8b) and almost completely removed by applying a 64 Hz filter (fig. 8c). Surface waves are also a low-frequency noise source that propagate at about 100 m/s at the Neches River site. The effect of increasing the low-cut filter is to remove progressively more of the low-frequency dominated surface waves. Surface wave strength is noticeably diminished as the filter was raised from 16 Hz to 64 Hz and finally 96 Hz (figs. 8b, c, and d). Along with the desirable reduction in surface wave strength is a reduction in reflected energy strength, which produces an undesirable decrease in signal-to-noise ratio, particularly at the 96 Hz low-cut filter setting (fig. 8d). A setting of 64 Hz was chosen for the reflection survey as a compromise that allowed enough reflected signal to be recorded while eliminating bridge noise and reducing surface wave strength.

The effect of the 64-Hz low-cut filter is shown on power spectra of 10-m offset traces from the Neches River reflection survey, recorded before (fig. 9a) and after (fig. 9b) muting the surface-wave dominated part of the record. Before muting, power peaks are centered at 31, 46, and 63 Hz (fig. 9a). After muting the surface-wave

dominated part of the record, the 31 Hz and 46 Hz peaks are diminished and the 63 Hz peak remains nearly as strong as it was before the mute (fig. 9b). Unlike surveys at High Island and Sabine Pass, where lower low-cut filters were employed, the low frequency (less than 50 Hz) surface wave peaks are weaker at the Neches River site than the recorded compressional wave signal. Like at the Sabine Pass marsh site, little seismic energy above 100 Hz was recorded.

Processing steps to produce a stacked section (fig. 5c) included surface wave, air wave, and first-arrival mutes, bandpass filtering, velocity analysis, moveout correction, and CMP stacking. A weak reflector appears to be present as early as 0.015 s, which corresponds to a depth of about 8 m. This horizon may be an inadvertent stack of a weak refracted arrival, or it may correlate to the stratigraphic boundary between muddy Holocene floodplain deposits and underlying upper Pleistocene or lower Holocene Deweyville sands penetrated in nearby cores and foundation borings. A stronger reflector arrives at 0.025 s two-way time, which converts to 18 m depth. This is near the 17 m depth at which stiff upper Pleistocene clay and sandy clay of the Beaumont Formation are found in the borings. Several reflectors are visible as late as 0.130 s, which corresponds to a depth of 120 m. Overall data quality is better than that at the Sabine Pass marsh and not as good as that at the High Island beach.

DISCUSSION

Surface Wave and Compressional Wave Separation

A major limitation of compressional wave reflection surveys of the shallow subsurface is the interference of surface waves and reflected waves at near-source distances. Because the vertical component of surface waves is much stronger than that of typical reflected waves, geophone response is dominated by surface wave motion regardless of the dynamic range of the seismograph. This limitation is particularly severe where near-surface sediments are dry (air-filled pores) and unconsolidated;

compressional velocities can be less than 1000 m/s in these environments (Paine, 1994), not greatly higher than typical surface wave velocities of several hundred meters per second. Further, higher seismic frequencies are rapidly attenuated in dry sediments, making it difficult to filter low frequency surface waves without significantly degrading the overlapping frequency range of the reflected waves.

In wet, unconsolidated coastal environments represented by the three test sites and common in many parts of the world, adequate separation between surface waves and reflected compressional waves is attained much closer to the source due to the relatively low surface wave velocities (80 to 150 m/s at the coastal sites) and relatively high compressional wave velocities (about 1500 m/s). At High Island, for example, reflectors at two-way times as early as 0.010 s were recorded. While this is an early time, relatively high compressional velocities also mean that (1) the earliest observable reflector may be deeper than the near-surface zone of interest, and (2) seismic wavelengths are longer for a given frequency than in environments with lower compressional velocities, which reduces vertical resolution proportionately.

Shear-wave surveys offer promise if shallower depths are desired than those practical for a compressional wave survey. These surveys take advantage of lower shear wave velocities to increase resolution and use horizontally polarized shear waves to reduce the strength of the recorded surface wave.

Frequency Content

Frequency content is important because broader frequency ranges and higher frequencies increase seismic resolution and make it easier to filter surface wave noise. One issue is the frequency content of the source pulse, and another is the frequency content of the reflected wave at the geophone after subsurface attenuation. Hammer sources such as those used at the three coastal sites are considered to be low-frequency sources compared to explosive and projectile sources (Miller and others, 1986). Power

spectra calculated after surface wave mutes show the highest frequency content at the High Island site, where peak signal power was recorded between 100 and 200 Hz. This implies that the soil probe hammer source produces significant seismic energy at least as high as 200 Hz. At seismic velocities of 1500 m/s, the wavelength at 200 Hz is 7.5 m. The theoretical limit of vertical resolution is between 1/4 and 1/8 wavelength (Widess, 1973), which is to 1 to 2 m.

Frequency content and vertical resolution is not as favorable at the Sabine Pass marsh and the Neches River floodplain. After surface wave mutes, peak seismic energy is found between 50 and 90 Hz at Sabine Pass and between 55 and 80 Hz at the Neches River. The same source was used at all three sites and there was little difference in coupling between the source and the land surface. Lower frequencies recorded at the Sabine Pass and Neches River sites are likely due to preferential subsurface attenuation of higher frequencies.

Exploration Depth

Determining both the minimum and maximum exploration depth was an objective of this study, but the minimum depth was more critical because the geological targets were within the Holocene and late Pleistocene units near the surface. For the compressional wave surveys, minimum exploration depth is highly dependent upon the velocity difference between surface waves and compressional waves, which was greatest at the High Island beach site. At this site, the earliest reflector visible over an adequate range of source-receiver offsets had an arrival time of about 0.010 s, which corresponds to a depth of about 7 m. This is at or below the contact between Holocene and Pleistocene sediments at the site, thus only Pleistocene reflectors are visible on the reflection line. The Sabine Pass and Neches River sites have similar near-surface compressional wave velocities but higher surface-wave velocities, which suggests that earliest detectable reflectors are later than 0.010 s and deeper than 7 m. The shallowest visible reflectors are

calculated at 14 m for Sabine Pass and 8 m at the Neches River. These depths are sufficiently shallow to image some Holocene deposits at these sites

Maximum exploration depths are surprising for so small a source. Reflections were recorded as late as 0.200 s at High Island and 0.130 s at Sabine Pass and Neches River sites. Velocity analysis at these relatively late times is hindered by the acquisition geometry designed for shallower reflectors, but estimated depths to the deepest reflectors are 200 m at High Island and about 120 m at the Sabine Pass and Neches River sites. The soil probe hammer has a practical exploration depth range of 5 to more than 100 m at these coastal sites.

Potential Applications

Seismic reflection methods adapted for the shallow subsurface have several potential applications in coastal environments such as those represented in the upper Texas coast. The seismic tests carried out in this study demonstrate that reflection surveys can allow a better understanding of Holocene and late Pleistocene stratigraphy as shallow as a few meters below the land surface (perhaps shallower with shear-wave sources). Reflection surveys can provide a geological context for existing boreholes, both between and beneath the holes, and can guide placement of new boreholes. They can augment an abundance of existing high resolution inner shelf and estuarine seismic reflection data with needed shallow data landward of the shoreline. Finally, reflection surveys such as those carried out in this study can be used to determine offset on numerous reactivated coastal zone faults such as those mapped by White and Tremblay (1995).

CONCLUSIONS

Shallow seismic reflection profiling using small impulsive sources is a viable method of imaging near surface Holocene and late Pleistocene strata along the upper Texas coast. The modified soil probe hammer is a simple, low energy, broad frequency

band seismic source that generates a consistent seismic pulse with frequencies to at least 200 Hz. Tests at three representative coastal environments, including unvegetated beach sands at High Island, Holocene marsh deposits at Sabine Pass, and a vegetated floodplain along the Neches River, show that near-surface sediment characteristics strongly influence data quality. Highest quality data were collected in the beach environment, where surface wave velocities were below 80 m/s, recorded peak frequencies were between 100 to 200 Hz, and reflections were recorded as shallow as 7 m and as deep as 200 m. Data quality in the marsh at Sabine Pass and the vegetated floodplain along the Neches River was not as good. At these sites, surface wave velocities were higher, peak frequencies were below 100 Hz, minimum exploration depths were deeper (8 to 10 m), and maximum exploration depths were shallower (about 120 m).

Despite similar target depths and near-surface water tables at each site, optimum acquisition parameters differed. At High Island, where the only major noise sources were wind and breaking waves, one shot per shotpoint and a relatively low filter setting of 16 Hz produced good data. At the Sabine Pass marsh, where data quality was poor perhaps because of trapped organic gases in pore space, a low-cut filter setting of 32 Hz diminished surface wave noise. More shots at each shotpoint might reduce random wind-related noise at this site. At the Neches River site, where data quality was moderate, a high filter setting of 64 Hz was required to diminish traffic noise, source-related surface waves, and bridge vibrations. Optimum processing steps and parameters also differ for each environment.

Similar shallow reflection surveys are relatively easy to perform and may prove useful in a variety of coastal environments. Potential applications of this technique include studies of late Quaternary stratigraphy, near-surface faulting, and buried archeological sites. On-land surveys can augment borehole data, guide placement of boreholes, and extend offshore and estuarine seismic surveys across the critical land-sea boundary.

ACKNOWLEDGMENTS

This study was funded by the U.S. Geological Survey under grant 14-08-0001-A0912, Robert A. Morton, Principal Investigator.

REFERENCES

- Aronow, Saul, and Barnes, V. E., 1982, Geologic atlas of Texas, Houston sheet: The University of Texas at Austin, Bureau of Economic Geology, map scale 1:250,000.
- Fisher, W. L., Brown, L. F., Jr., McGowen, J. H., and Groat, C. G., 1973, Environmental geologic atlas of the Texas coastal zone, Beaumont-Port Arthur area: The University of Texas at Austin, Bureau of Economic Geology, 93 p.
- Lehner, Peter, 1969, Salt tectonics and Pleistocene stratigraphy on continental slope of northern Gulf of Mexico: American Association of Petroleum Geologists Bulletin, v. 53, p. 2431-2479.
- Mayne, W. H., 1962, Common reflection point horizontal data stacking techniques: Geophysics, v. 27, p. 927-938.
- Miller, R. D., Pullan, S. E., Waldner, J. S., and Haeni, F. P., 1986, Field comparison of shallow seismic sources: Geophysics, v. 51, p. 2067-2092.
- Miller, R. D., Steeples, D. W., Hill, R. W., Jr., and Gaddis, B. L., 1990, Identifying intra-alluvial and bedrock structures shallower than 30 meters using seismic reflection techniques, *in* Ward, S. H., ed., Geotechnical and environmental geophysics:

Tulsa, Oklahoma, Society of Exploration Geophysicists, Investigations in Geophysics No. 5, v. 3, p. 89-97.

Paine, J. G., 1994, Subsidence beneath a playa basin on the Southern High Plains, U. S. A.: evidence from shallow seismic data: Geological Society of America Bulletin, v. 106, p. 233-242.

Steeple, D. W., and Miller, R. D., 1990, Seismic reflection methods applied to engineering, environmental, and groundwater problems, *in* Ward, S. H., ed., Geotechnical and environmental geophysics: Tulsa, Oklahoma, Society of Exploration Geophysicists, Investigations in Geophysics No. 5, v. 1, p. 1-30.

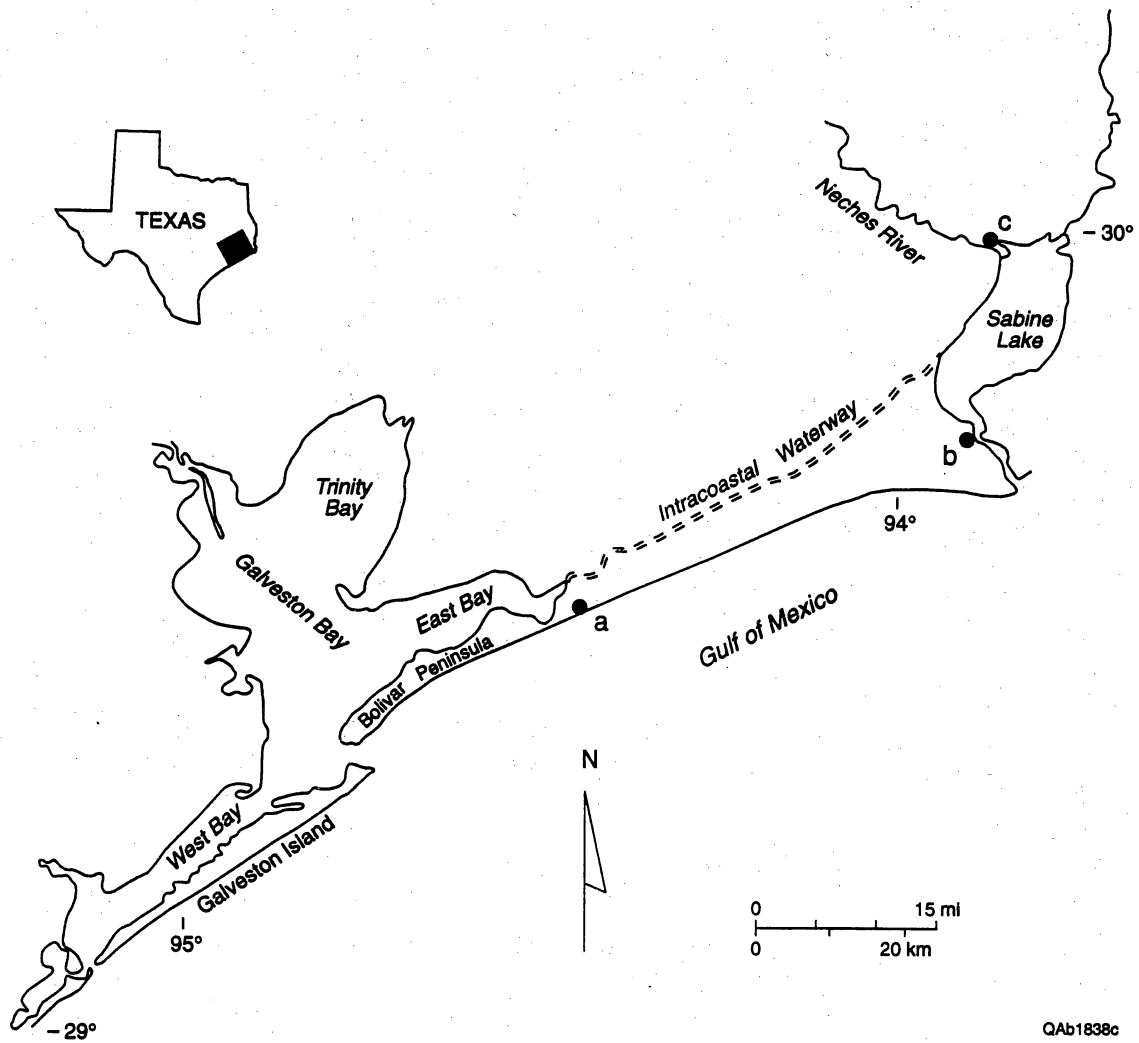
White, W. A., and Tremblay, T. A., 1995, Submergence of wetlands as a result of human-induced subsidence and faulting along the upper Texas Gulf Coast: Journal of Coastal Research, v. 11, p. 788-807.

Widess, M. B., 1973, How thin is a thin bed? Geophysics, v. 38, p. 1176-1180.

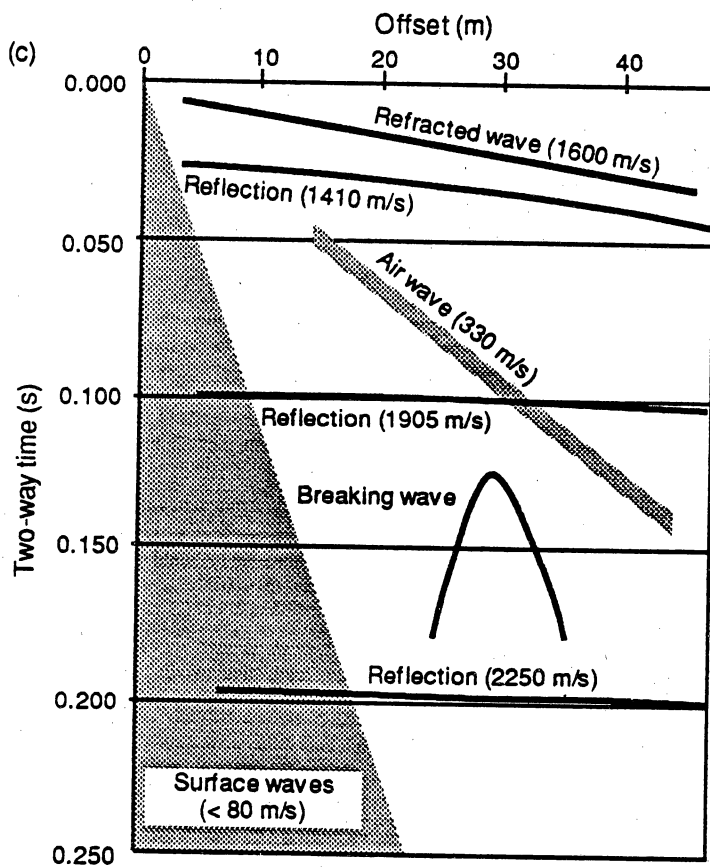
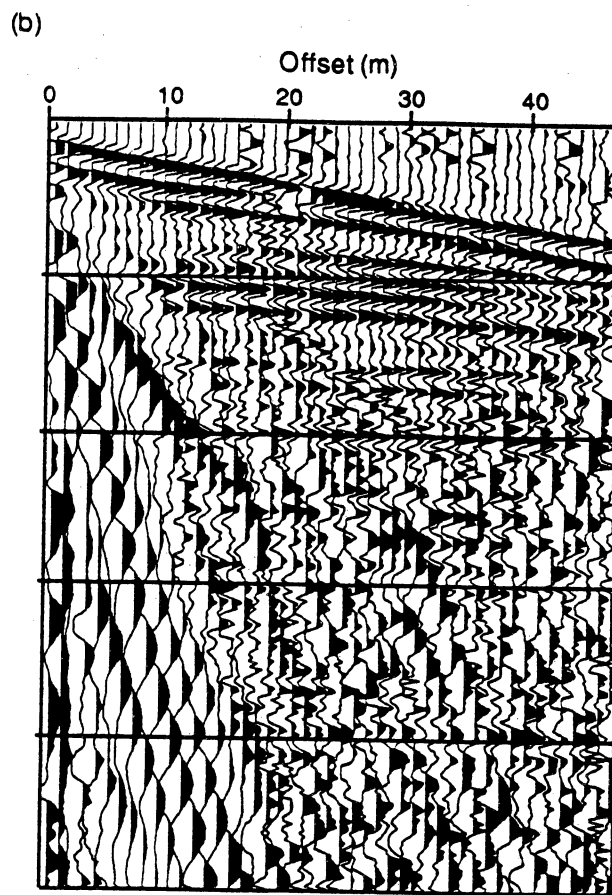
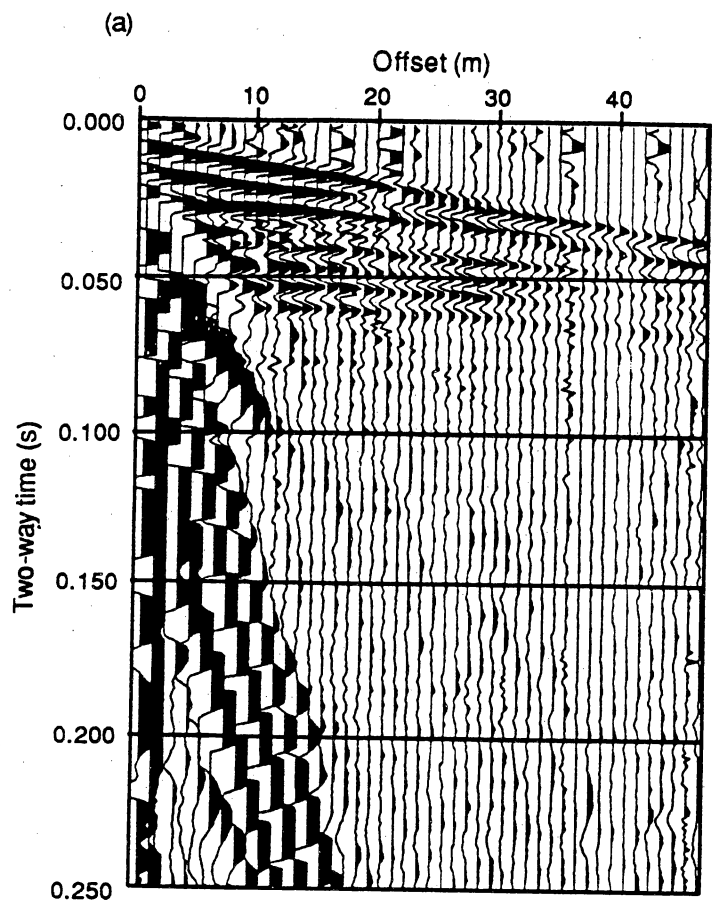
Yilmaz, Ozdogan, 1987, Seismic data processing: Tulsa, Oklahoma, Society of Exploration Geophysicists, Investigations in Geophysics No. 2, 526 p.

FIGURE CAPTIONS

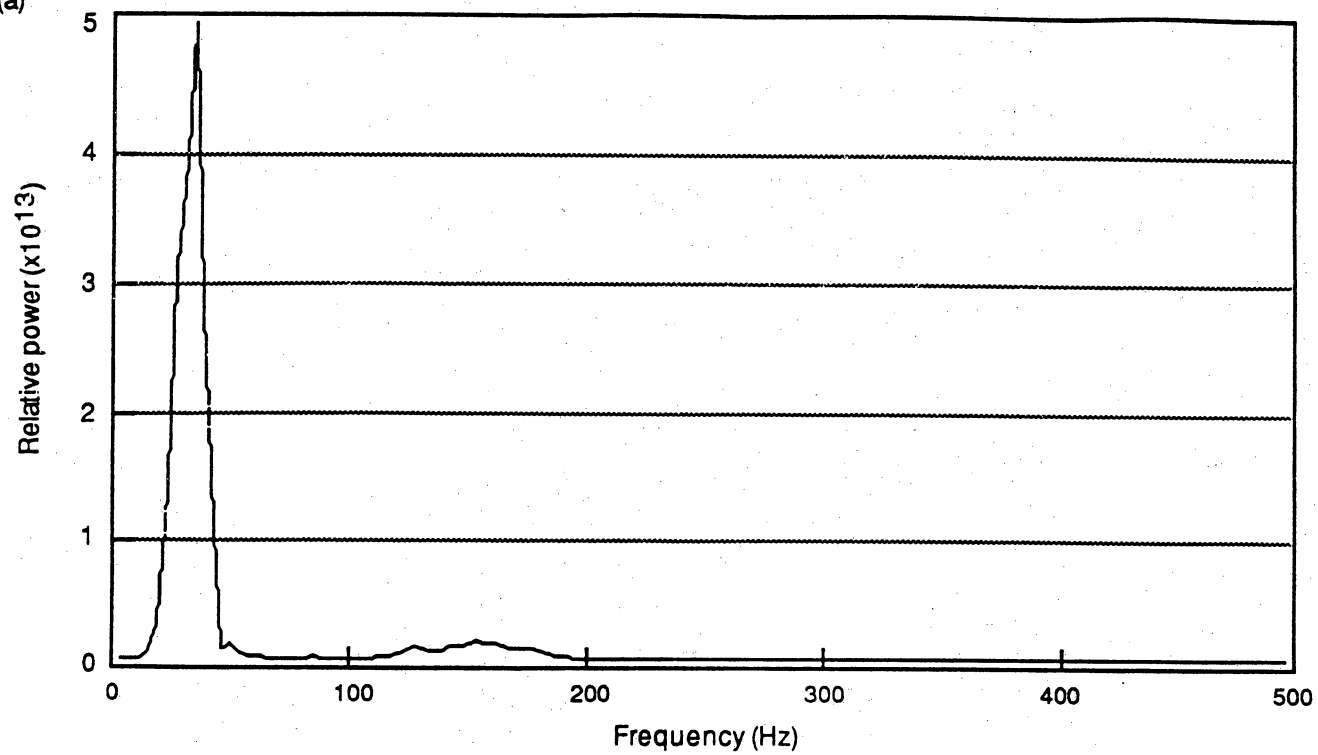
- Figure 1. Map of the upper Texas coast showing the location of three seismic testing sites: gulf beach at High Island (a), chenier plain marsh at Sabine Pass (b), and modern floodplain along the Neches River (c).
- Figure 2. (a) Field record HIRL1003 from gulf beach at High Island with 36 dB display gain, (b) field record with automatic gain control (0.05 s window) applied, and (c) interpreted types of seismic energy.
- Figure 3. High Island power spectrum at 10 m source-receiver offset, (a) before and (b) after surface wave mute.
- Figure 4. Stacking velocity picks, best-fit velocity function, and time-to-depth conversion curve for seismic reflection line at High Island test site.
- Figure 5. Processed seismic reflection sections from test sites at (a) High Island, (b) Sabine Pass, and (c) Neches River. Traces are 0.5 m apart and are displayed with automatic gain control (0.1 s window) applied.
- Figure 6. Field record SPRL1127 from Sabine Pass site. Highest amplitudes in each trace have been equalized.
- Figure 7. Sabine Pass power spectrum at 10 m source-receiver offset, (a) before and (b) after surface wave mute.
- Figure 8. Field records from low-cut filter test at Neches River site. During the test, data were acquired with the low-cut filter at (a) 4 Hz, (b) 16 Hz, (c) 64 Hz, and (d) 96 Hz. Records displayed with highest amplitude equalized for each trace.
- Figure 9. Neches River power spectrum at 10 m source-receiver offset, (a) before and (b) after surface wave mute.



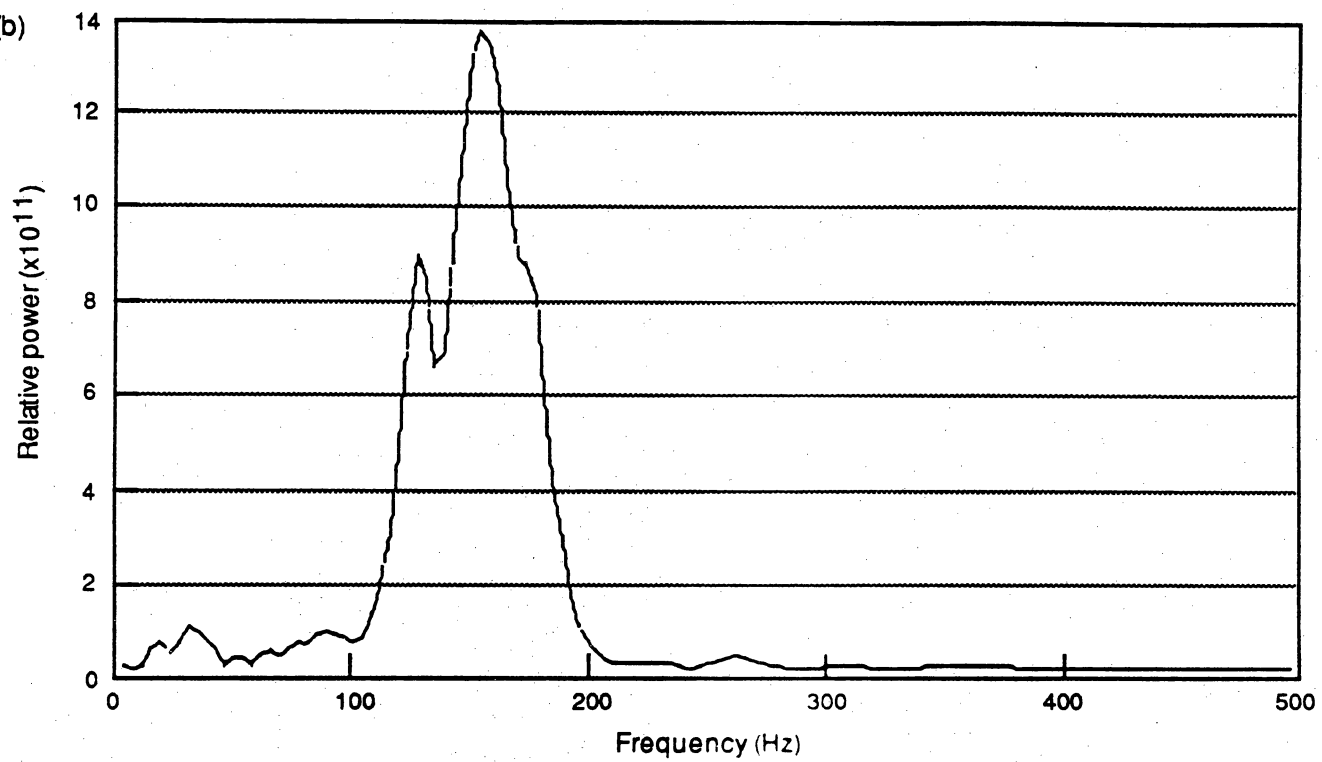
QAb1838c

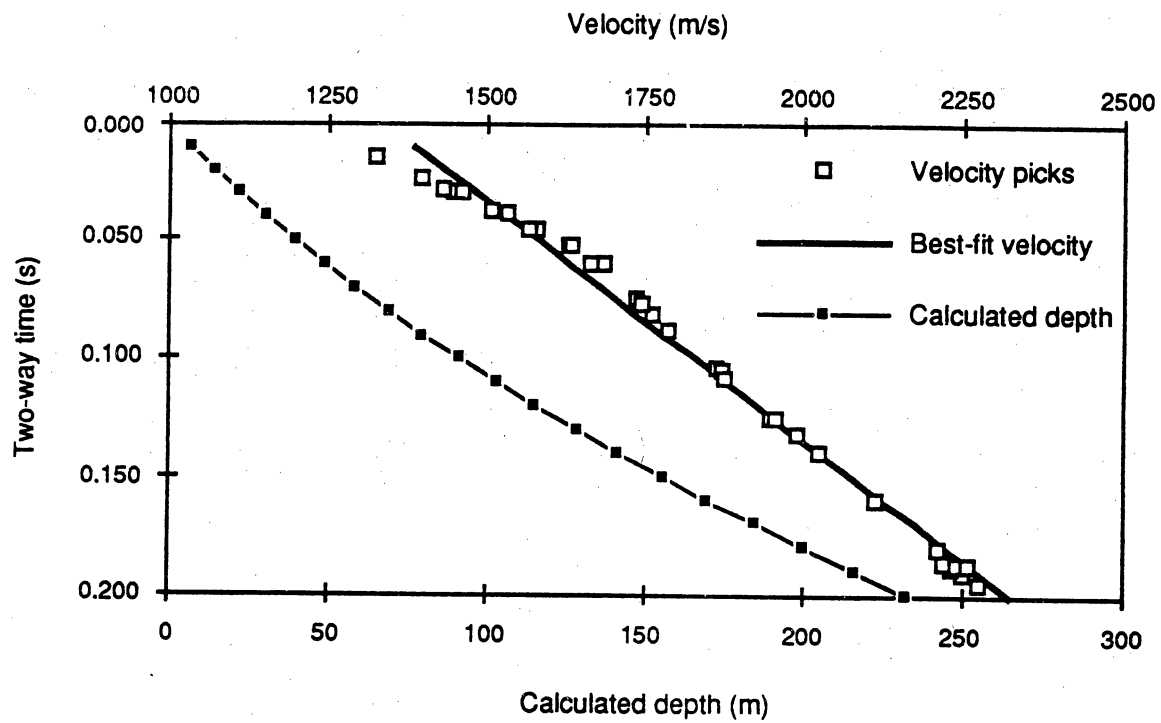


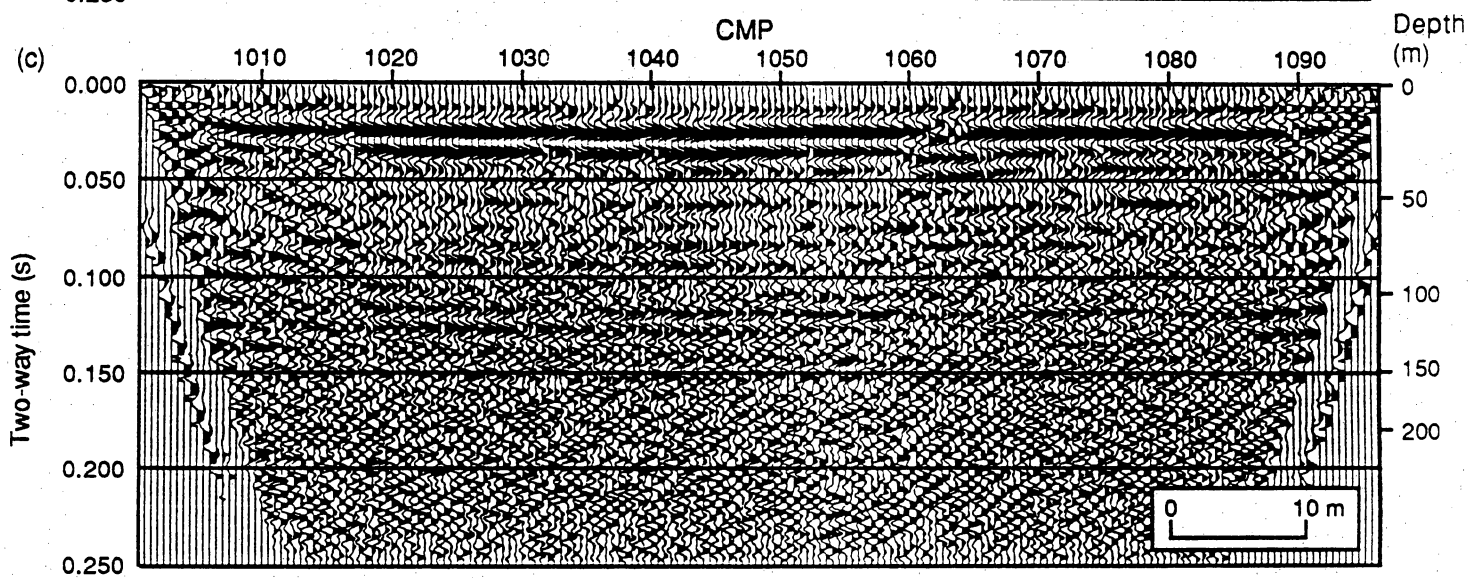
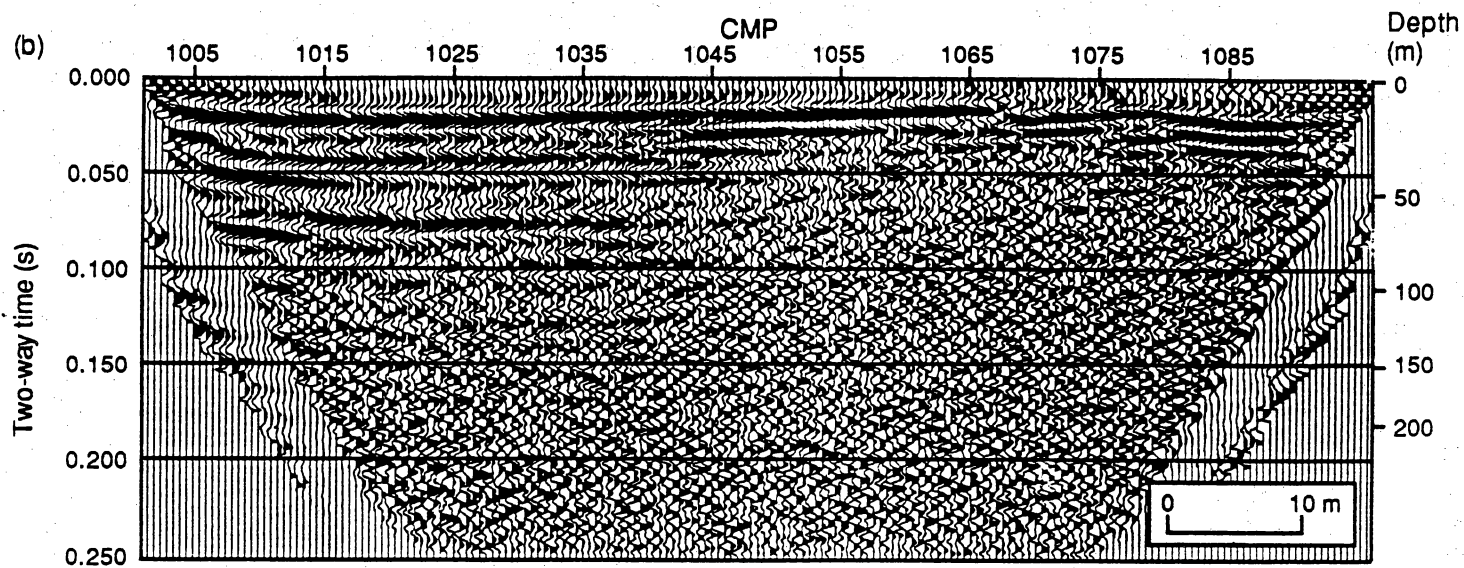
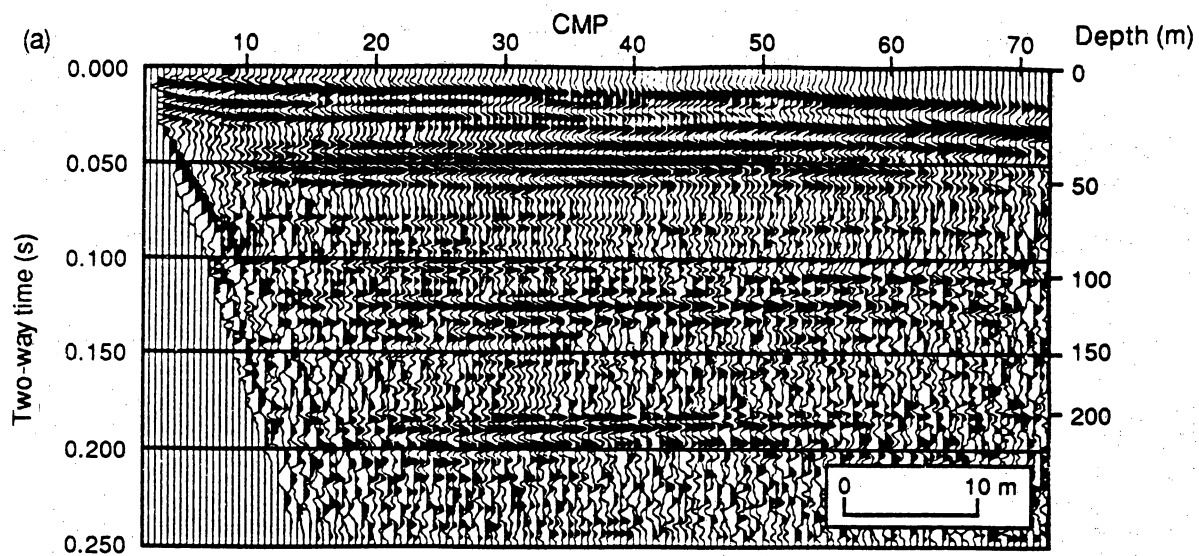
(a)

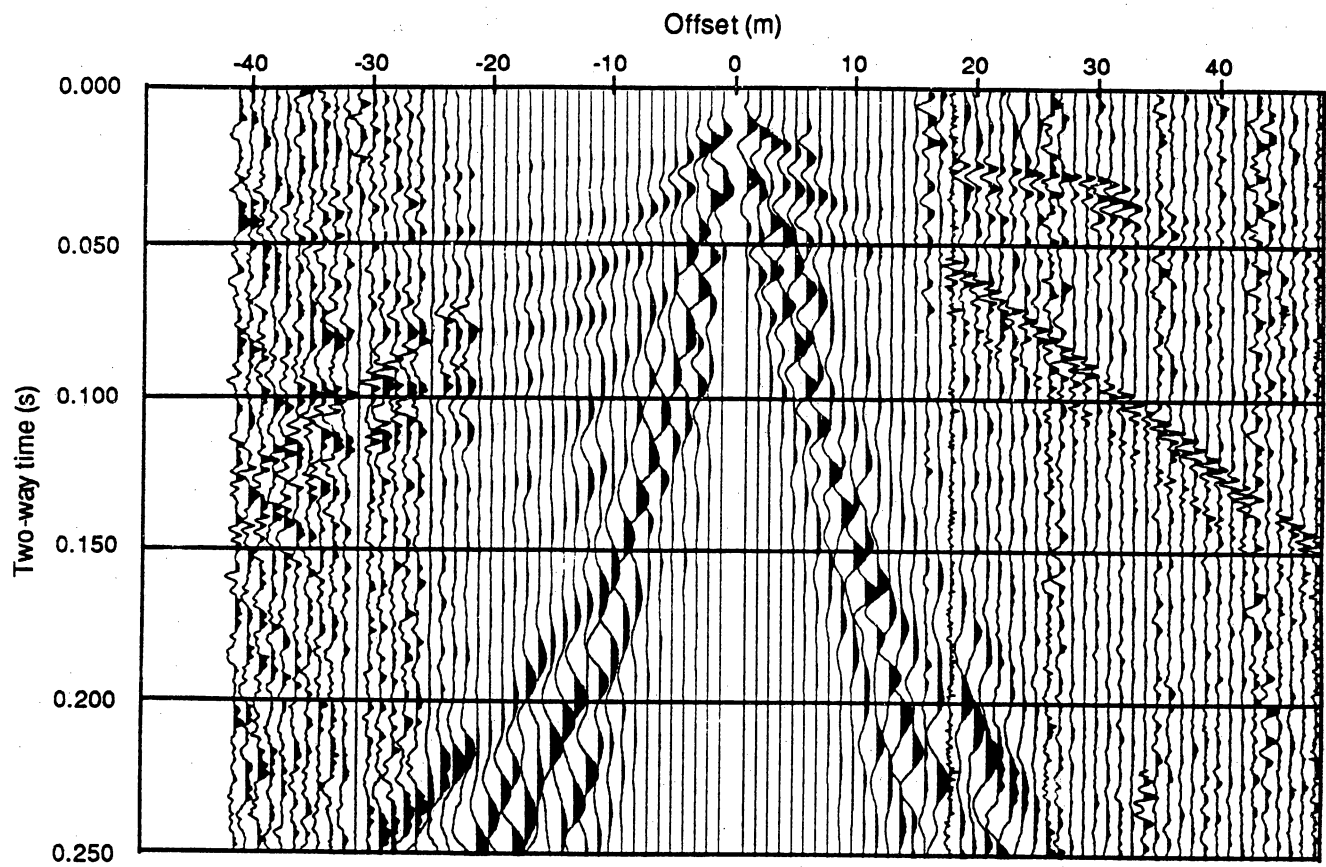


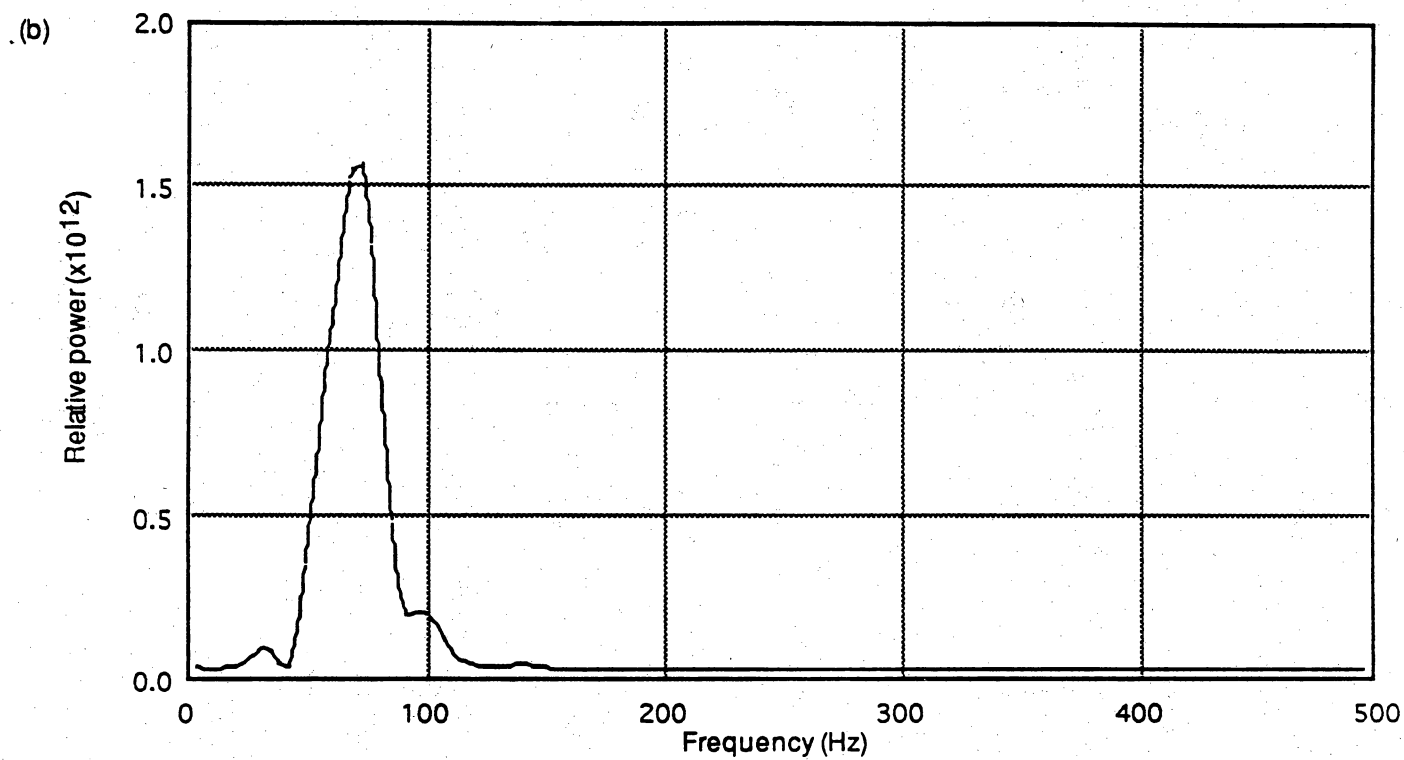
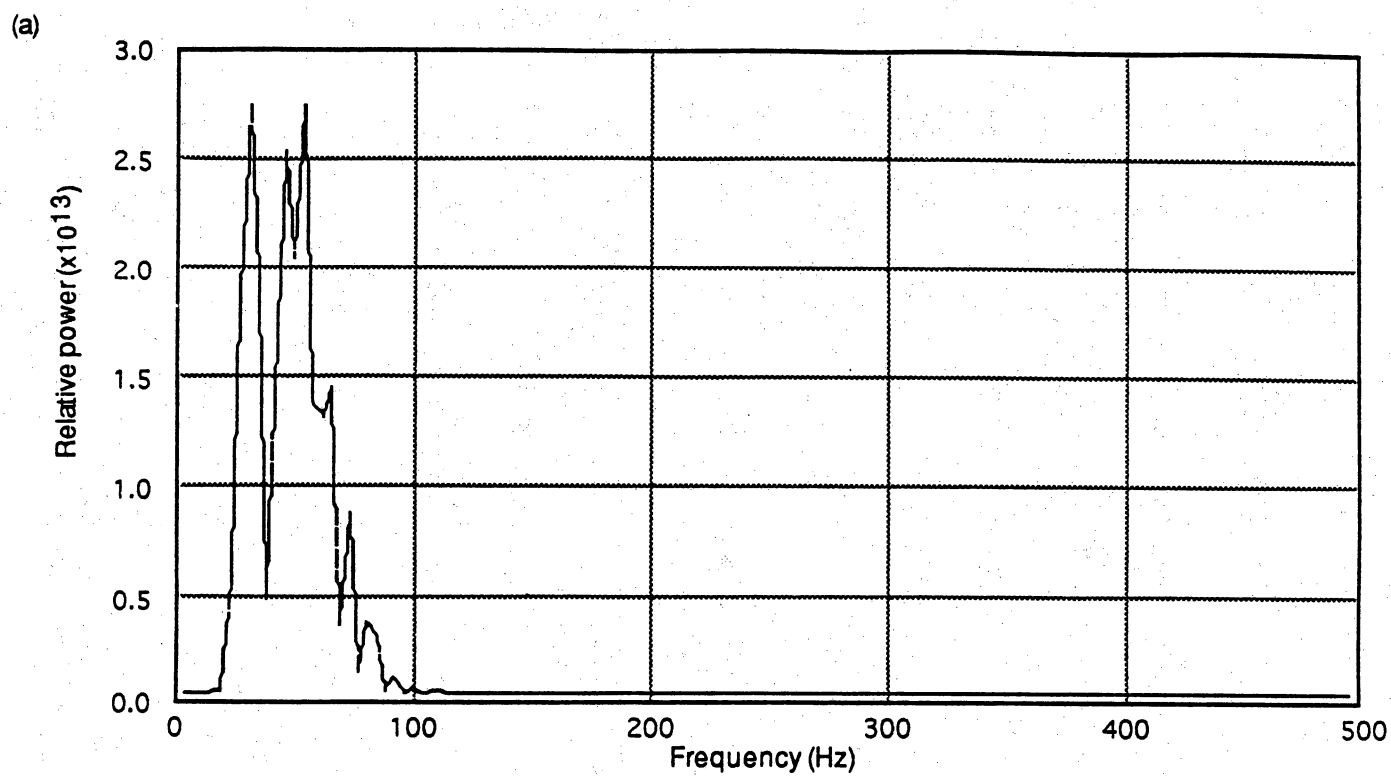
(b)

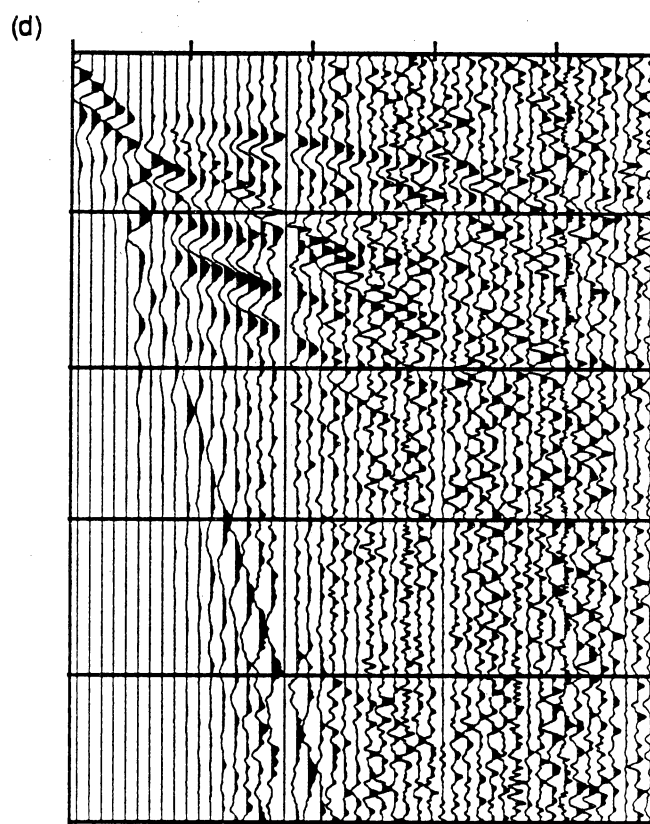
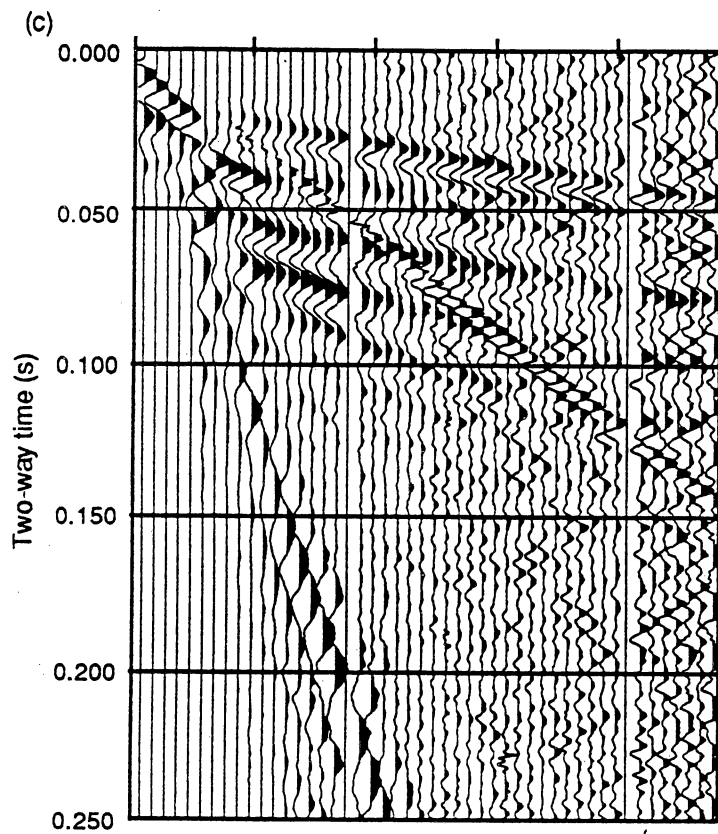
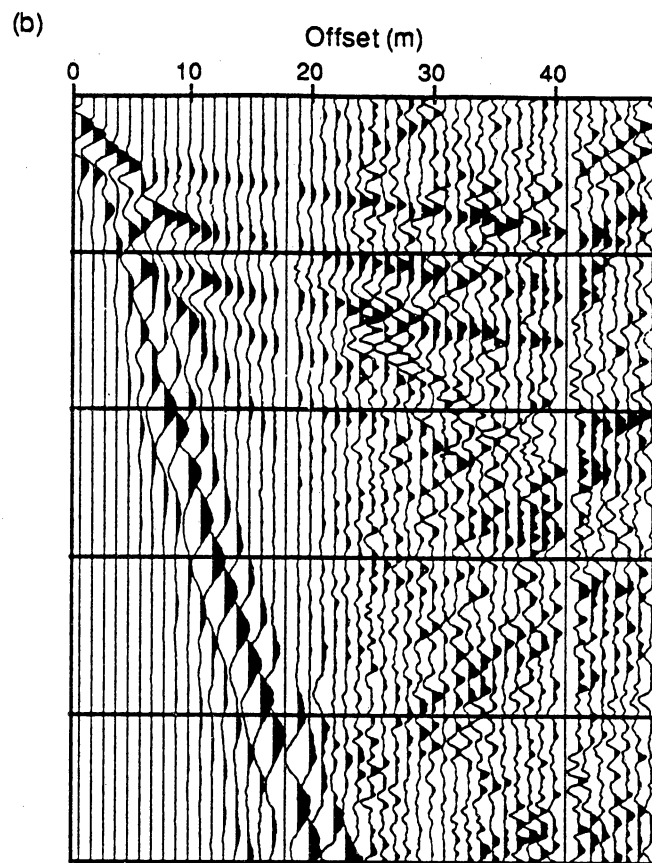
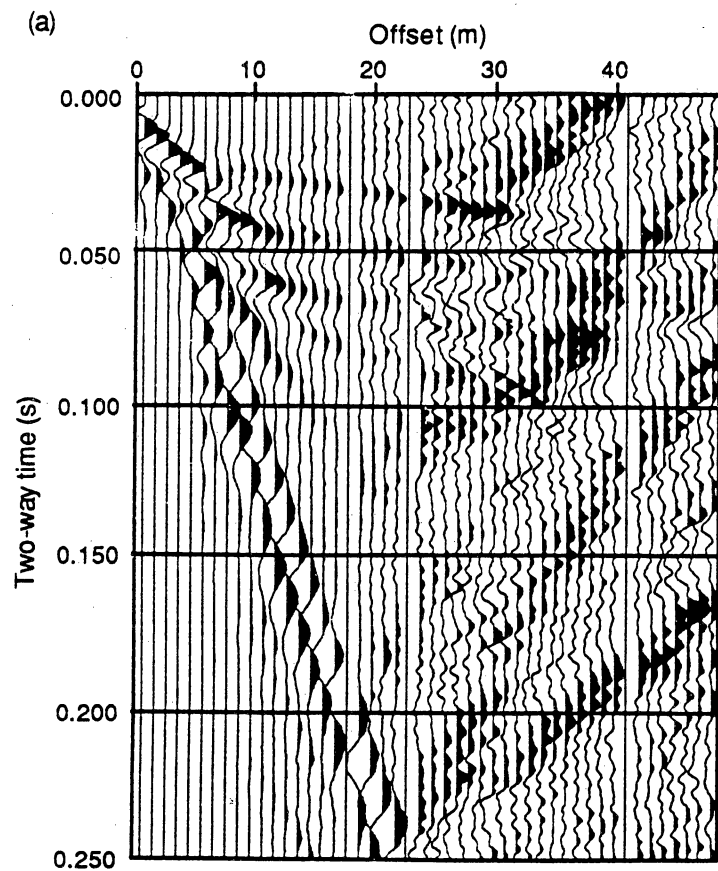












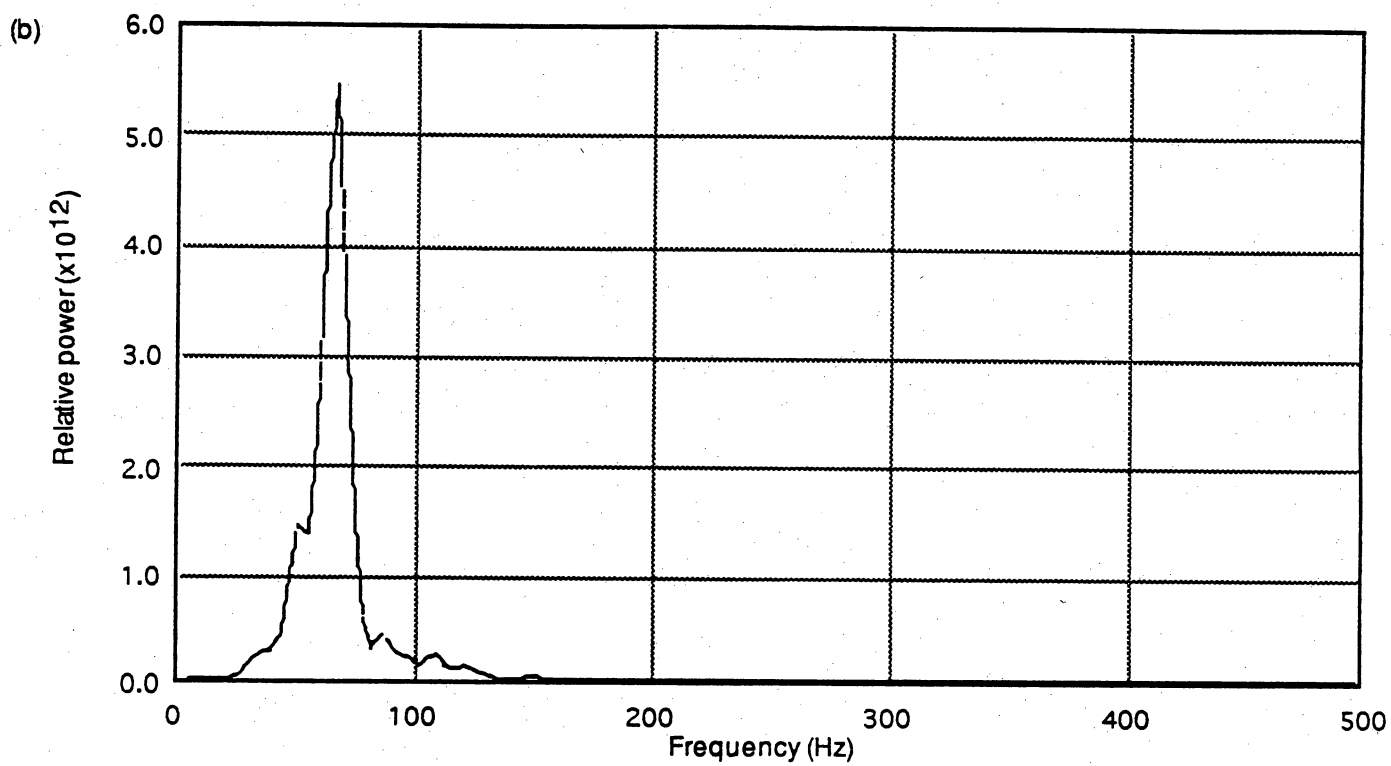
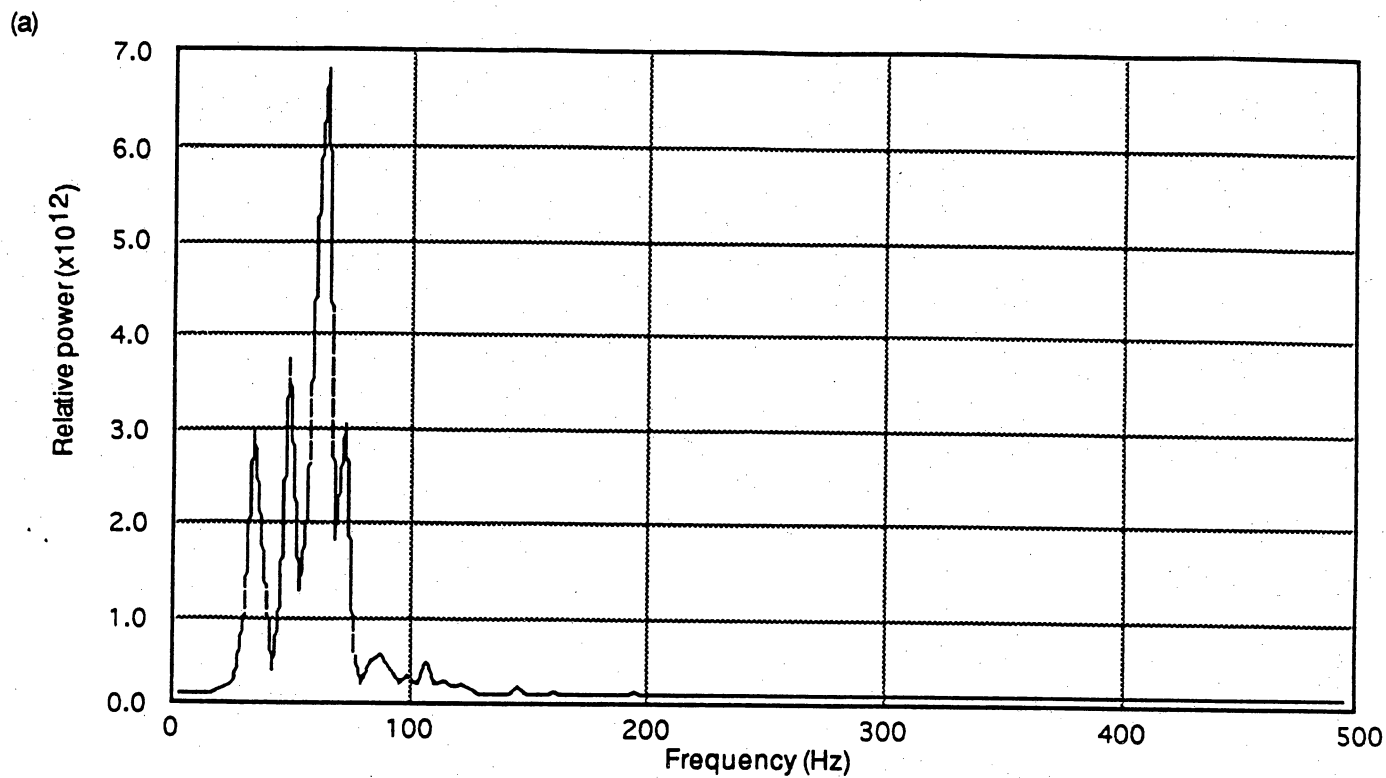


Table 1. Equipment used to collect shallow seismic data at High Island, Sabine Pass, and Neches River test sites.

| | |
|-----------------------|--|
| Energy sources | 3.6 kg modified soil probe hammer (reflection source) |
| | 5.4 kg sledge hammer on aluminum plate (refraction source) |
| Geophones | Mark Products L-40A (40 Hz, 515 ohm coil resistance, 13 cm spikes) |
| Seismograph | Bison 9048 (48 channel, 16 bit analog to digital conversion) |

Table 2. Recording parameters and acquisition geometry used during seismic reflection surveys.

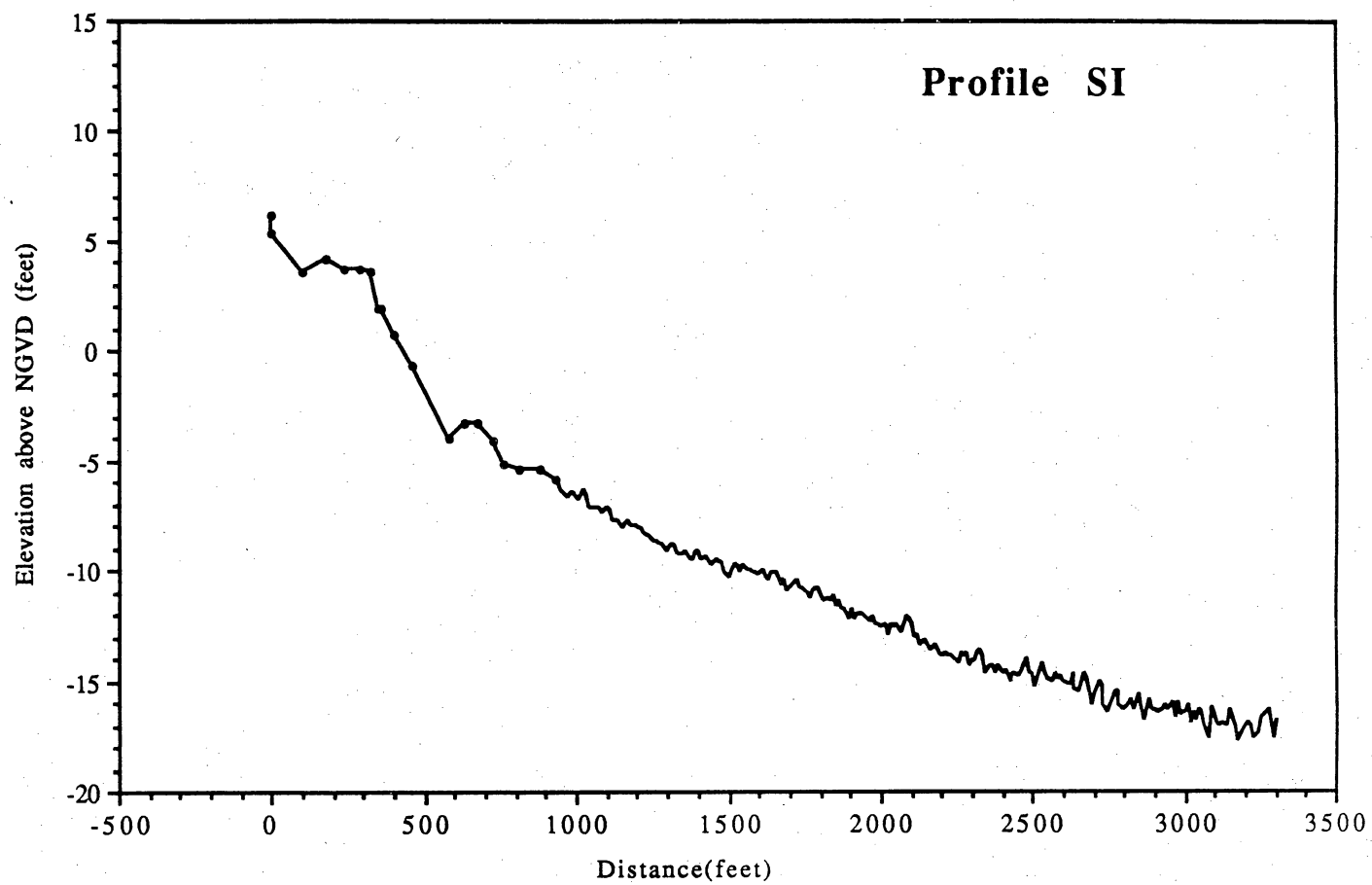
| | High Island (January 3, 1995) | Sabine Pass (January 4, 1995) | Neches River (January 4, 1995) |
|----------------------------------|----------------------------------|----------------------------------|-----------------------------------|
| Spread type | End-on | End-on | Split |
| Source to near trace offset (m): | 1 | 1 | 1 |
| Spread length (m) | 47 | 47 | 23 |
| Source stacks | 1 | 1 | 1 |
| Geophones in array | 1 | 1 | 1 |
| Geophone spacing (m) | 1 | 1 | 1 |
| Recording channels | 48 | 48 | 48 |
| Sample interval (ms) | 1.0 | 0.5 | 0.5 |
| Record length (s) | 1.0 | 0.25 | 0.25 |
| Analog low-cut filter (Hz) | 16 | 32 | 64 |
| Analog high-cut filter (Hz) | 1000 | 1000 | 1000 |
| Data fold | 24 | 48 | 24 |

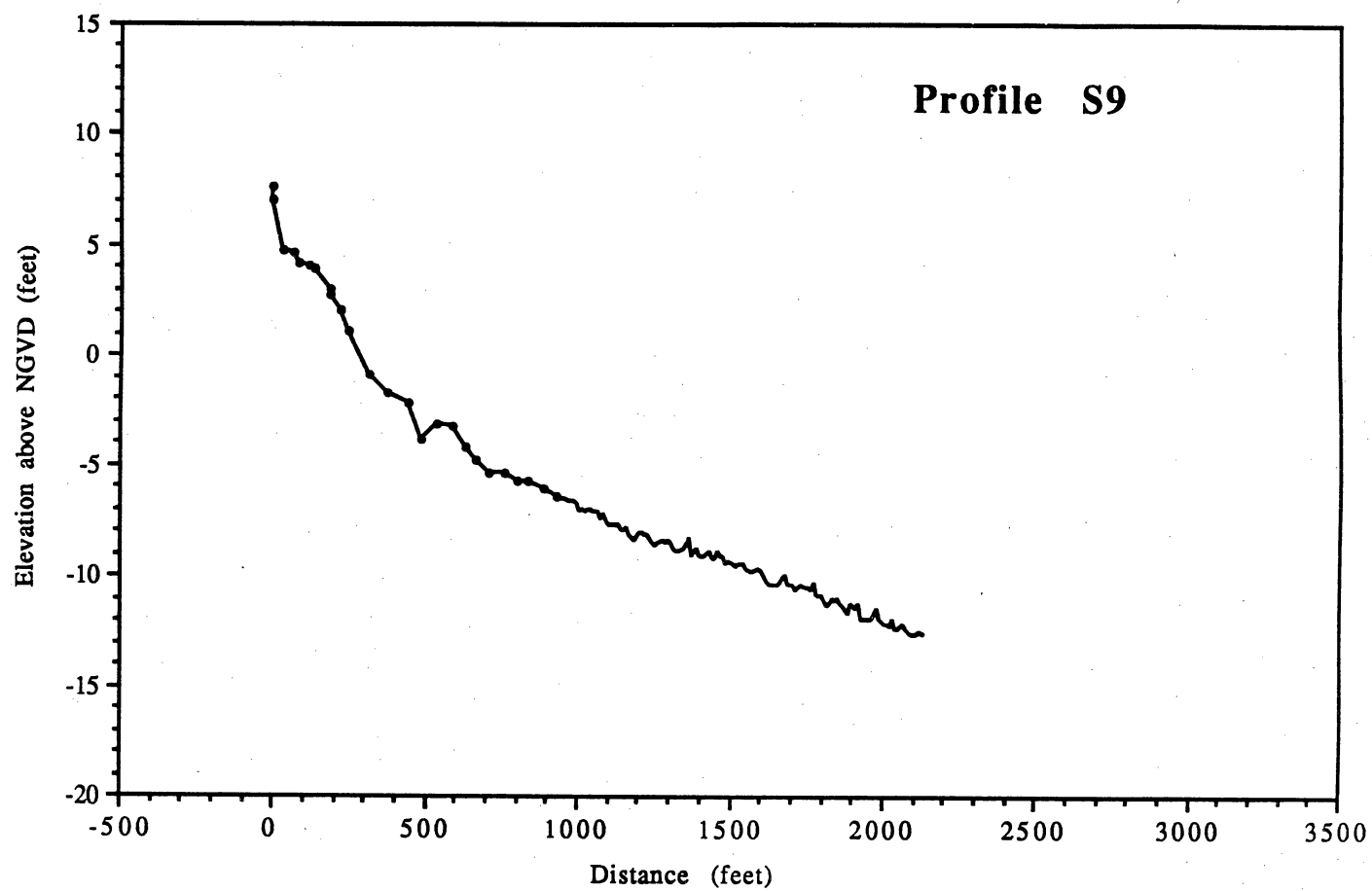
Addendum 9. Pre-project Profiles and Sediment Textures, Beach Nourishment Project

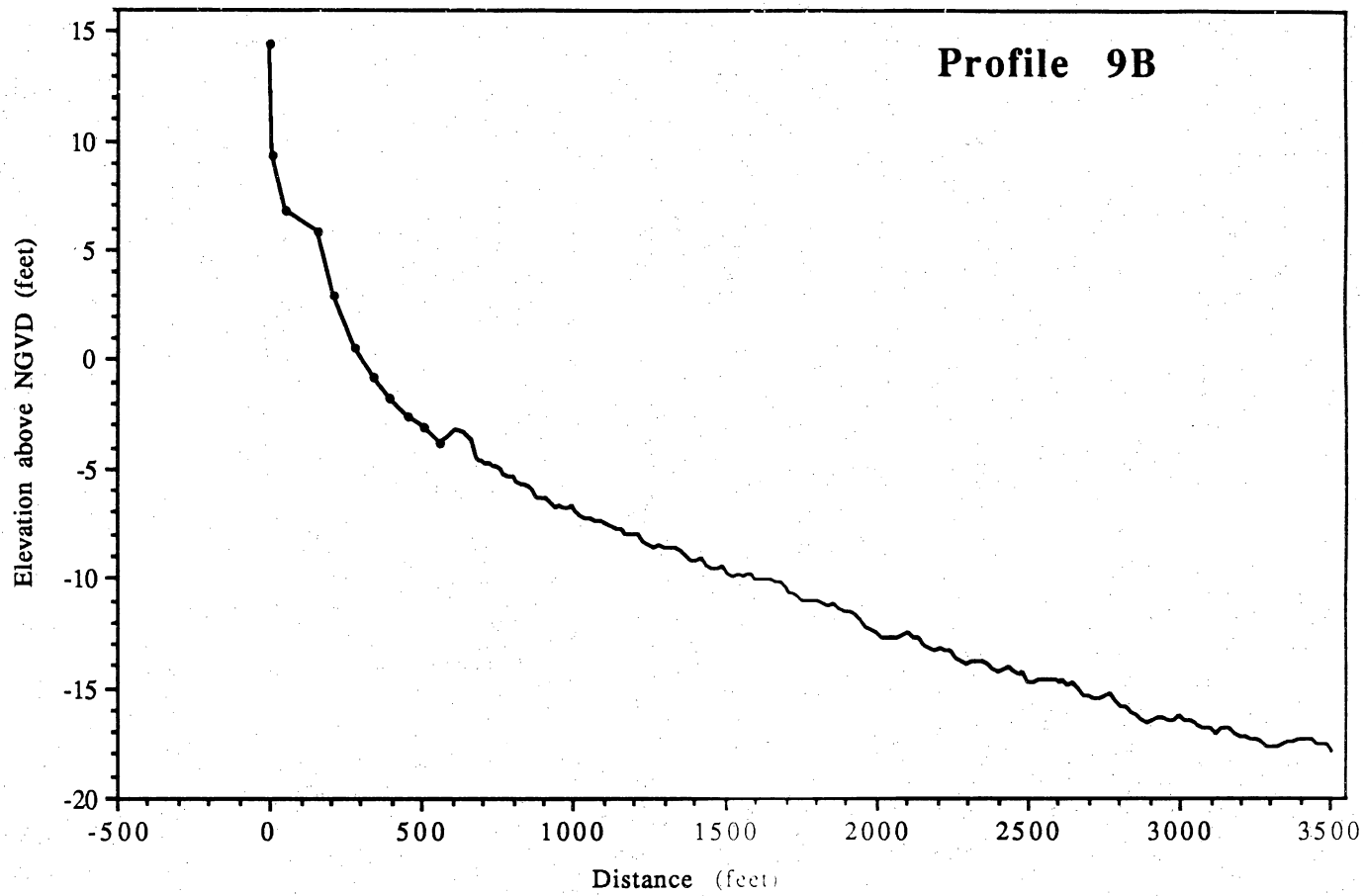
GPS UTM coordinates Galveston Surveys

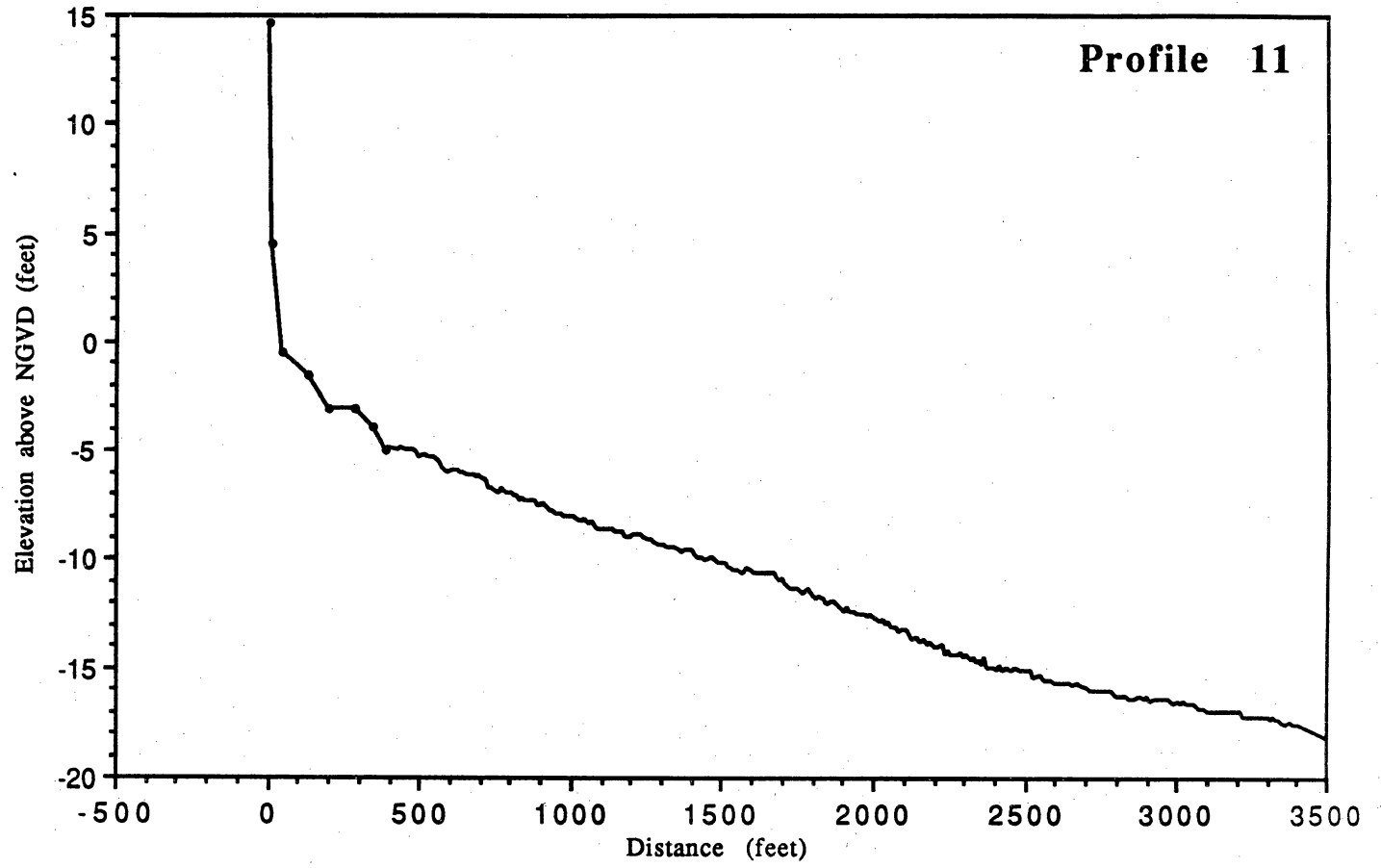
| Profile no. | UTM Coordinates | |
|--------------|-----------------|-------------|
| S8 | 328128.648 | 3243216.188 |
| SI | 327928.186 | 3242984.517 |
| S9 | 327728.354 | 3242750.516 |
| 9B | 327485.247 | 3242532.448 |
| 11 | 327302.283 | 3242284.932 |
| 12 | 327118.571 | 3242129.948 |
| 15 | 326741.445 | 3241802.697 |
| 18 | 326385.299 | 3241497.489 |
| 20 | 326179.937 | 3241317.498 |
| 22 | 325864.794 | 3241076.027 |
| 23A | 325745.854 | 3240991.415 |
| 26 | 325443.996 | 3240774.210 |
| 29 | 325089.773 | 3240521.363 |
| 31 | 324750.484 | 3240278.538 |
| 33 | 324473.180 | 3240098.352 |
| 36 | 324113.029 | 3239875.446 |
| 39 | 323744.028 | 3239624.768 |
| 42 | 323343.890 | 3239398.496 |
| 45 | 323007.686 | 3239174.865 |
| 48 | 322690.178 | 3238958.090 |
| W0 | 322340.245 | 3238744.756 |
| W1 | 322078.773 | 3238586.913 |
| Sed. samples | | |
| B1 | 330540.000 | 3242870.000 |
| B2 | 331138.000 | 3243179.000 |
| B3 | 330438.000 | 3242472.000 |
| B4 | 329817.000 | 3243038.000 |
| B5 | 329420.000 | 3242293.000 |
| S8-2 | 328484.000 | 3242843.000 |
| S8-3 | 328588.000 | 3242730.000 |
| S8-4 | 328701.000 | 3242601.000 |
| SI-2 | 328187.000 | 3242687.000 |
| SI-3 | 328346.000 | 3242541.000 |
| SI-4 | 328466.000 | 3242433.000 |
| S9-4 | 328188.000 | 3242265.000 |
| S9-3 | 328080.000 | 3242360.000 |
| S9-2 | 327960.000 | 3242517.000 |
| 9B-4 | 327948.000 | 3242051.000 |
| 9B-3 | 327829.000 | 3242160.000 |
| 9B-2 | 327689.000 | 3242319.000 |
| 11-2 | 327429.000 | 3242074.000 |
| 11-3 | 327591.000 | 3241968.000 |
| 11-4 | 327716.000 | 3241830.000 |
| 12-4 | 327560.000 | 3241642.000 |
| 12-3 | 327418.000 | 3241829.000 |

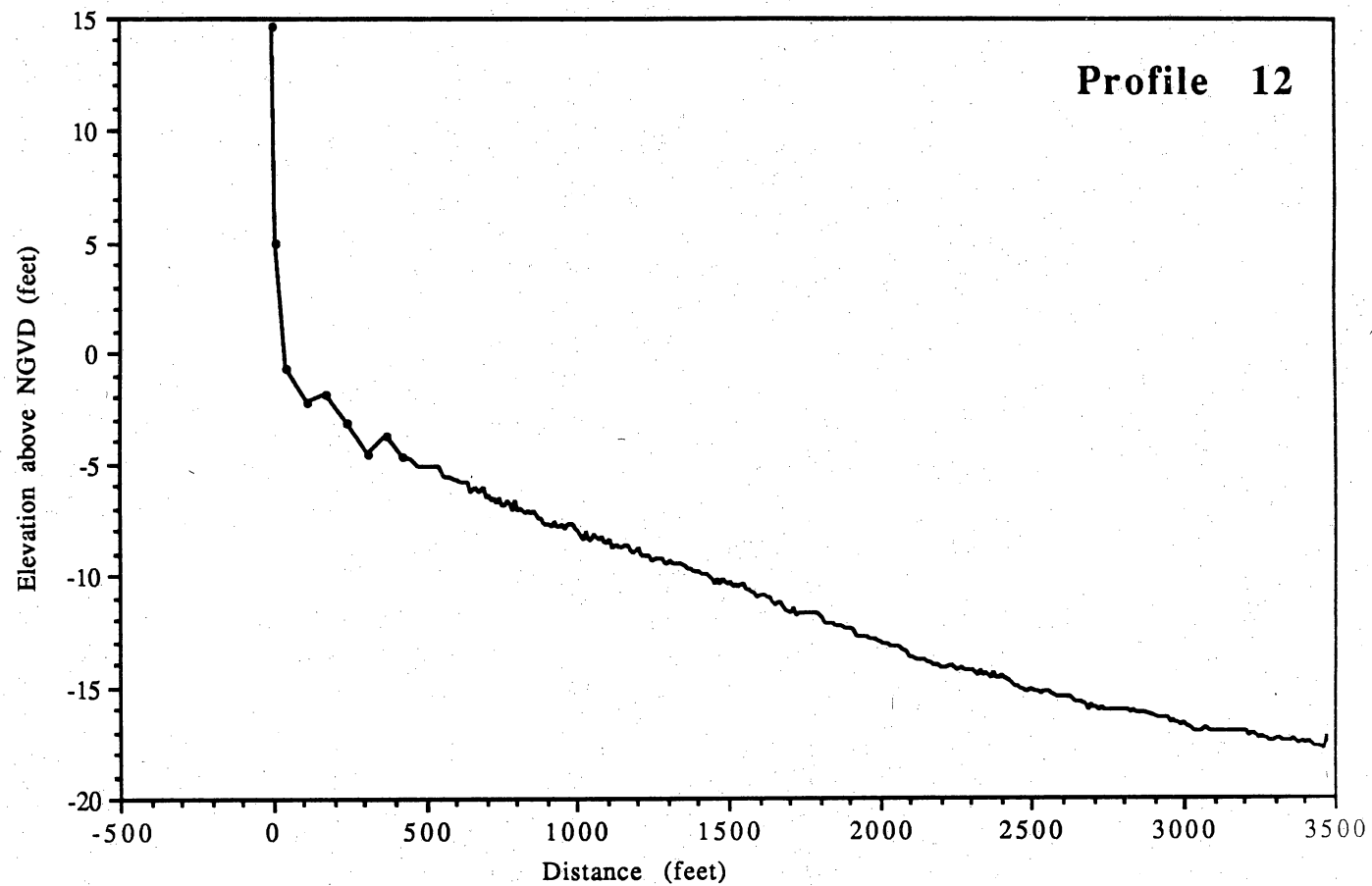
| | | |
|-------|------------|-------------|
| 12-2 | 327275.000 | 3241949.000 |
| 15-3 | 327016.000 | 3241482.000 |
| 15-4 | 327177.000 | 3241350.000 |
| 18-3 | 326689.000 | 3241199.000 |
| 18-2 | 326536.000 | 3241323.000 |
| 20-2 | 326350.000 | 3241145.000 |
| 20-3 | 326475.000 | 3241008.000 |
| 20-4 | 326595.000 | 3240877.000 |
| 22-3 | 326146.000 | 3240788.000 |
| 22-2 | 326041.000 | 3240917.000 |
| 23A-3 | 325968.000 | 3240681.000 |
| 23A-4 | 326114.000 | 3240514.000 |
| 26-4 | 325782.000 | 3240348.000 |
| 26-2 | 325584.000 | 3240619.000 |
| 29-2 | 325209.000 | 3240354.000 |
| 29-3 | 325321.000 | 3240234.000 |
| 29-4 | 325439.000 | 3240063.000 |
| 31-4 | 325108.000 | 3239786.000 |
| 31-3 | 324956.000 | 3239993.000 |
| 31-2 | 324884.000 | 3240135.000 |
| 33-3 | 324677.000 | 3239785.000 |
| 33-4 | 324789.000 | 3239601.000 |
| 36-2 | 324227.000 | 3239707.000 |
| 39-2 | 323858.000 | 3239466.000 |
| 39-4 | 324113.000 | 3239124.000 |
| 42-4 | 323611.000 | 3238864.000 |
| 42-3 | 323497.000 | 3239111.000 |
| 45-2 | 323091.000 | 3238984.000 |
| 45-3 | 323228.000 | 3238854.000 |
| 45-4 | 323368.000 | 3238666.000 |
| 48-3 | 322897.000 | 3238680.000 |
| 48-2 | 322819.000 | 3238776.000 |
| W0-2 | 322463.000 | 3238508.000 |
| W0-4 | 322567.000 | 3238266.000 |
| W1-4 | 322291.000 | 3238094.000 |
| W1-3 | 322225.000 | 3238261.000 |
| W1-2 | 322193.000 | 3238357.000 |

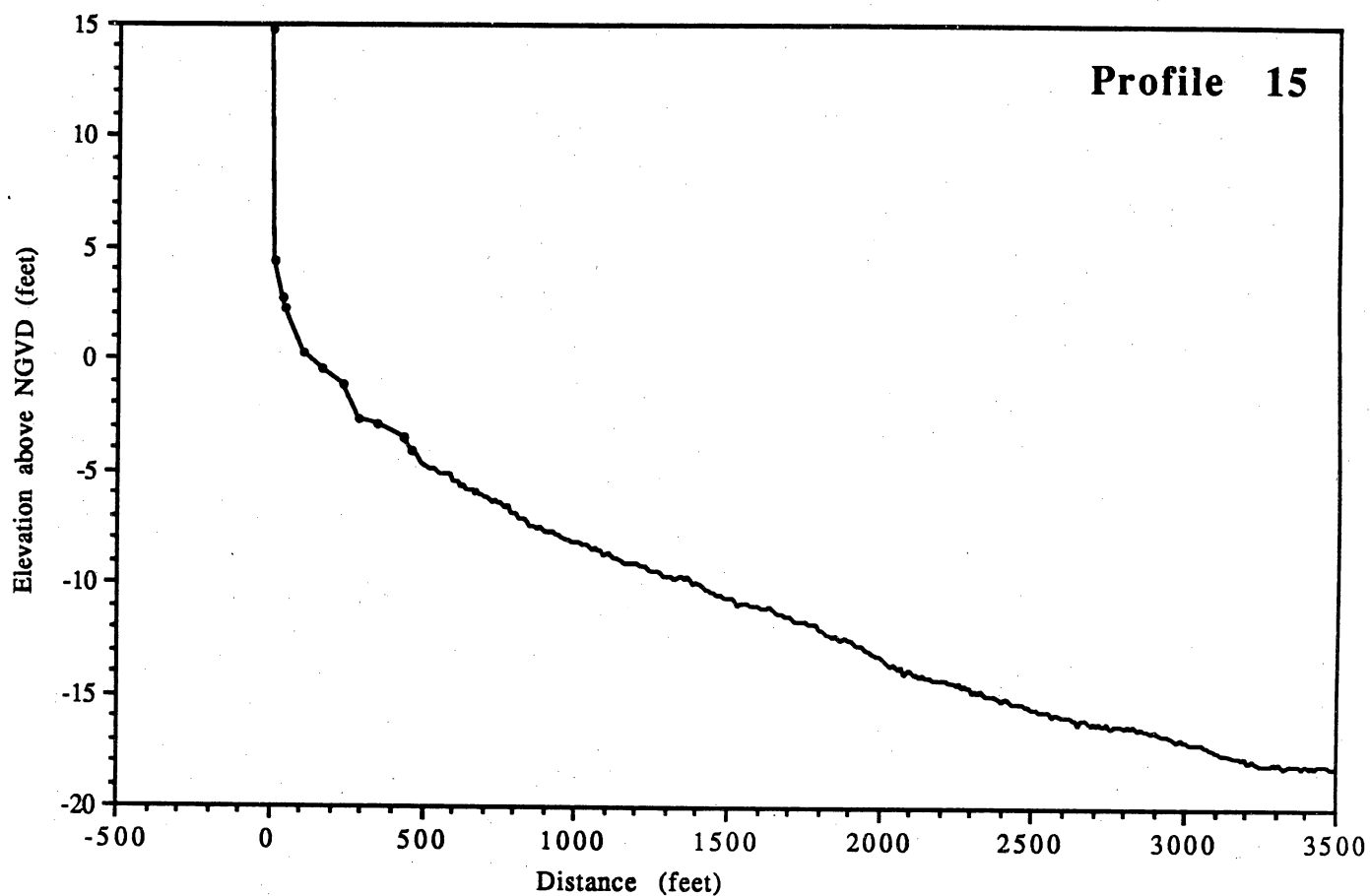


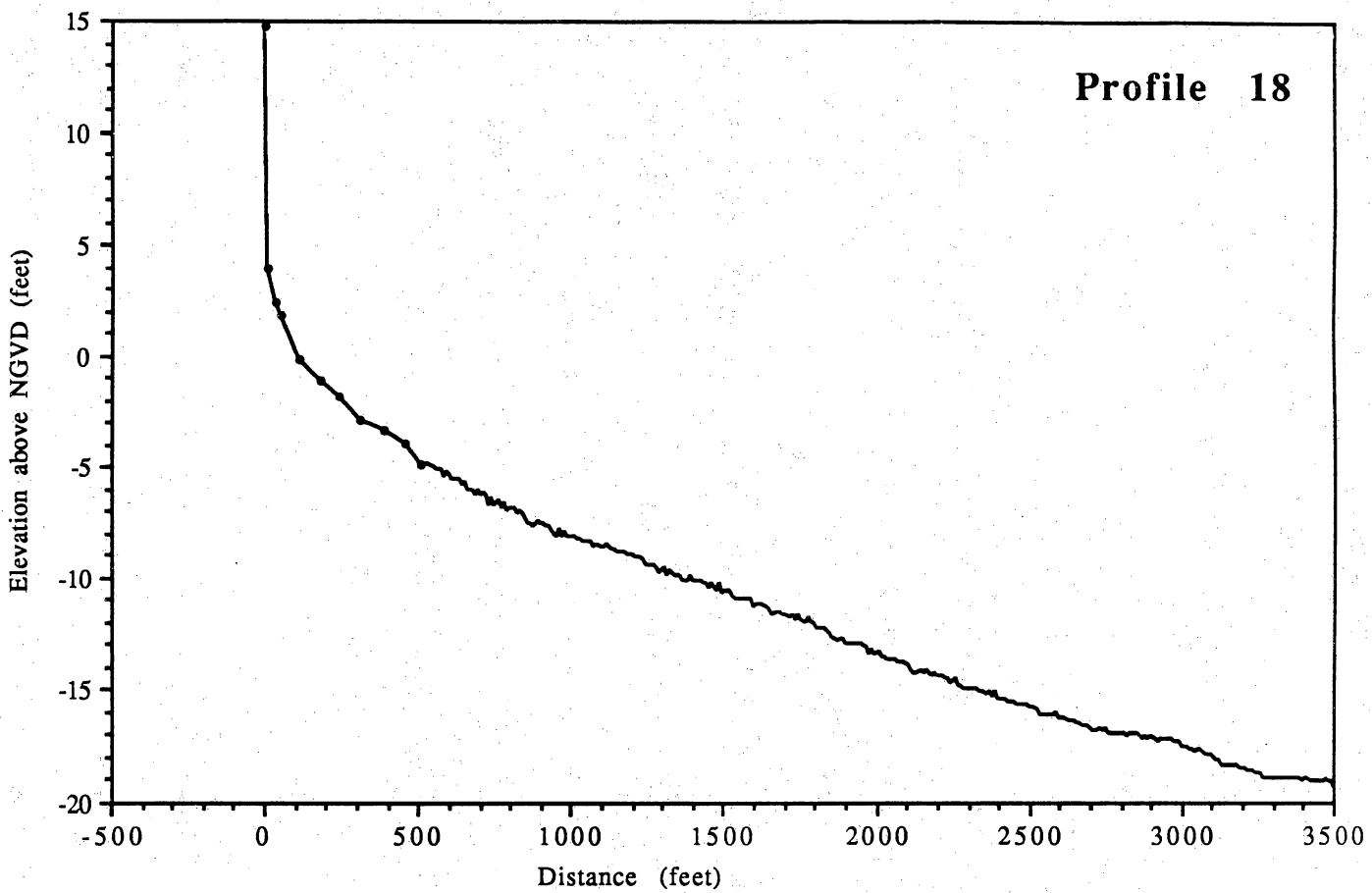


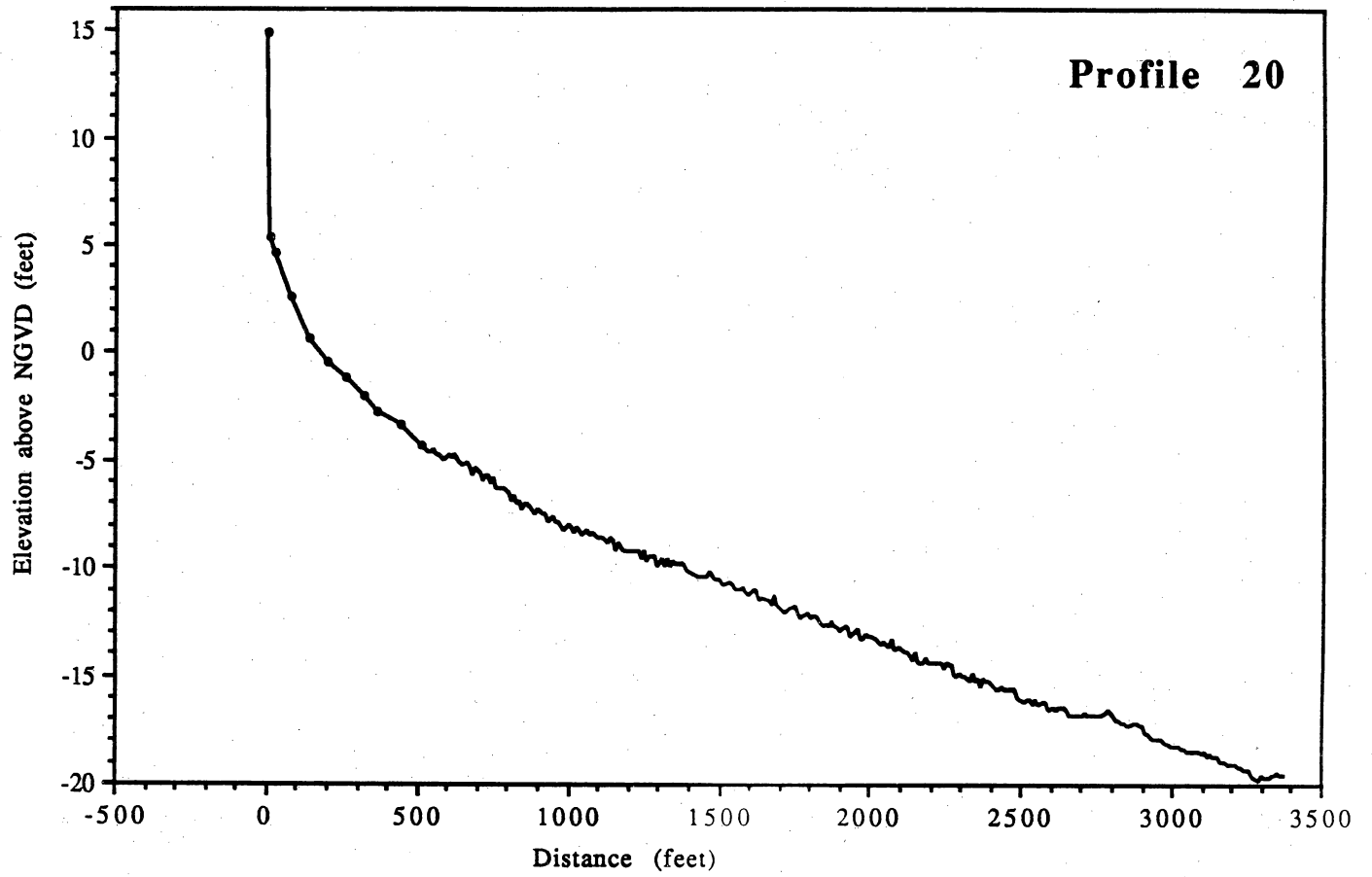




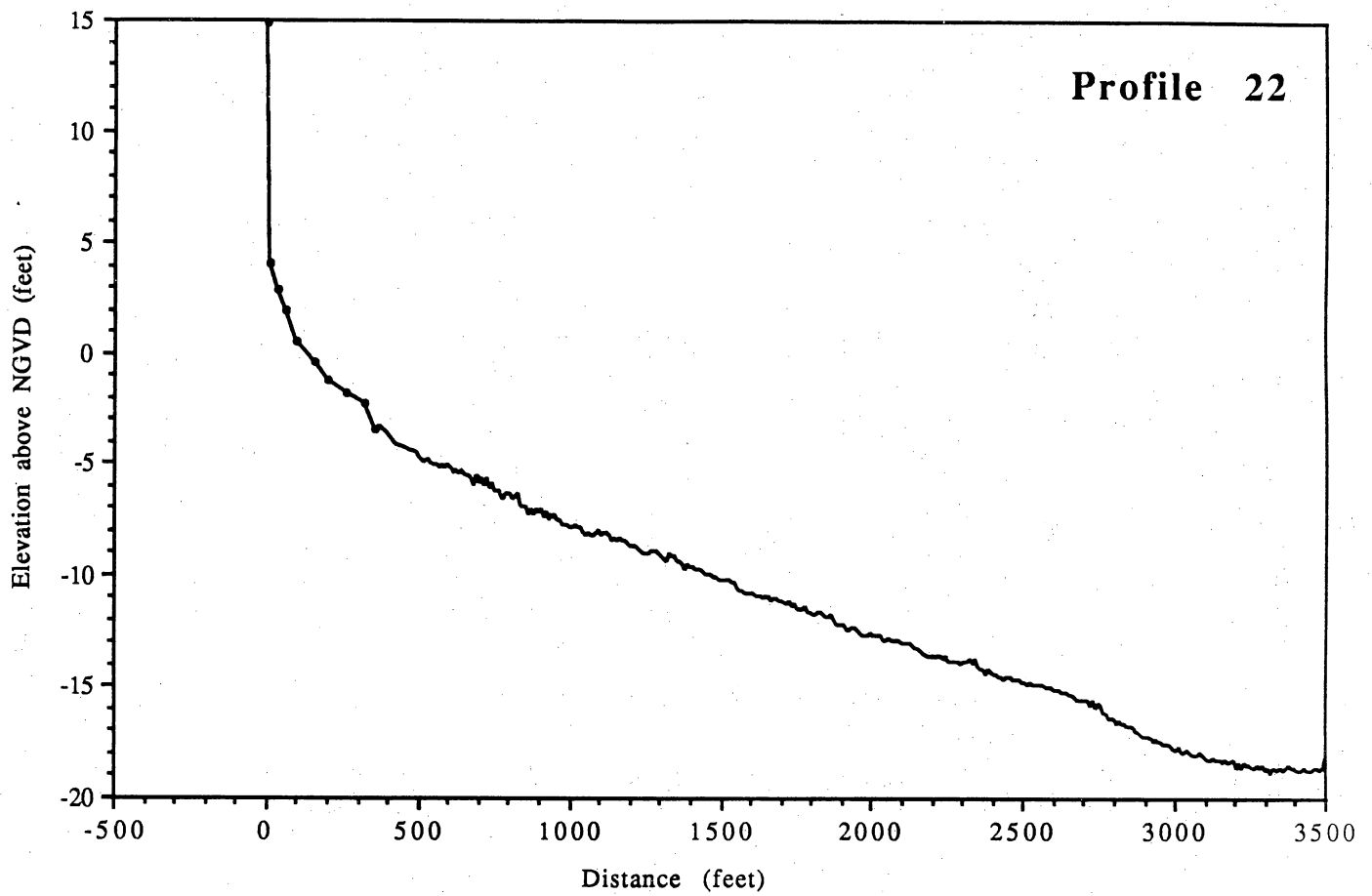


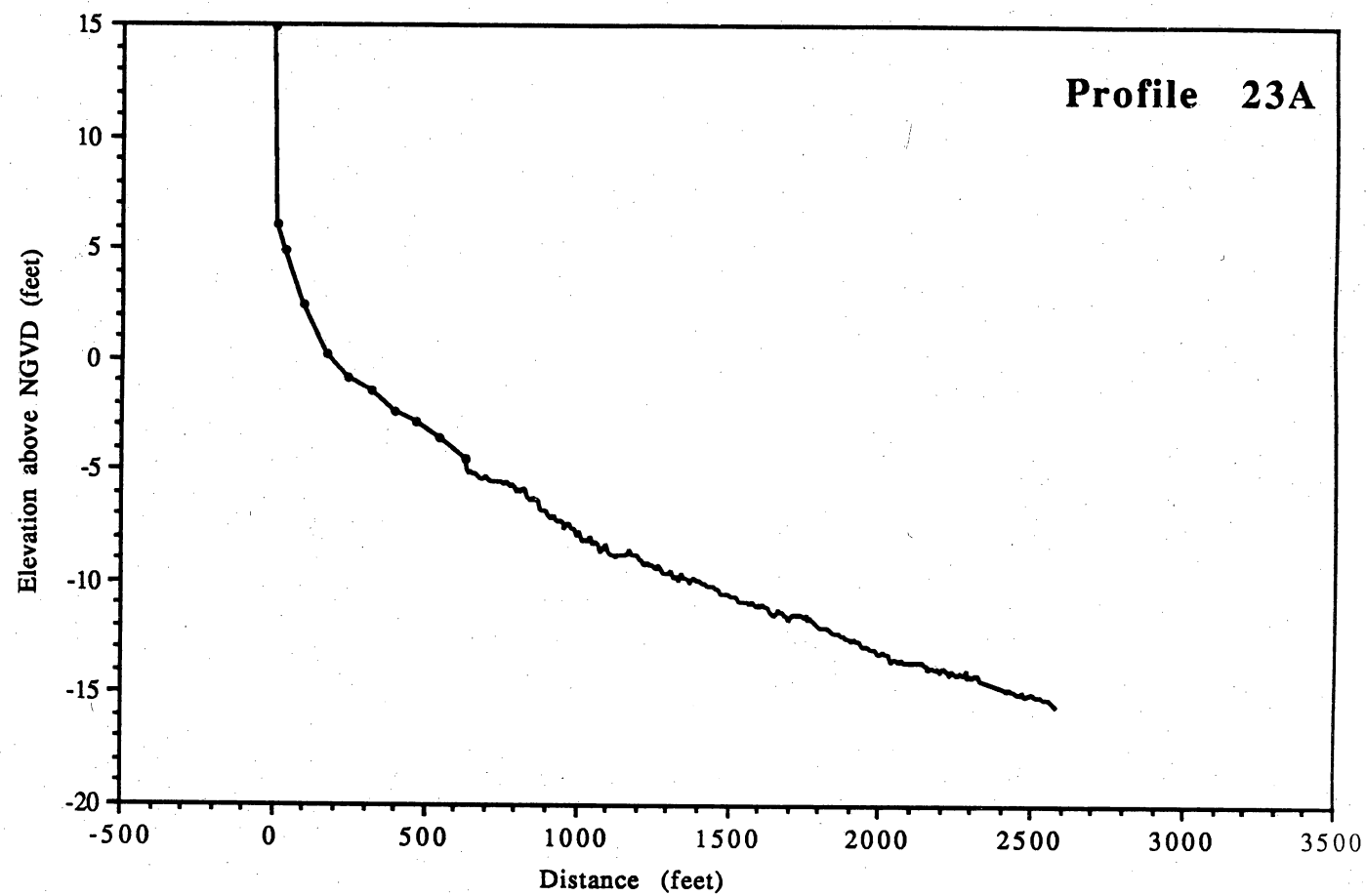


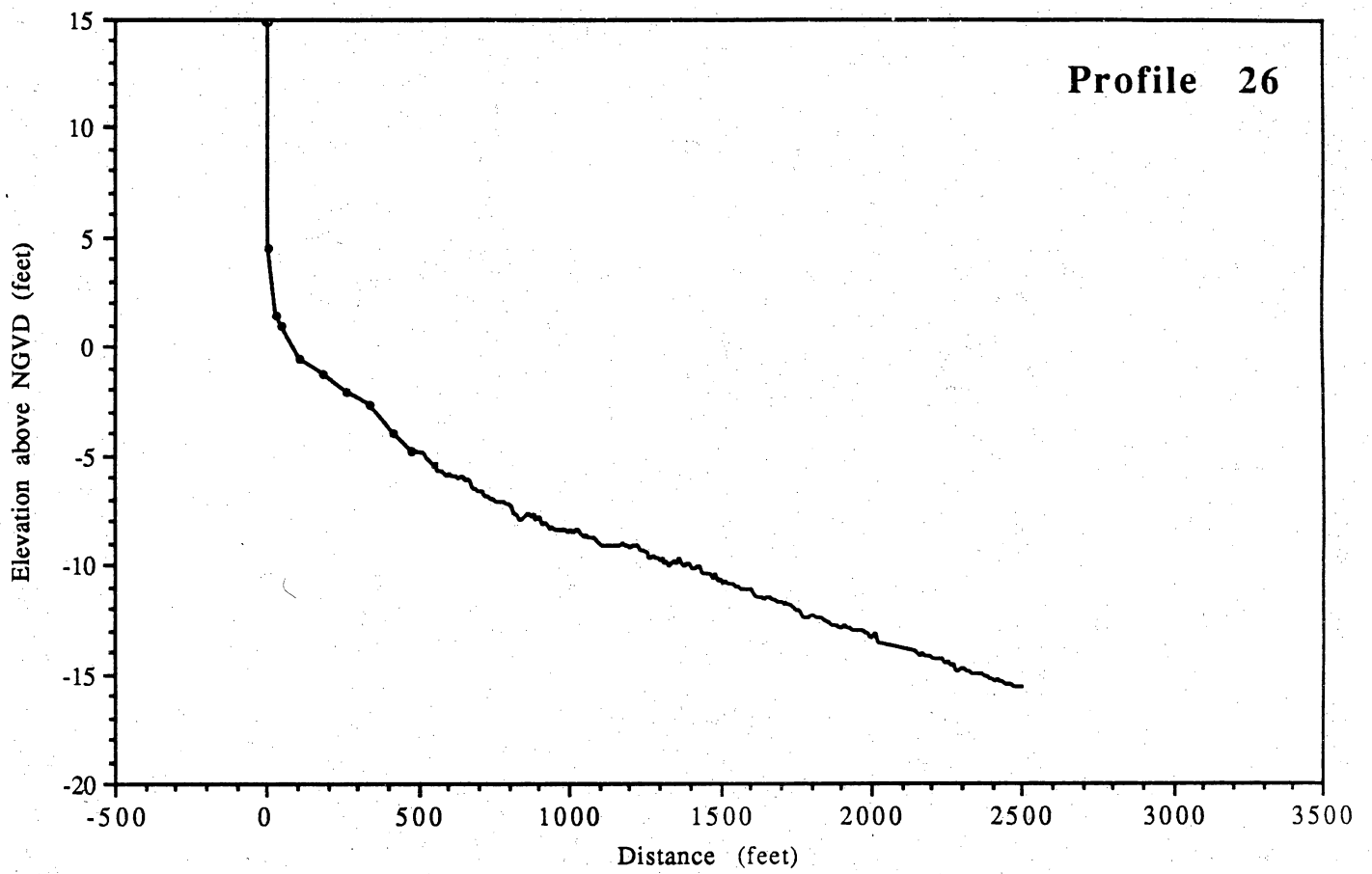




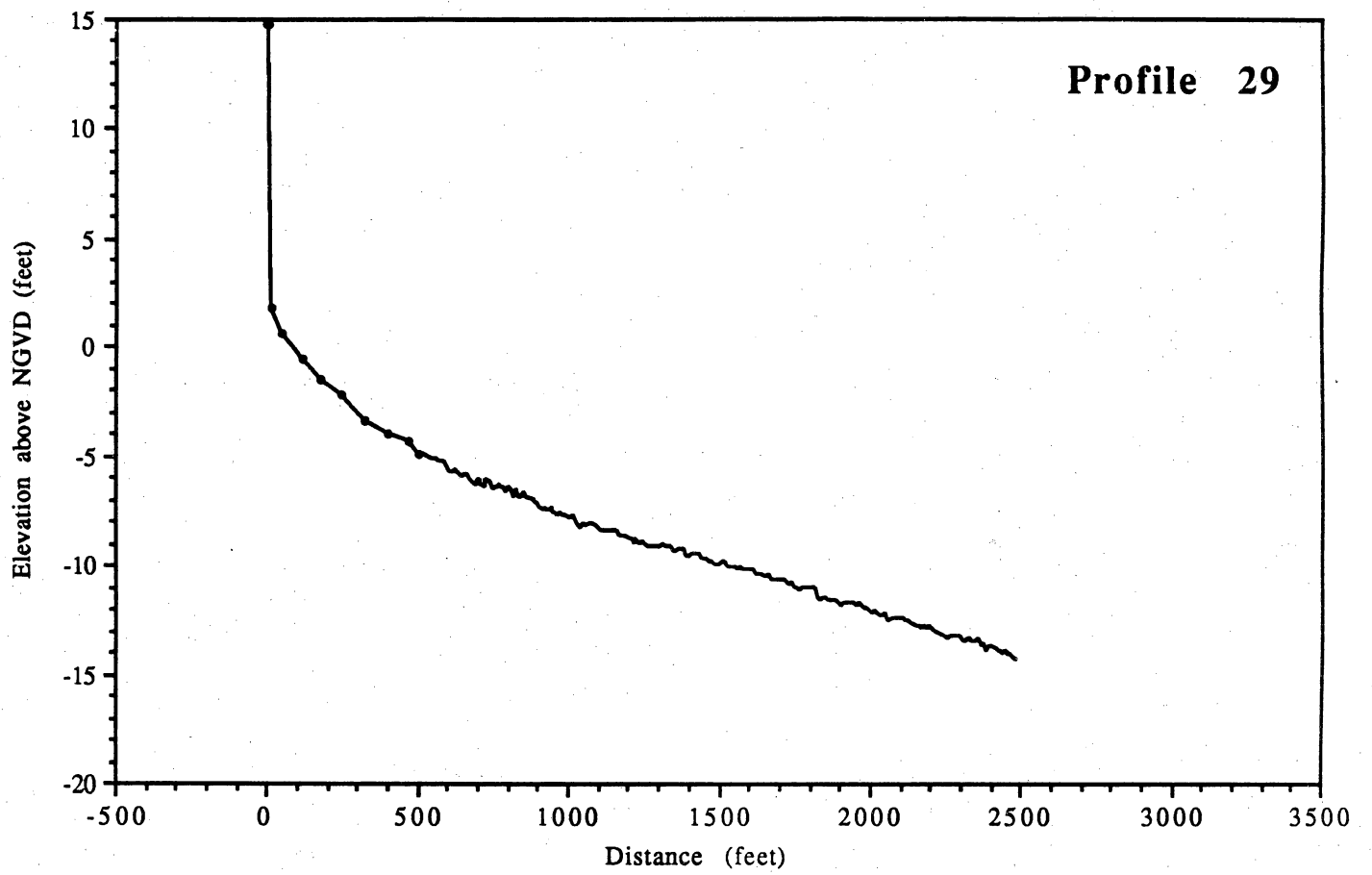
Profile 22

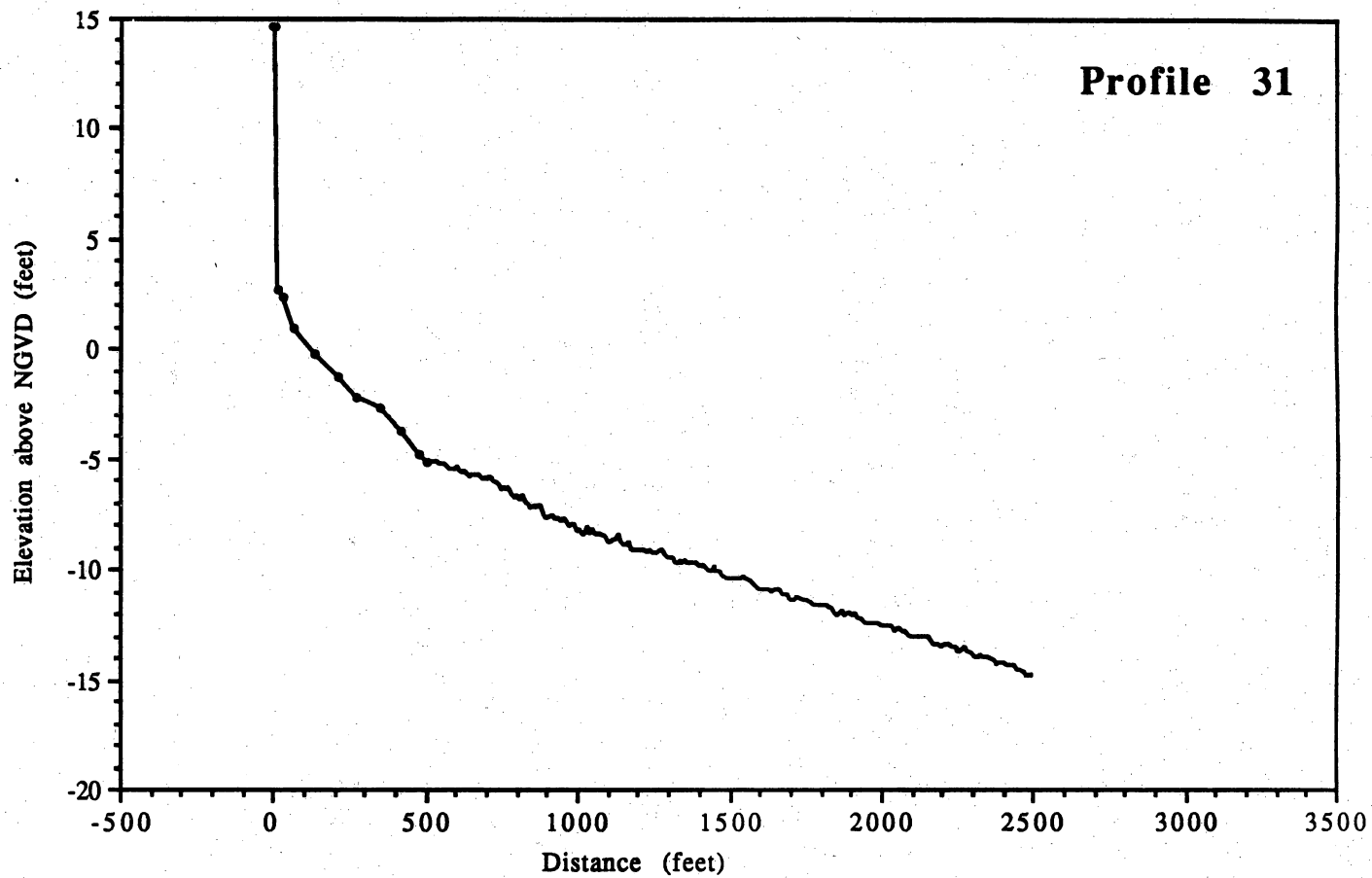




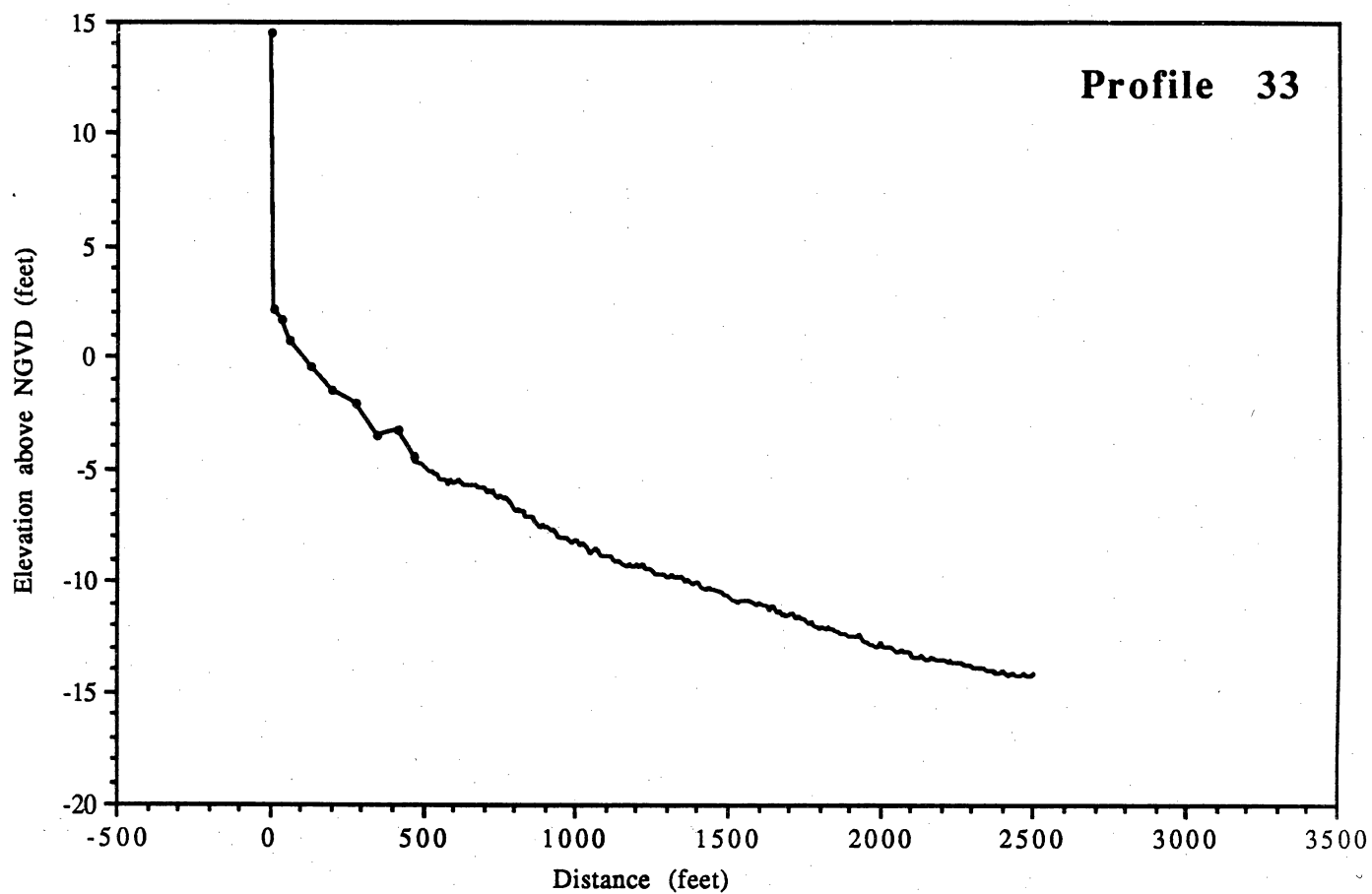


Profile 29

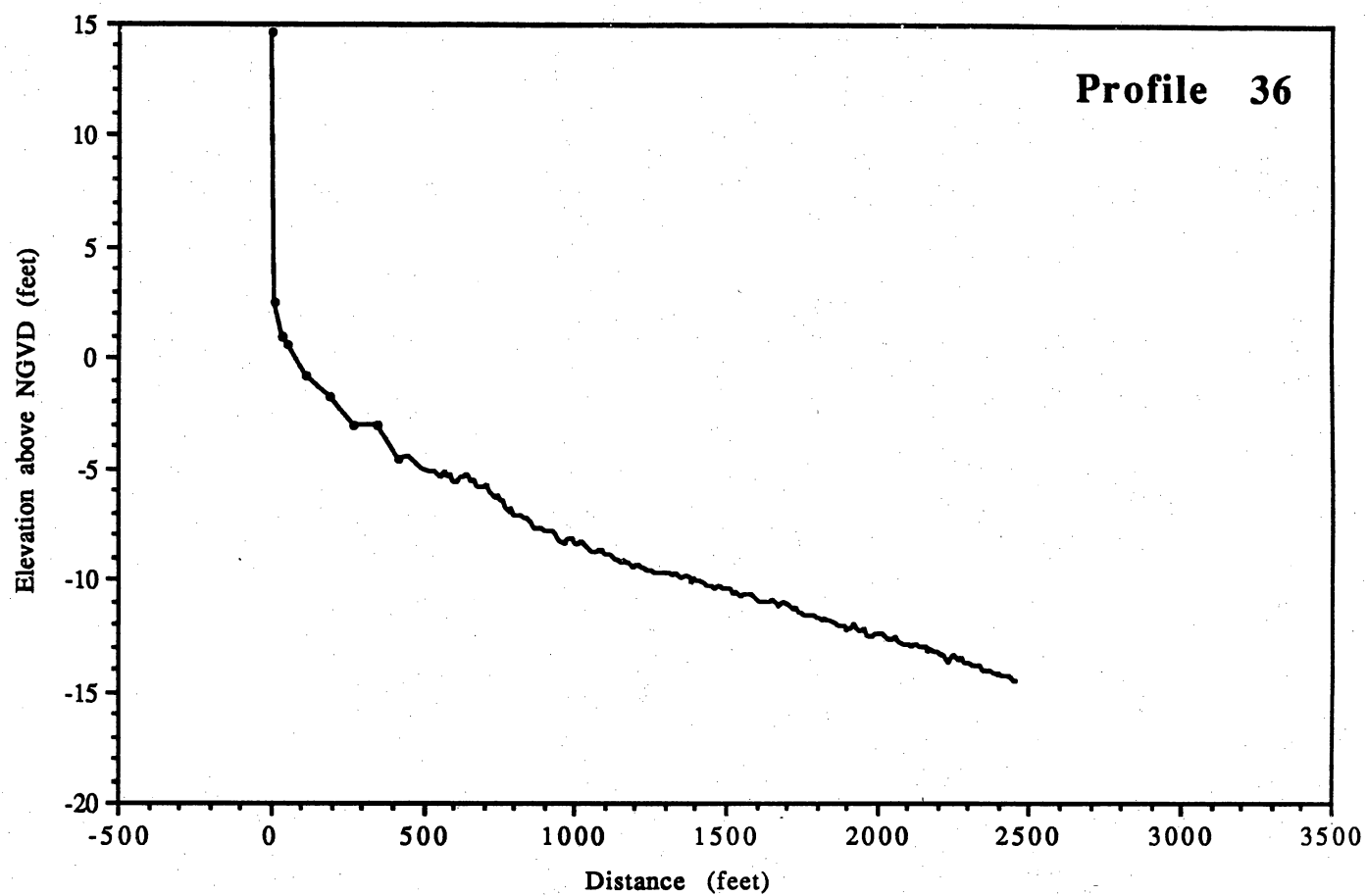


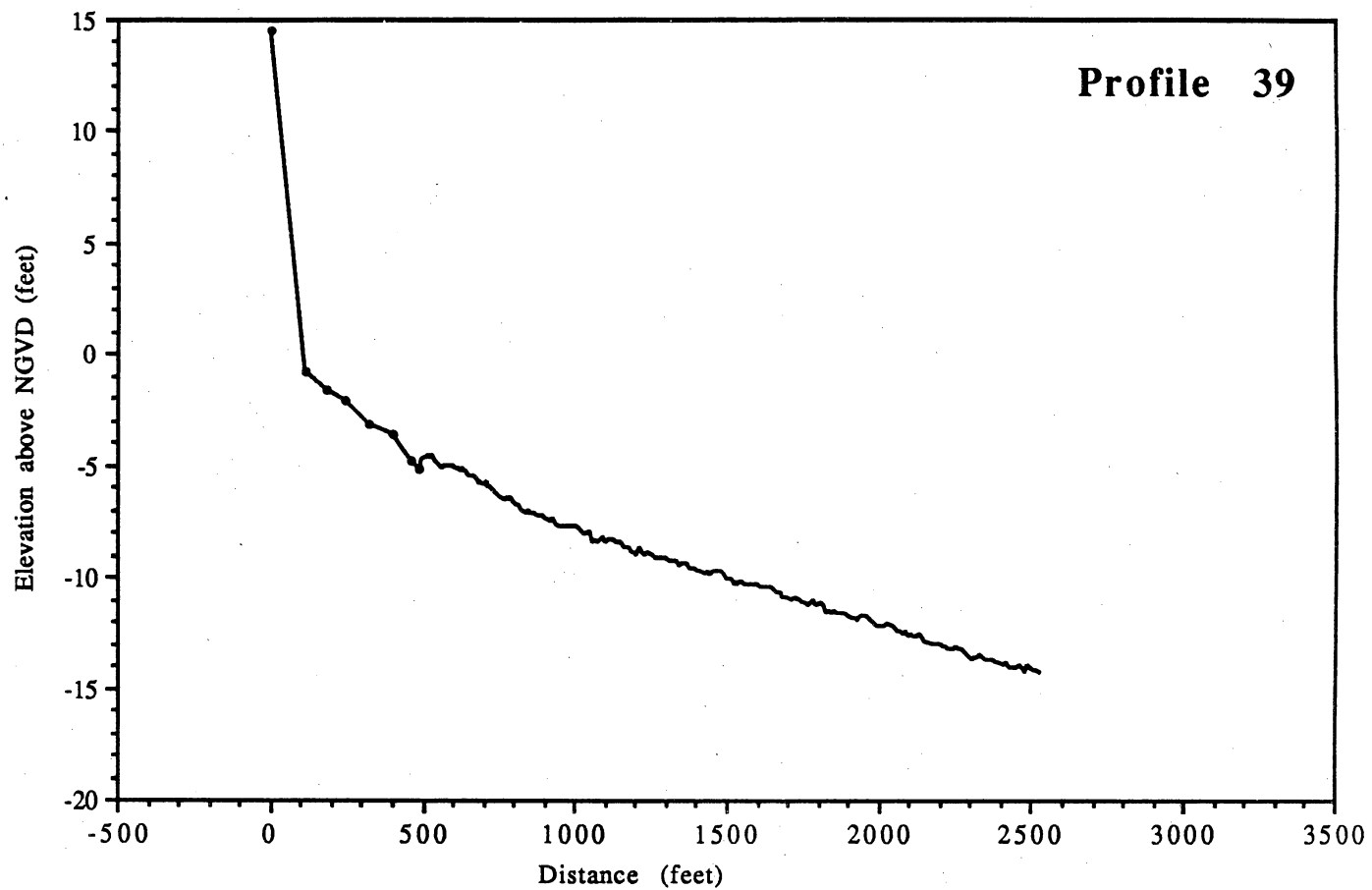


Profile 33

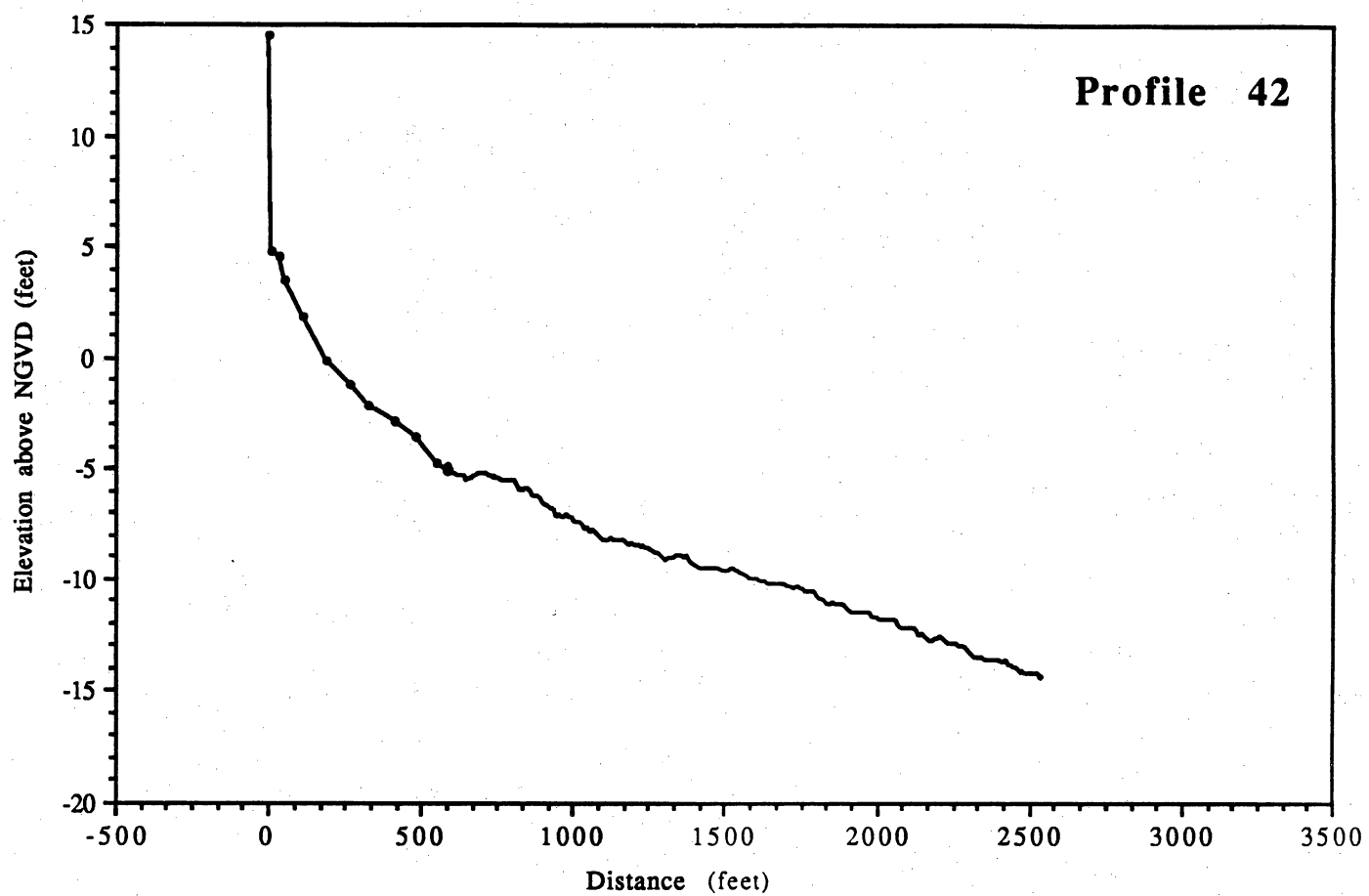


Profile 36

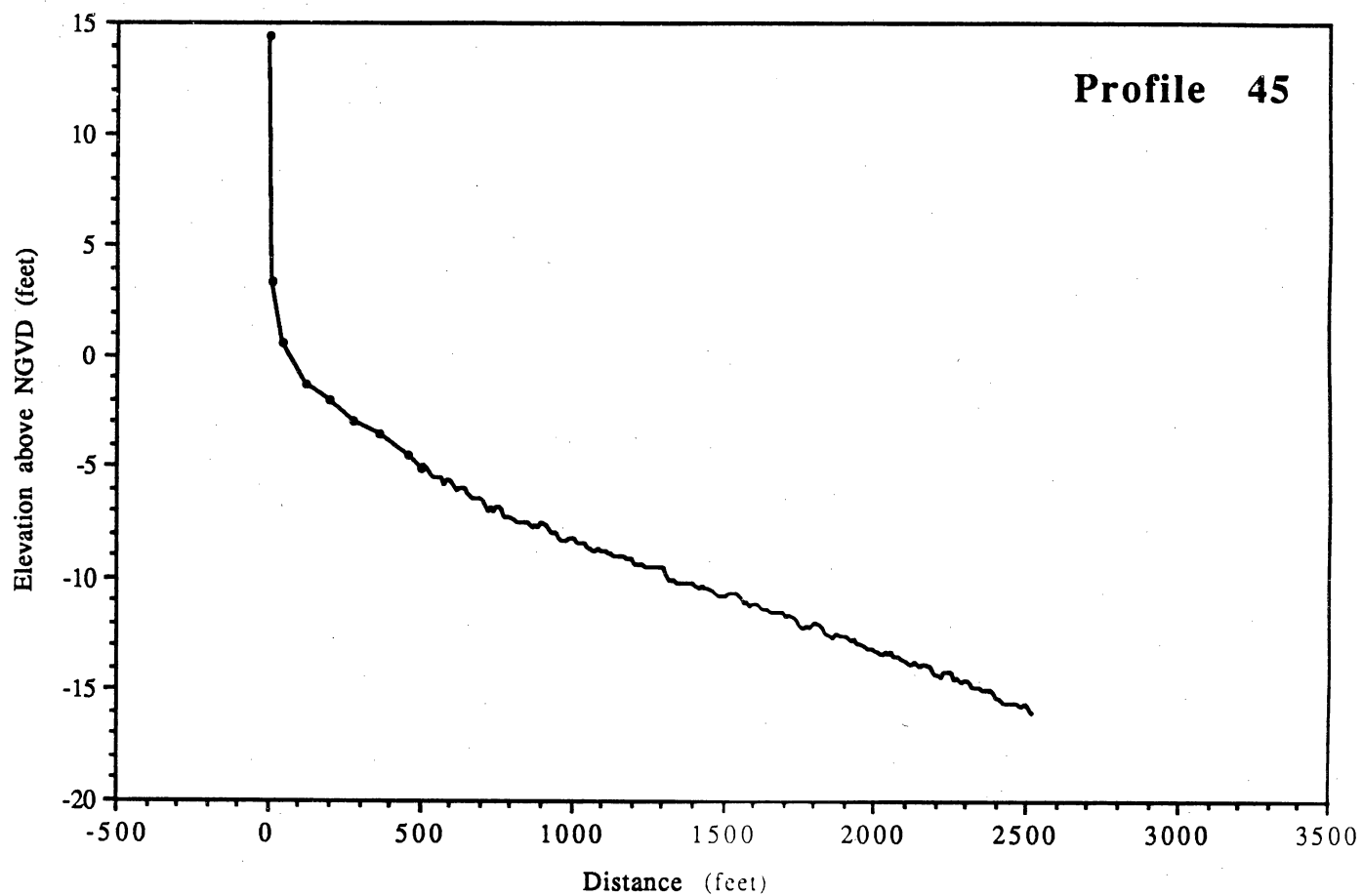




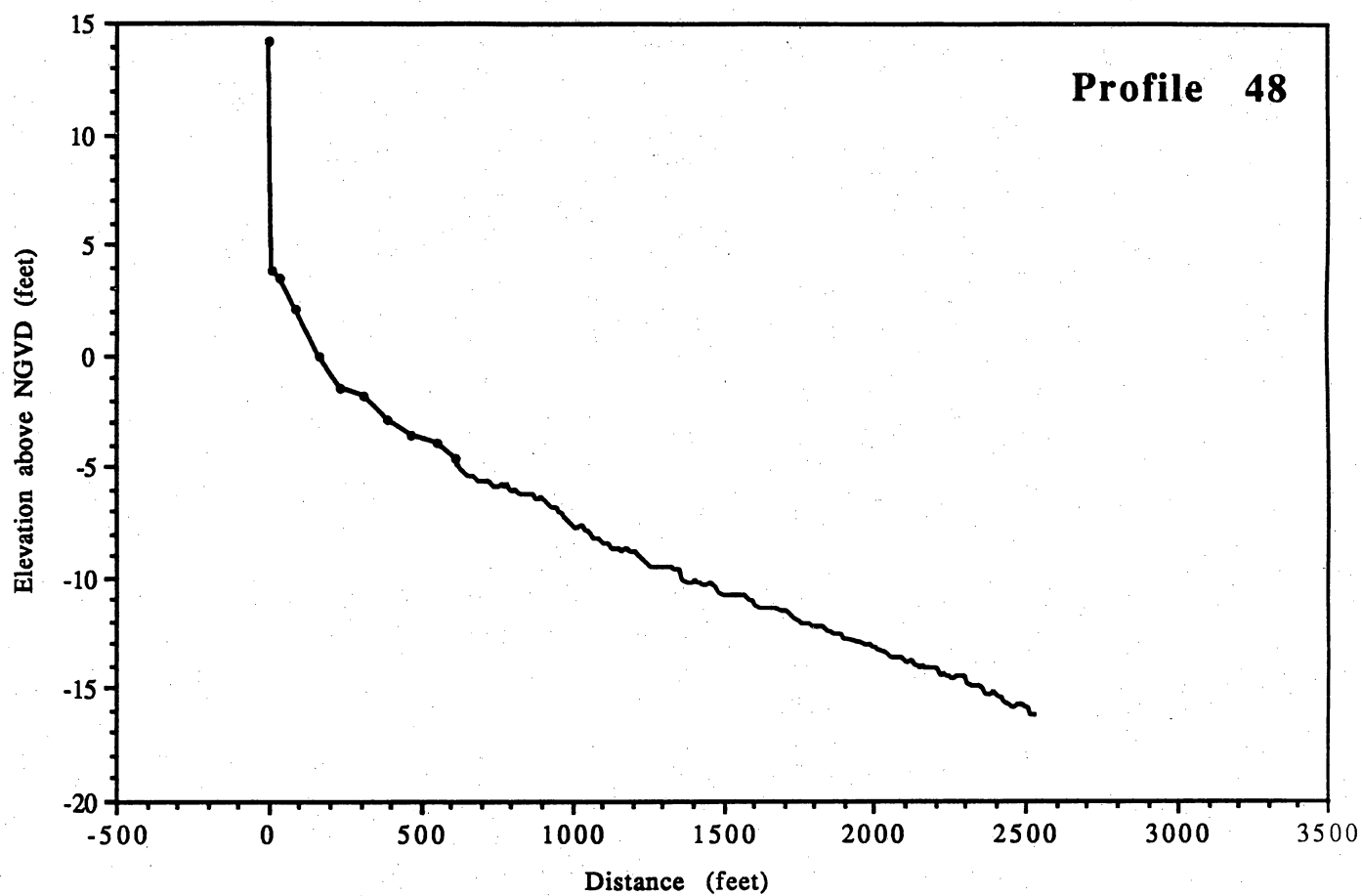
Profile 42

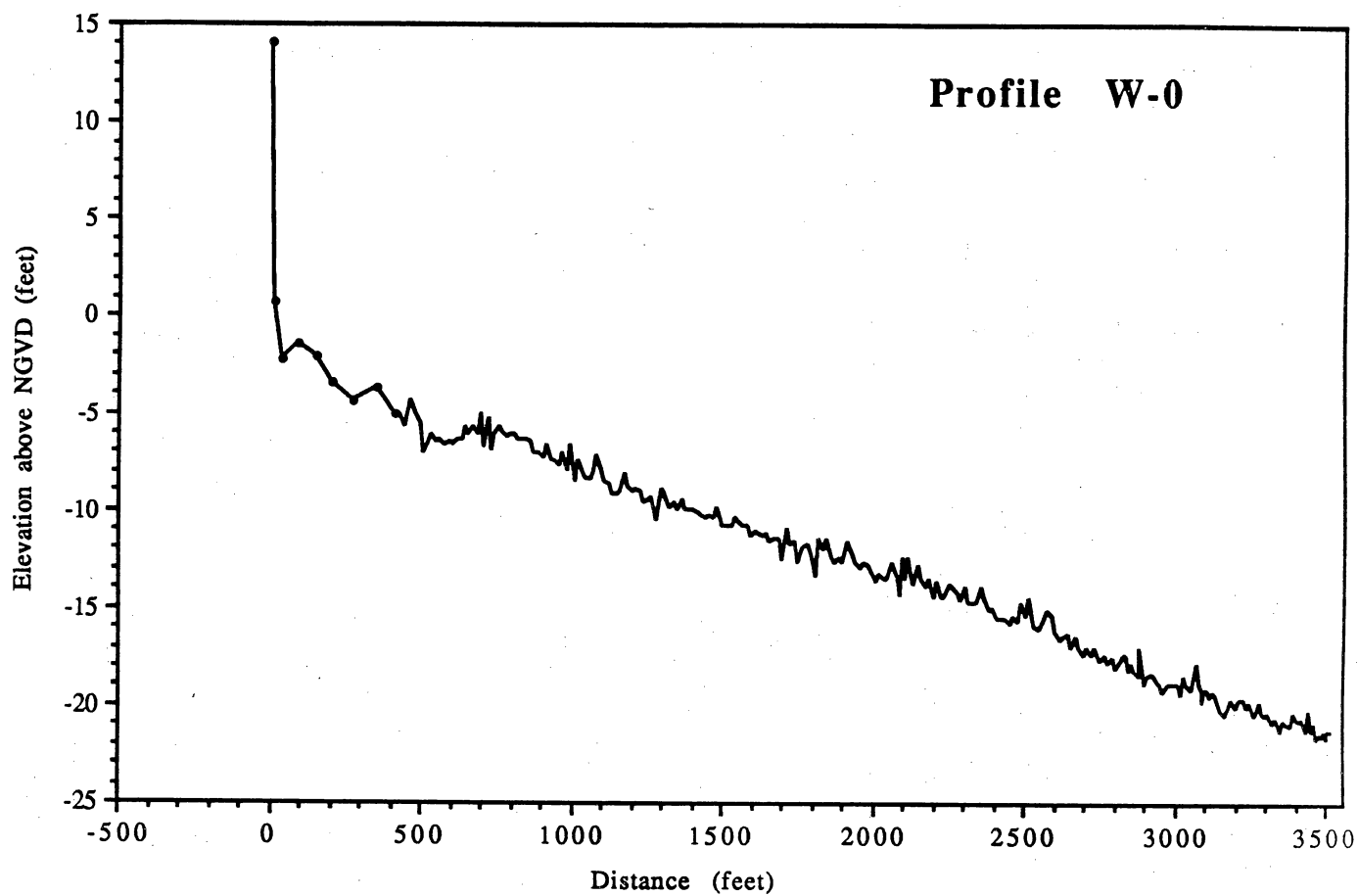


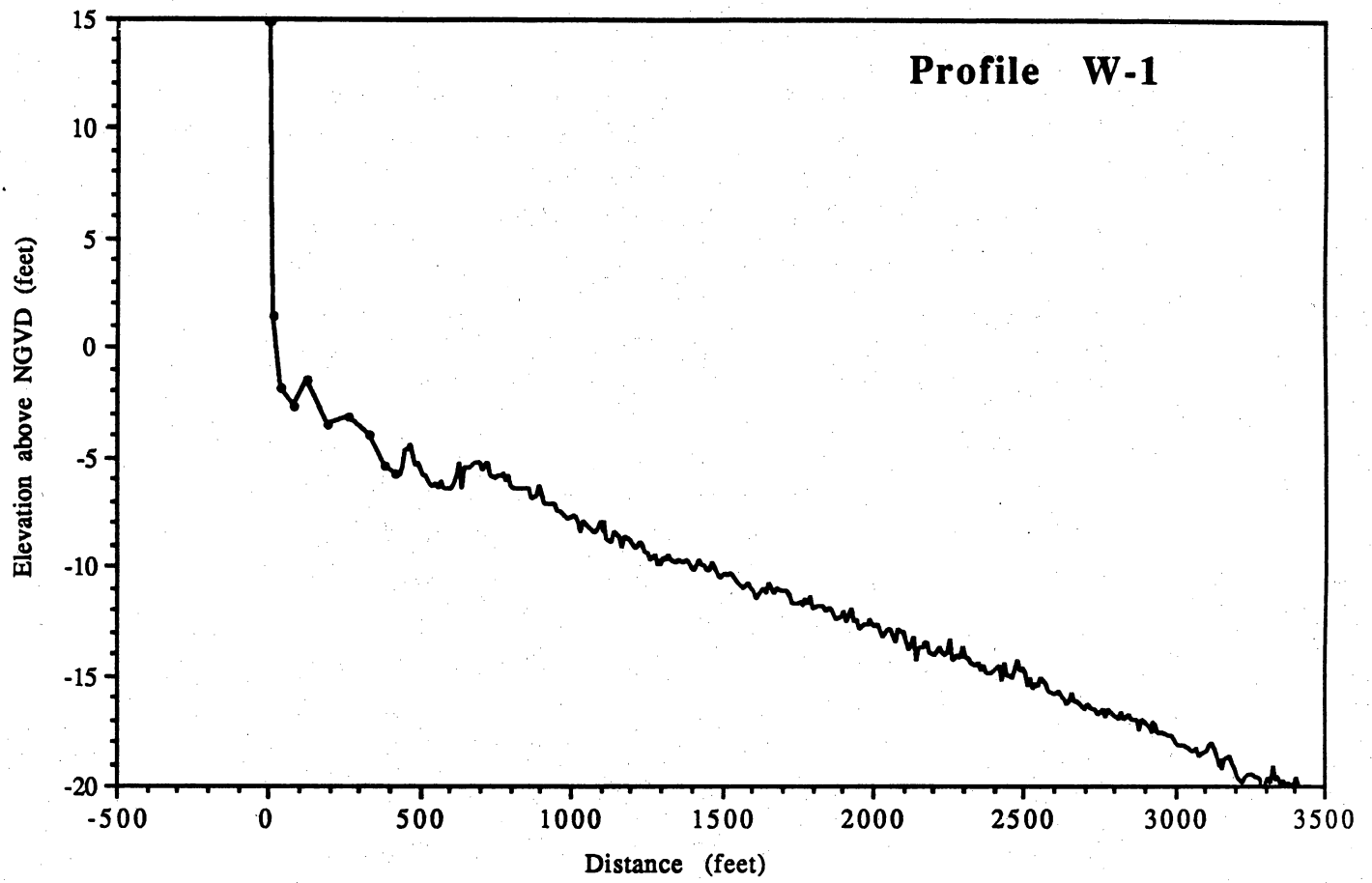
Profile 45



Profile 48







Particle Size Analyses - Sieve
Galveston Island area

| | | cumulative %'s | | | | | |
|-----|--------|----------------|------|------|------|-------|-------|
| Lab | Sample | 2.0ø | 2.5ø | 3ø | 3.5ø | 4.0ø | pan |
| # | ID | % | % | % | % | % | % |
| 1 | W-0-2 | 0.0 | 0.1 | 2.5 | 77.1 | 99.3 | 100.0 |
| 2 | W-0-4 | 0.1 | 0.2 | 2.4 | 50.3 | 98.0 | 100.0 |
| 3 | W-1-2 | 0.1 | 0.1 | 2.2 | 75.8 | 99.0 | 100.0 |
| 4 | W-1-4 | 0.1 | 0.2 | 2.6 | 67.7 | 99.5 | 100.0 |
| 5 | 48-2 | 0.3 | 0.4 | 2.4 | 54.3 | 96.7 | 100.0 |
| 6 | 48-3 | 0.0 | 0.1 | 8.0 | 82.6 | 99.5 | 100.0 |
| 7 | 48-A | 0.2 | 0.7 | 37.0 | 96.9 | 99.9 | 100.0 |
| 8 | 45-2 | 0.1 | 0.1 | 2.2 | 71.0 | 98.7 | 100.0 |
| 9 | 45-4 | 0.8 | 0.9 | 3.5 | 51.4 | 95.4 | 100.0 |
| 10 | 45-A | 1.1 | 2.8 | 39.2 | 97.2 | 99.8 | 100.0 |
| 11 | 42-3 | 0.1 | 0.1 | 1.9 | 68.4 | 98.1 | 100.0 |
| 12 | 42-4 | 1.0 | 1.2 | 3.7 | 48.7 | 95.0 | 100.0 |
| 13 | 42-A | 0.3 | 1.6 | 30.8 | 96.0 | 99.9 | 100.0 |
| 14 | 39-2 | 0.1 | 0.2 | 2.3 | 72.7 | 98.8 | 100.0 |
| 15 | 39-4 | 0.8 | 1.0 | 3.7 | 49.3 | 93.6 | 100.0 |
| 16 | 39-A | 1.1 | 2.9 | 34.7 | 97.7 | 100.0 | 100.0 |
| 17 | 36-2 | 0.2 | 0.3 | 5.8 | 79.1 | 99.2 | 100.0 |
| 18 | 36-A | 0.6 | 2.0 | 36.8 | 97.6 | 100.0 | 100.0 |
| 19 | 33-4 | 0.4 | 0.6 | 3.8 | 50.8 | 96.1 | 100.0 |
| 20 | 33-A | 1.2 | 2.3 | 25.1 | 94.7 | 99.9 | 100.0 |
| 21 | 31-2 | 0.0 | 0.0 | 3.0 | 78.5 | 99.7 | 100.0 |
| 22 | 31-4 | 0.4 | 0.5 | 3.0 | 48.5 | 95.3 | 100.0 |
| 23 | 31-A | 0.4 | 1.0 | 20.1 | 94.3 | 99.9 | 100.0 |
| 24 | 29-2 | 0.0 | 0.2 | 6.2 | 78.0 | 98.6 | 100.0 |
| 25 | 29-3 | 0.0 | 0.0 | 2.0 | 74.5 | 99.0 | 100.0 |
| 26 | 29-4 | 0.5 | 0.7 | 2.7 | 44.6 | 98.3 | 100.0 |
| 27 | 29-A | 1.6 | 3.4 | 30.8 | 95.2 | 99.9 | 100.0 |
| 28 | 26-2 | 0.1 | 0.2 | 3.7 | 68.5 | 99.4 | 100.0 |
| 29 | 26-A | 1.2 | 2.7 | 27.3 | 95.7 | 99.8 | 100.0 |
| 30 | 12-2 | 0.2 | 0.3 | 4.2 | 67.4 | 99.6 | 100.0 |
| 31 | 23A-4 | 0.3 | 0.5 | 3.9 | 58.0 | 97.0 | 100.0 |
| 32 | 23A-A | 0.7 | 2.1 | 32.5 | 94.8 | 99.9 | 100.0 |
| 33 | 22-3 | 0.0 | 0.1 | 1.6 | 67.5 | 99.0 | 100.0 |
| 34 | 22-A | 0.1 | 0.9 | 35.1 | 97.4 | 100.0 | 100.0 |
| 35 | 20-2 | 0.2 | 0.2 | 8.4 | 86.1 | 99.5 | 100.0 |
| 36 | 20-3 | 0.0 | 0.1 | 2.1 | 68.2 | 98.7 | 100.0 |

| | | | | | | | |
|----|------|-----|------|------|------|-------|-------|
| 37 | 20-4 | 0.0 | 0.1 | 3.7 | 61.6 | 96.8 | 100.0 |
| 38 | 20-A | 0.0 | 0.9 | 32.0 | 96.4 | 99.8 | 100.0 |
| 39 | 18-2 | 0.1 | 0.2 | 5.3 | 81.5 | 99.3 | 100.0 |
| 40 | 18-A | 1.0 | 3.2 | 43.4 | 97.6 | 99.9 | 100.0 |
| 41 | 15-4 | 0.8 | 1.0 | 8.1 | 70.2 | 97.0 | 100.0 |
| 42 | 15-A | 1.4 | 8.4 | 59.0 | 98.4 | 99.9 | 100.0 |
| 43 | 12-3 | 0.1 | 0.2 | 4.1 | 65.5 | 98.4 | 100.0 |
| 44 | 12-4 | 0.6 | 0.8 | 8.9 | 75.7 | 97.3 | 100.0 |
| 45 | 12-A | 4.9 | 8.3 | 50.7 | 98.3 | 99.9 | 100.0 |
| 46 | 11-2 | 0.1 | 0.2 | 3.3 | 72.0 | 98.4 | 100.0 |
| 47 | 11-3 | 0.0 | 0.2 | 3.8 | 66.5 | 98.4 | 100.0 |
| 48 | 11-4 | 0.9 | 1.2 | 9.0 | 73.2 | 97.8 | 100.0 |
| 49 | 11-A | 4.1 | 10.4 | 56.1 | 98.6 | 99.9 | 100.0 |
| 50 | 9B-2 | 0.1 | 0.2 | 8.3 | 85.4 | 99.5 | 100.0 |
| 51 | 9B-3 | 0.2 | 0.4 | 5.2 | 71.0 | 98.4 | 100.0 |
| 52 | 9B-4 | 1.1 | 1.6 | 11.6 | 72.3 | 97.4 | 100.0 |
| 53 | 9B-A | 0.5 | 6.3 | 56.6 | 98.2 | 100.0 | 100.0 |
| 54 | S9-2 | 0.1 | 0.3 | 5.1 | 73.8 | 98.7 | 100.0 |
| 55 | S9-3 | 0.2 | 0.4 | 4.3 | 63.2 | 98.1 | 100.0 |
| 56 | S9-4 | 0.7 | 1.3 | 9.4 | 64.3 | 97.0 | 100.0 |
| 57 | S9 | 0.9 | 3.6 | 39.3 | 96.8 | 99.9 | 100.0 |
| 58 | SI-2 | 0.2 | 0.7 | 6.6 | 70.0 | 98.6 | 100.0 |
| 59 | SI-3 | 0.7 | 1.0 | 5.8 | 58.7 | 97.7 | 100.0 |
| 60 | SI-4 | 1.1 | 1.8 | 11.7 | 72.8 | 97.7 | 100.0 |
| 61 | SI | 1.0 | 5.1 | 35.2 | 94.9 | 99.9 | 100.0 |
| 62 | S8-2 | 0.1 | 0.2 | 4.5 | 68.6 | 99.2 | 100.0 |
| 63 | S8-3 | 0.0 | 0.3 | 4.1 | 56.4 | 98.1 | 100.0 |
| 64 | S8-4 | 0.1 | 0.6 | 10.1 | 78.8 | 99.0 | 100.0 |
| 65 | S8-A | 0.2 | 1.2 | 19.2 | 91.4 | 99.7 | 100.0 |
| 66 | B-1 | 0.1 | 0.4 | 14.0 | 84.7 | 99.3 | 100.0 |
| 67 | B-2 | 0.1 | 0.6 | 14.8 | 82.7 | 98.0 | 100.0 |
| 68 | B-3 | 0.1 | 0.3 | 11.8 | 80.2 | 99.3 | 100.0 |
| 69 | B-4 | 0.2 | 0.6 | 10.0 | 82.0 | 98.8 | 100.0 |
| 70 | B-5 | 0.2 | 0.6 | 14.8 | 83.2 | 99.5 | 100.0 |

Particle Size Analyses- Hydrometer
Galveston Island area

| Lab # | Sample ID | Sand % | Silt % | Clay % |
|-------|-----------|--------|--------|--------|
| 1 | W-0-2 | 95 | 2 | 3 |
| 2 | W-0-4 | 94 | 1 | 5 |
| 3 | W-1-2 | 96 | 0 | 4 |
| 4 | W-1-4 | 95 | 0 | 5 |
| 5 | 48-2 | 96 | 1 | 3 |
| 6 | 48-3 | 96 | 1 | 3 |
| 7 | 48-A | 97 | 1 | 2 |
| 8 | 45-2 | 96 | 2 | 2 |
| 9 | 45-4 | 93 | 3 | 4 |
| 10 | 45-A | 97 | 0 | 3 |
| 11 | 42-3 | 96 | 1 | 3 |
| 12 | 42-4 | 90 | 6 | 4 |
| 13 | 42-A | 95 | 2 | 3 |
| 14 | 39-2 | 94 | 3 | 3 |
| 15 | 39-4 | 91 | 6 | 3 |
| 16 | 39-A | 98 | 0 | 2 |
| 17 | 36-2 | 98 | 0 | 2 |
| 18 | 36-A | 98 | 0 | 2 |
| 19 | 33-4 | 94 | 3 | 3 |
| 20 | 33-A | 98 | 0 | 2 |
| 21 | 31-2 | 98 | 0 | 2 |
| 22 | 31-4 | 94 | 4 | 2 |
| 23 | 31-A | 98 | 0 | 2 |
| 24 | 29-2 | 90 | 4 | 6 |
| 25 | 29-3 | 97 | 1 | 2 |
| 26 | 29-4 | 93 | 3 | 4 |
| 27 | 29-A | 97 | 0 | 3 |
| 28 | 26-2 | 96 | 1 | 3 |
| 29 | 26-A | 97 | 0 | 3 |
| 30 | 12-2 | 94 | 2 | 4 |
| 31 | 23A-4 | 94 | 3 | 3 |
| 32 | 23A-A | 97 | 1 | 2 |
| 33 | 22-3 | 96 | 1 | 3 |
| 34 | 22-A | 97 | 0 | 3 |
| 35 | 20-2 | 97 | 1 | 2 |
| 36 | 20-3 | 96 | 1 | 3 |

| | | | | |
|----|------|----|---|---|
| 37 | 20-4 | 94 | 3 | 3 |
| 38 | 20-A | 97 | 1 | 2 |
| 39 | 18-2 | 96 | 2 | 2 |
| 40 | 18-A | 98 | 0 | 2 |
| 41 | 15-4 | 94 | 3 | 3 |
| 42 | 15-A | 97 | 1 | 2 |
| 43 | 12-3 | 95 | 2 | 3 |
| 44 | 12-4 | 94 | 2 | 4 |
| 45 | 12-A | 97 | 1 | 2 |
| 46 | 11-2 | 95 | 2 | 3 |
| 47 | 11-3 | 95 | 2 | 3 |
| 48 | 11-4 | 94 | 2 | 4 |
| 49 | 11-A | 97 | 0 | 3 |
| 50 | 9B-2 | 96 | 1 | 3 |
| 51 | 9B-3 | 95 | 2 | 3 |
| 52 | 9B-4 | 95 | 1 | 4 |
| 53 | 9B-A | 97 | 1 | 2 |
| 54 | S9-2 | 96 | 1 | 3 |
| 55 | S9-3 | 95 | 2 | 3 |
| 56 | S9-4 | 92 | 3 | 5 |
| 57 | S9 | 96 | 1 | 3 |
| 58 | SI-2 | 95 | 2 | 3 |
| 59 | SI-3 | 93 | 2 | 5 |
| 60 | SI-4 | 93 | 2 | 5 |
| 61 | SI | 96 | 0 | 4 |
| 62 | S8-2 | 95 | 0 | 5 |
| 63 | S8-3 | 94 | 1 | 5 |
| 64 | S8-4 | 94 | 1 | 5 |
| 65 | S8-A | 96 | 0 | 4 |
| 66 | B-1 | 95 | 0 | 5 |
| 67 | B-2 | 95 | 0 | 5 |
| 68 | B-3 | 94 | 1 | 5 |
| 69 | B-4 | 93 | 0 | 7 |
| 70 | B-5 | 95 | 0 | 5 |

**Addendum 10. Shoreline Shape and Projection Program (SSAP): Objectives,
Techniques, and Initial Results**

SHORELINE SHAPE AND PROJECTION PROGRAM (SSAP): OBJECTIVES, TECHNIQUES, AND INITIAL RESULTS

James C. Gibeaut and Robert A. Morton
Bureau of Economic Geology
The University of Texas at Austin

INTRODUCTION

Dolan et al. (1991) reviewed four statistical methods for calculating shoreline rates-of-change from time series of shoreline positions. These methods include the following: (1) end point rate; (2) average of rates (Foster and Savage, 1989); (3) linear regression; and (4) jackknife (Efron, 1982). Fenster et al. (1993) presented a new method that combines polynomial regression, weighted linear regression, and knowledge of site-specific coastal processes. Because of the various methods proposed for calculating shoreline change rates, the long stretches of shoreline for which rates are needed, and the wide-spread use of Geographic Information Systems (GIS) for shoreline mapping, the Bureau of Economic Geology developed a computer program that automates the calculation of rates-of-change, compares the different methods, and interacts with a GIS or a computer automated drafting program (CAD). A future development will involve morphological analysis of historical shorelines for use in modifying predicted shoreline shape and position.

The development of this computer program has been the first step in investigating the merits and detriments of the various statistical methods for determining shoreline rates-of-change from time series of historical shorelines. We can now quickly calculate shoreline rates-of-change and project future shoreline positions in a GIS or CAD program. This appendix describes the approach the program takes to this problem, the methods of rate-of-change analysis that are currently encoded, and some preliminary results from Galveston Island, Texas. With further application of this program, the overall best method or the need for a new method may be revealed.

COMPUTER PROGRAM

Objectives and Current Capabilities

Our overall computer programming goal is to automate the analysis of shoreline shape and change using time series of shoreline positions. The Shoreline Shape and Projection Program (SSAPP) is a modular FORTRAN program that uses subroutines to perform tasks required to compute shoreline rates-of-change and to project shorelines into the future based on those rates-of-change. It is written for the Windows 3.1 operating system and requires at least a 386 personal computer with 16 megabytes of random access memory. Specific objectives and characteristics of SSAPP include the following:

- (1) SSAPP is able to use map data from and provide results to a GIS such as Arc/Info or CAD system such as AutoCad.
- (2) As an alternative to mapped data, the program can use data where shoreline positions are provided as relative distances along a predetermined transect.
- (3) When using map data, the baseline segments are automatically oriented by considering the orientations of mapped shorelines within a segment length.
- (4) The user may select the length of baseline segments and the distance between transects where shoreline change rates are determined and along which future shoreline positions are projected.
- (5) One can map predicted shoreline positions using selected future dates and rate-of-change method.
- (6) Currently, the results of five methods of calculating shoreline rates-of-change are provided: (1) end point; (2) linear regression; (3) jackknife; (4) average of rates; and (5) weighted regression as presented by Fenster et al. (1993).

Automatic Baseline and Transect Determination

Baseline orientation can have a significant effect on calculated rates-of-change and on projecting future shoreline positions. If the baseline does not conform well to actual shoreline

orientations, rates-of-change may be overestimated (Fig. 1). Nonconformal baselines also will not provide the correct frame of reference for determining the direction of shoreline change and may skew the shape of projected shorelines. Different baselines, therefore, may greatly alter the final results of a rate-of-change analysis. SSAPP overcomes this problem by objectively and rapidly determining baseline orientations.

SSAPP invokes a baseline and transect determination routine when input data consist of a time series of digitized shorelines, such as from a GIS. First, the linear trend of all combined shoreline data is calculated. All data are then rotated around the average northing and easting position so that the shoreline trend is zero (horizontal in an x,y plot). Using the value for baseline length provided by the user, the program then increments to the left of the average point (rotation point) and searches for all shoreline points lying within that increment (baseline segment) along the rotated trend line (x-axis). For each shoreline year within this segment, a linear regression is performed. The slopes and y-intercepts of each shoreline within the segment are then averaged. The end points of the initial baseline are determined by using this average line formula and the x-values bounding the increment. This baseline is subsequently adjusted and the rest of the baseline calculations proceed differently as described below.

To adjust the initial baseline and calculate the remaining baselines, SSAPP searches for points within an x-axis interval the length of the selected baseline length and centered on the x-value determined by adding the baseline length to the last endpoint of the previous baseline segment. When adjusting the initial baseline, the search is centered around the last end point of the current baseline segment. All y-values for shoreline positions within this interval are then averaged. The new baseline is now defined by the coordinates of the previous baseline endpoint and the x-value obtained by adding the baseline length to the x-value of the previous endpoint and the average y-value. If the difference between the new y-value (average y-value) and the y-value of the previous baseline endpoint is greater than 0.1, then all shoreline data are rotated around the previous baseline endpoint by the amount of the angle formed by the juncture of the previous baseline and the newly determined baseline. Thus all shoreline data are realigned to the trend of the new baseline and a new search and endpoint calculation are made. This continues until the 0.1 tolerance is met or ten iterations are made. When the end of the shoreline data is reached to the left, the routine begins again at the center of the data and proceeds to the right.

Transects are automatically placed along the baselines at user-selected intervals. Baseline length divided by desired transect interval must be a whole number. The first transect is placed at the beginning end point of a baseline and is oriented so that it bisects the angle formed between

the adjacent baselines. Subsequent transects within a baseline are oriented perpendicular to the baseline. If the selected baseline length and the transect interval are equal, then transects are placed in the middle of baselines and are oriented perpendicular to the baselines. The transects are numbered with the center transect as zero and transects to the left as negative and to the right as positive numbers. Figure 2 is an example of baselines and transects automatically constructed by SSAPP.

Once each baseline is determined, SSAPP then proceeds to determine the distance from the baseline of each shoreline that crosses the transect. The program searches for points spanning the transect for each shoreline. Once the closest points on each side of the transect are found, a linear interpolation is made to determine the point where the transect crosses the shoreline. The distance from the baseline for each shoreline is then calculated.

Rate-of-Change Methods

Currently, SSAPP calculates rate-of-change values using five methods as described below.

End Point Rate-of-change

This is a simple routine that for each location determines the distance between the earliest and latest shoreline positions and divides by the number of years, thus providing an annual rate-of-change.

Linear Regression Rate-of-change

For this method, all the available data are used in a linear regression. The slope of the regression line is the shoreline rate-of-change. SSAPREG is actually a subroutine within SSAPP that computes the coefficients for any desired order of polynomial. When it is called to compute a linear regression rate-of-change, a polynomial order of one is passed to the routine.

Jackknife Rate-of-Change

This routine uses the Jackknife method as described by Efron (1982) to compute shoreline rates-of-change. A family of linear regression lines are computed by successively eliminating a

single and different point. The slopes of these regression lines are then averaged to yield an annual rate-of-change.

Average of Rates Rate-of-Change

Foster and Savage (1989) developed this technique using data from Florida. It involves averaging the end point rates computed for all possible combinations of two points in a time series. Each combination of points must pass a minimum time criterion (T_{min}), however, to be included in the average.

$$T_{min} = [\sqrt{(E_1)^2 + (E_2)^2}] / R_1$$

Where E_1 and E_2 are the assumed error ranges for shoreline position measurements 1 and 2, respectively, and R_1 is the end point rate for the longest time span in the time series. The end-point combinations with time spans greater than T_{min} are considered "long-term" rates and their rates are averaged to yield the rate-of-change value.

Weighted Rate-of-Change (as presented by Fenster (1993))

This method of rate calculation is relatively complicated compared to the above methods. First an optimum polynomial is fitted to the time series based on the minimum description length criterion (MDL) as follows:

$$MDL_K = MSE_K + [\ln(N) \times K \times \sigma^2] / N$$

where MDL_K is the minimum description length for a model with K terms, MSE_K is the mean squared error of the model, K is the number of terms in the polynomial, N is the number of data points, and σ^2 is the noise variance. The model with the smallest MDL_K is selected for further analysis. In SSAPP the user selects the maximum K to be considered by the method.

Once the optimum polynomial is determined, points where the slope changes sign are found. These points indicate a change in the direction of shoreline movement at particular times. If there are no changes in the sign of the slope, then a linear regression is used as the rate-of-change. If changes of sign in the slope do occur, the most recent point when the slope changes is selected and all data prior to that time are weighted to zero. A new linear regression is calculated and is called the "zero-weight line." The user has the option to select the slope of this line as the best

rate-of-change value. This would be the case if specific knowledge of a change in coastal processes suggest that the earlier data should be completely disregarded (weighted to zero).

Often specific knowledge of coastal processes is not available or it is not clear to what extent the earlier data should be considered. The Fenster method allows an objective means to value data that is available before a change in trend. This is accomplished by incrementally increasing the weights of the earlier data and recalculating the linear regression and MDL_K. The weights are increased until the MDL_K is equal to or just less than that of the MKL_K for the earlier determined optimum polynomial. Thus a nonlinear model is forced to be linear through a weighted linear regression technique.

Program Input

Shoreline data may be provided as digitized shorelines through a GIS such as Arc/Info or as an ASCII file in which data have been reduced to time series of shoreline distances from a baseline at particular locations along the shoreline. Often when digitizing or storing shoreline data within a GIS, sections of shoreline are digitized as separate polylines. For example, pieces of a shoreline on photographs or on topographical maps may be digitized separately and later merged to obtain continuous coverage. SSAPP recognizes these sections on input and does not require them to be in any particular geographical order. The user working within the GIS simply creates an ASCII output file of shoreline coordinates for input to SSAPP. Within ArcInfo, an ASCII dump of a shoreline coverage with the dates given as line indentifications or attributes will suffice. SSAPP is written to take advantage of double precision math, but double precision values are not required for input. The coordinate system for data input must be either State Plane or Universal Transverse Mercator (UTM). SSAPP does not perform any coordinate or map projection transformations.

The program queries the user for specific input parameters shown below. For this illustration, program questions are in all upper case, user responses are in italics, and program generated progress statements are in plain lower case text.

IN WHAT FORM ARE THE DATA?

1=TIME SERIES OF SHORELINE COORDINATES

2=TIME SERIES OF SHORELINE DISTANCES BY TRANSECT

1

SHORELINE FILE NAME? *galves.dat*

ARE DATA IN FEET (f) or METERS (m)? <m> *m*
 ENTER DESIRED BASELINE LENGTH IN METERS: *200*
 ENTER DISTANCE BETWEEN TRANSECTS DESIRED: *200*
 ENTER THE MAP ERROR IN METERS <8.5> *8.5*
 CONVERT RESULTS FROM METERS TO FEET? Y/N <N> *n*
 OUTPUT FILE FOR SHORELINE CHANGE RATES? *change.out*
 OUTPUT FILE FOR STATISTICAL PARAMETERS? *param.out*
 OUTPUT FILE FOR PROJECTED SHORELINES? *proshore.out*
 Reading and sorting data...
 Calculating regression of all shoreline points...
 Rotating shoreline points to linear trend...
 Plotting rotated shorelines...
 Determining baselines and transects...
 Calculating end-point rate...finished.
 Calculating long-term linear regression rate...finished.
 Calculating jackknife rate...finished.
 Calculating average-of-rates rate...finished.
 Calculating Fenster et al. rate...
 MAXIMUM ORDER FOR POLYNOMIAL (5 MAX)? *3*
 finished.
 Calculating projected shorelines...
 HOW MANY PROJECTIONS? (5 MAX) *1*
 LIST THE CALENDER YEARS FOR PROJECTION *2025*
 finished.

During the above processing, graphics screens are opened and plots of shorelines, baselines, and transects are drawn as the program progresses.

Program Output

During execution, SSAPP first plots the shoreline data to the screen, then baselines and transects are overlain on the shorelines. After data processing, one may choose to view plots of relative shoreline distances along a transect versus the year for any given transect. Overlain on these plots are lines representing the fit of the various methods for calculating rates-of-change

The program creates two files. The first contains rate-of-change information for each transect and the coordinates of predicted shoreline positions (Table 1). The second file provides statistical parameters for each transect related to the results of the models (primarily Fenster's MDL model) (Table 2). Information in this second file may be used to evaluate the various rate-of-change calculations.

SSAPP provides an ASCII file of predicted shoreline positions in an Arc/Info line format for direct input to the GIS. SAPP also provides an ASCII DXF file of all shorelines, baselines, transects, and predicted shorelines. When the DXF file is imported into a CAD program, each shoreline is placed on separate layers. Baselines and transect lines are also placed on separate layers.

Tabel 1. - Sample of partial output file from SSAPP showing results of rate-of-change anlayses (TRAN= transect number, EPR= end point rate, LR= linear regression, JK= jackknife, AOR= average of rates, Wt.ed= weighted regression (Fenster method), 0-WT= zero-weight linear regression, Time Span= earliest and latest shoreline year that crosses the transect.

SHORELINE CHANGE RATES

shoreline file name: galves.dat

run date and time: 09/29/95 10:35

Baseline length= 200.0 m

Transect Spacing = 200.0 m Map Error= 8.5m

| METHODS | | | | | | | PREDICTED yr 2025 end point method UTM zone 15 | | |
|---------|-------|-------|-------|-------|--------|--------|--|----------|----------|
| TRAN | EPR | LR | JK | AOR | Wt.ed | 0-WT | Time Span | Easting | Northing |
| -117 | 0 | 0 | ***** | 0 | 0 | 0 .00- | .00 | 312940.4 | 3232413 |
| -118 | 1.13 | 1.75 | 1.52 | 1.9 | 1.12 | -0.2 | 1850.00-1990.00 | 312769 | 3232310 |
| -115 | -0.74 | -0.38 | -0.75 | -2.83 | -10.6 | -12.4 | 1850.00-1990.00 | 312598.3 | 3232205 |
| -114 | -1.34 | -0.94 | -1.37 | -5.83 | -10.73 | -12.32 | 1850.00-1990.00 | 312428.7 | 3232098 |
| -113 | -1.46 | -1.02 | -1.46 | -5.74 | -10.58 | -12.13 | 1850.00-1990.00 | 312257 | 3231995 |
| -112 | -1.54 | -1.07 | -1.49 | -5.44 | -10.08 | -11.61 | 1850.00-1990.00 | 312088.9 | 3231889 |
| -111 | -1.57 | -0.99 | -1.34 | -4.88 | -9.51 | -11.12 | 1850.00-1990.00 | 311919.2 | 3231779 |

Table 2. - Sample of partial output file from SSAPP showing statistical parameters from the results of rate-of-change analysis. TRAN= transect number, R2= linear regression correlation coefficient, MDL= minimum description length criterion, K= number of terms in optimum polynomial, LCP= latest critical point, WTS= weight applied to data earlier than the latest critical point, ANGLE= angle between the zero-weight line and the weighted line in the Fenster method.

SHORELINE CHANGE STATISTICS AND PARAMETERS

Shoreline file name: galves.dat

Run date and time: 9/29/95 10:35

Baseline length= 200.00m

Transect Spacing= 200.00m Map Error= 8.50m

| PARAMETERS | | | | | | |
|------------|------|----------|---|------|--------|-------|
| TRAN | R2 | MDL | K | LCP | WTS | ANGLE |
| -117 | 0 | 0 | 1 | -999 | 0 | -999 |
| -116 | 0.28 | 12358.58 | 4 | 1963 | 0.3036 | 36.92 |
| -115 | 0.01 | 17055.02 | 4 | 1953 | 0.0087 | -0.78 |
| -114 | 0.08 | 12295.14 | 4 | 1948 | 0.0062 | -0.88 |
| -113 | 0.1 | 10198.62 | 4 | 1948 | 0.0062 | -0.89 |
| -112 | 0.13 | 7528.09 | 4 | 1947 | 0.0065 | -0.74 |
| -111 | 0.13 | 5498.64 | 4 | 1951 | 0.0072 | -0.86 |

PRELIMINARY RESULTS FROM GALVESTON ISLAND

Galveston Island, Texas (Fig. 3), a sandy barrier island, was used to demonstrate and evaluate the capabilities of SSAPP and to make an initial evaluation of the results of the various rates-of-change calculations. There is a variety of development along the shores of Galveston Island. On the northeast end, the Bolivar Roads south jetty has impounded sand, largely eroded from in front of the seawall to the west, causing the shoreline to accrete since the 1890's and forming East Beach (Morton 1974) (Fig. 3). The portion of the Galveston Seawall and associated groin system that backs the current beach stretches for 11 km in front of the city of Galveston. Construction of the seawall occurred in phases from 1902 to 1952 and groins were added along this stretch of shoreline in 1885 and 1939 (Morton 1974). Currently, waves often reach the seawall except where a beach nourishment project was constructed in 1994. Development along the Gulf shoreline of Galveston Island southwest of the seawall consists of single family homes, and no beach nourishment projects or hard structures have been constructed. The southwest end of Galveston Island is bordered by San Luis Pass which is a natural tidal inlet and is where large shoreline changes have occurred in conjunction with island progradation and tidal channel and ebb-tidal delta interaction with the shoreline.

For this analysis, a baseline length of 200 m and a transect spacing of 200 m were used. A baseline spacing of 200 m appeared to adequately follow the shapes of the shorelines, particularly toward the southwest end of the island (Fig. 3). The transect spacing of 200 m provided a relatively smooth projected shoreline for the scale of this example. As described above, users have the option of changing baseline and transect spacing, and if one wishes to study the shoreline on a smaller or larger scale, this may be warranted. The map error range used was 8.5 m, and the maximum polynomial ordered to be considered by the weighted method was 3 (for a max K of 4).

Figure 4 shows a plot of the five calculated rates-of-change along the Galveston Island shoreline. The alongshore shapes of the rates-of-change curves computed using the end point, linear regression, jackknife, and average-of-rates methods are similar. East of the seawall along East Beach all methods reflect the accretion that has occurred from impoundment of sediment by the jetty. The effect of the seawall and groin field, which are to the west of East Beach, is expressed as erosion just east of the east end of the seawall at transect 90. Littoral drift along this portion of the island is to the east, and the seawall and groins have interrupted littoral drift supply to the beach adjacent to the east end of the seawall causing local erosion. This section of shoreline (around transect 90) is apparently west of the direct influence of the sediment impoundment caused by the jetty.

In front of a relatively old part of the seawall between transects 55 and 80, the shoreline is nearly stable with rates-of-change of less than -0.5 m/yr. Farther to the west rates of erosion gradually increase and reach a maximum of almost -3.0 m/yr just west of the seawall at transect 25. Littoral drift here is to the west, and as was the case on the east end of the seawall, the seawall and groin field have interrupted littoral drift supply causing erosion. From transect 20, about 2.5 km west of the seawall, to transect -10, a distance of 5 km, erosion rates gradually decrease for all methods except the weighted method. From transect -10 to -40, the shoreline is stable to slightly erosional (less than -0.5 m/yr) for all the methods except the weighted method. Although the average-of-rates method along this stretch generally conforms with the end point, linear regression, and jackknife methods, it is relatively erratic with several transects showing slight accretion.

From transect -40 to -80, erosion rates for all methods gradually increase. This increase, however, is more pronounced in the average-of-rates and weighted methods. From -80 southwest to San Luis Pass, erosion rates decrease then increase, and at the end of the island, the rates reflect accretion associated with island progradation. Variance in rates-of-change from

transect -80 to the southwest end show the effects of San Luis Pass. Along this stretch, the linear regression method shows the least variance and the lowest rates-of-change. The Jackknife and end point methods show only slightly more variance, but the average-of-rates and weighted methods show large swings in rates-of-change.

As mentioned above, all methods except the weighted method have a similar alongshore shape in their rate-of-change curves. The average-of-rates method, however, shows more high- and low-frequency alongshore variance than the other methods. The weighted method also shows relatively large alongshore variance, and it departs dramatically from the other methods for about 16 km west of the seawall. Along this 16 km of shoreline, the weighted method computed erosion rates of 2 to 4 m/yr while the other methods determined the shoreline to be nearly stable (Fig. 4).

DISCUSSION

At many sites along the Texas coast the trends of shoreline movement and rates of change have been greatly influenced by human activities. These activities have locally altered the littoral processes and sediment supply, causing either the trends of shoreline movement to abruptly reverse or to rapidly accelerate and decelerate. Therefore it is important to analyze shoreline movement in a historical context that recognizes the altered physical conditions and their impact on future shoreline movement.

The end point, linear regression, and jackknife methods yield similar results and usually the lowest erosion rates (Fig. 4). These methods also show low alongshore variance compared to the average-of-rates and weighted methods. The weighted method departs radically from the other methods west of the seawall. Inspection of the weights and critical points reveals that the weighted method completely discounted (applied zero weights to) data prior to 1915 along this stretch. Therefore, the weighted method automatically considered the change in littoral processes caused by the seawall. The weighted method holds promise for a relatively objective, unsupervised way of computing rates-of-change.

The alongshore variance in the average-of-rates and weighted methods is of concern when projecting predicted shorelines. This variability is caused by varying availability of shorelines through the years for adjacent transects and by actual variance in the shapes of the shorelines. Even if the rate-of-change variance does reflect actual shoreline shape and change variability over the time period of analysis, projecting a new shoreline using those rates will likely produce

an unnatural shoreline shape. An example of this is shown in the inset in figure 3 where projected shorelines using the end point and weighted rates are mapped. The weighted method predicts landward shoreline movement of about 75 m, but there is a prominent bend in the shoreline that we have no reason to believe would actually form.

Over the next year we will devise a shoreline projection method that will consider shoreline shape. This method will perform various morphological analyses of actual and predicted shorelines. Such analyses may include fractal, fourier, and new hybrid techniques. Actual shorelines will be morphologically characterized, and using these characterizations, the "naturalness" of the predicted shorelines will be evaluated. Predicted shorelines that have unnatural shapes would suggest unreasonable rate-of-change values were used. This information may be used to go back and modify rate-of-change values for particular locations or to provide a limit on how far in the future one may reasonably project shorelines.

REFERENCES

Dolan, R., Fenster, M.S., and Holme, S.J., 1991, Temporal analysis of shoreline recession and accretion: *Journal of Coastal Research*, v. 7, no. 3, p. 723-744.

Efron, B., 1982, *The Jackknife, the Bootstrap and Other Resampling Plans*: Philadelphia, Pennsylvania: Society for Industrial and Applied Mathematics, 92p.

Fenster, M.S., Dolan, R., and Elder, J.F., 1993, A new method for predicting shoreline positions from historical data: *Journal of Coastal Research*, v. 9, no. 1, p. 147-171.

Foster, E.R. and Savage, R.J., 1989, Methods of historical shoreline analysis: in Magoon, O.T., Converse, H., Miner, D., Tobin, L.T., and Clark, D., (eds.), *Coastal Zone '89*, American Society of Civil Engineers, v. 5, p. 4434-4448.

Morton, R.A., 1974, *Shoreline changes on Galveston Island (Bolivar Roads to San Luis Pass) An analysis of historical changes of the Texas Gulf shoreline: Geological Circular 74-2*, Bureau of Economic Geology, The University of Texas at Austin, Austin, Texas, 34pp.

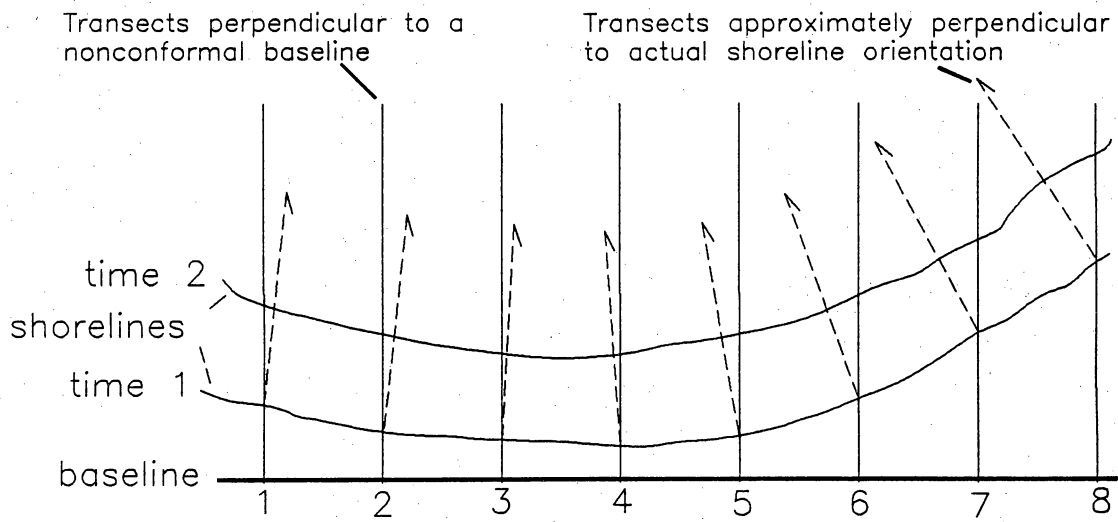
FIGURE CAPTIONS

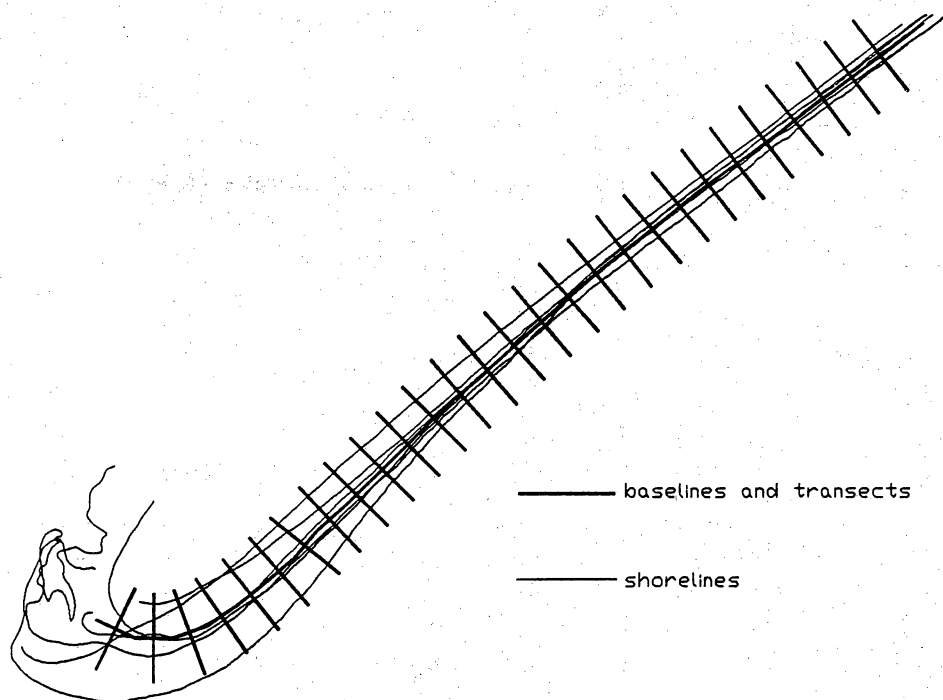
Figure 1. - Illustration of the effect of using a baseline obliquely oriented to shorelines on the computation of shoreline change rates and future shoreline projections. At transects one through eight, the distance between shorelines is greater for transects oriented perpendicular to a nonconformal baseline than it is for transects oriented perpendicular to the actual shoreline orientations (dashed lines). This may cause problems when projecting shorelines into the future based on historical erosion rates, because one must know in what direction to move the shoreline.

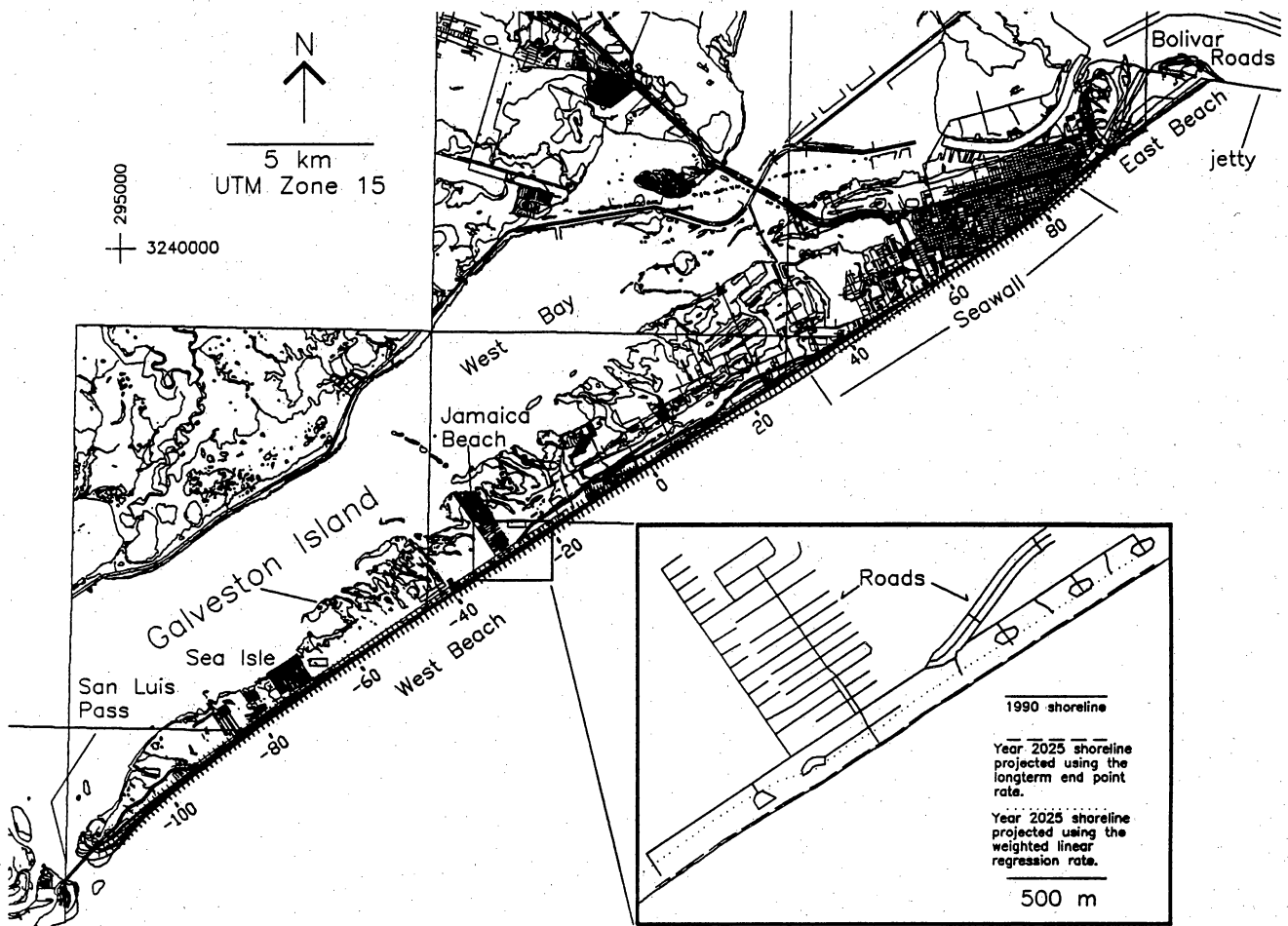
Figure 2. - Illustration of how SSAPP automatically tracks the historical shorelines and constructs a series of baselines and transects that conform to the historical shoreline trends. Here the baseline length selected is 200 m and the transect spacing is 200 m. The user, however, may change these values.

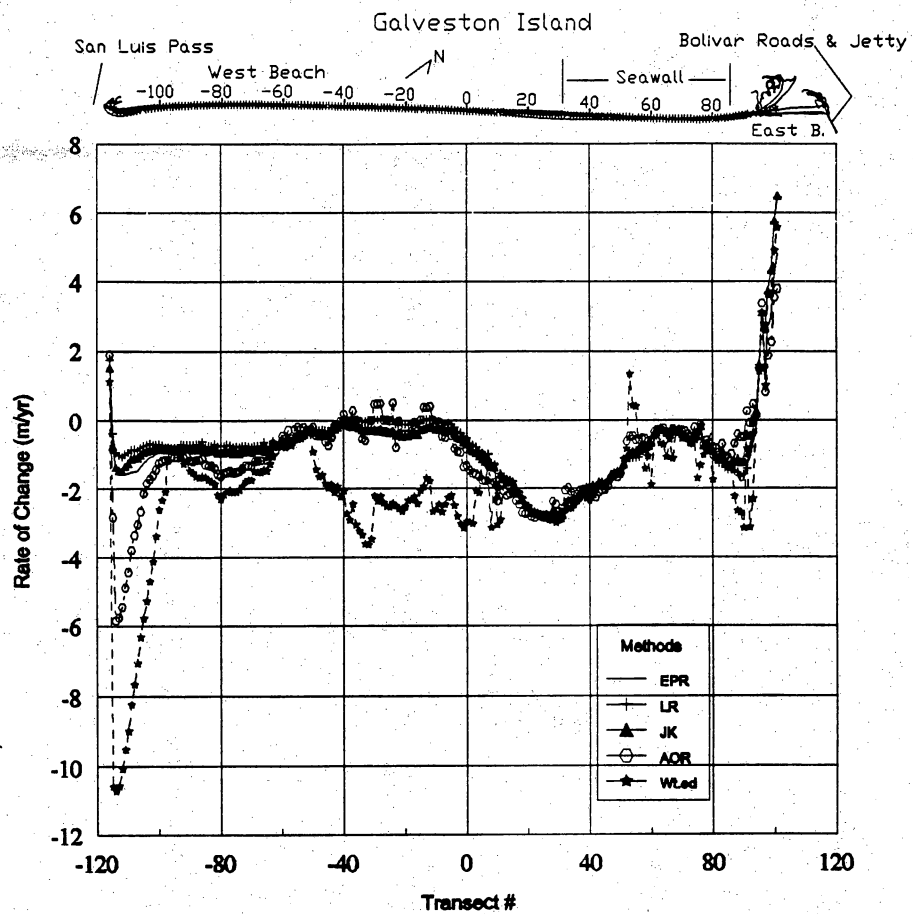
Figure 3. - Map of Galveston Island with shoreline transects and future shoreline projections. The inset shows the results of projecting the shoreline 30 years into the future to the year 2025 in the Jamaica Beach area. The end point rate-of-change, which uses shorelines from the 1850's and 1990's in this area, predicts that the shoreline will move landward only about 6 m. The weighted linear regression method, which discounts shorelines prior to about 1915, predicts that the shoreline will move landward about 75 m.

Figure 4. - Plot of shoreline change rates along Galveston Island computed by various methods: EPR= end point rate; LR= linear regression; JK= jackknife; AOR= average of rates; and Wt.ed= weighted. See text for explanation of methods.







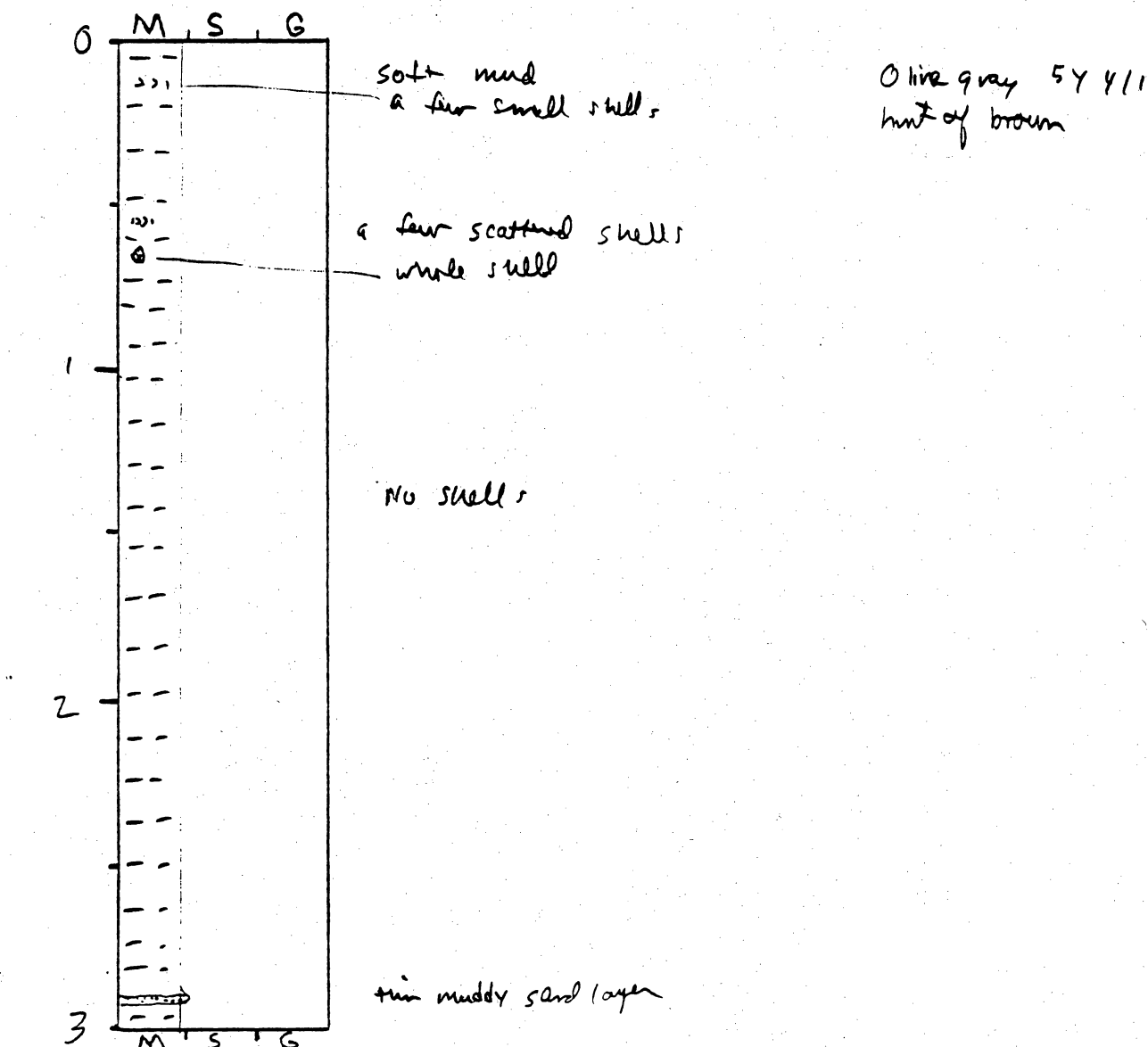


Addendum 11. Descriptions of Vibracores, Sabine Bank and Heald Bank

CORE LOG

CORE # SBV-9 (A) TYPE Vibracore LOCATION Sabin Bank
 LATITUDE 26° 38.090' LONGITUDE 94° 03.449' SURFACE ELEVATION 18'
 DEPTH PENETRATED ? LENGTH RECOVERED 7' 2" % COMPACTION 2
 OBTAINED BY Gibeault, R/v Kit Jone DATE 10-10-94
 DESCRIBED BY W/mr DATE 2-3-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



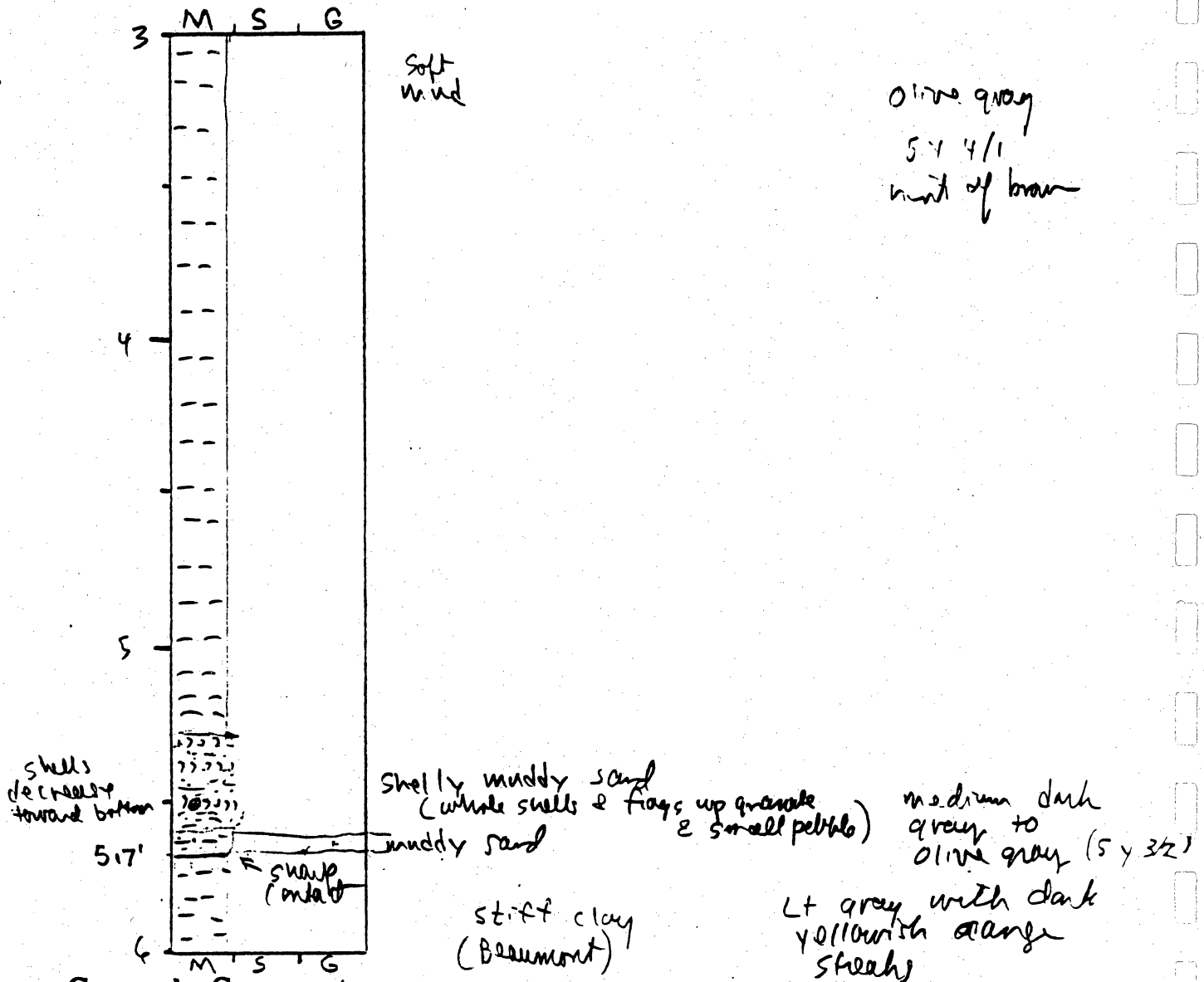
General Comments:

CORE LOG

CORE # SBV-9 (B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



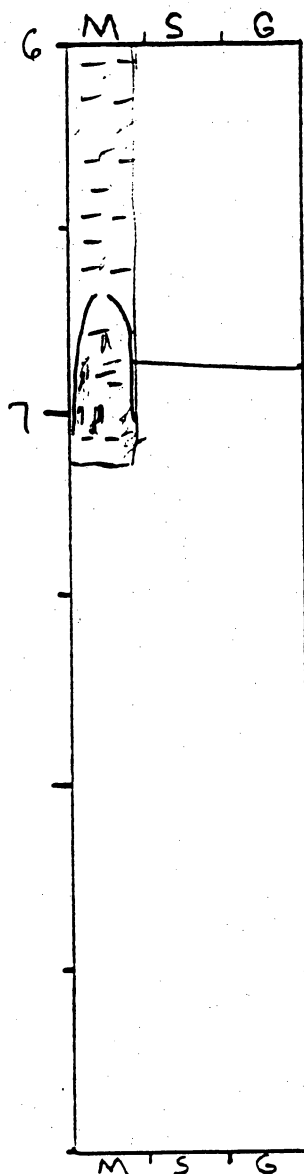
General Comments:

CORE LOG

CORE # SBV-9(c) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



stiff clay (mottled)
 (Beaumont)
 No shells

light gray to
 pale olive
 with dark
 yellowish
 orange streaks
 (vertical)

core catcher

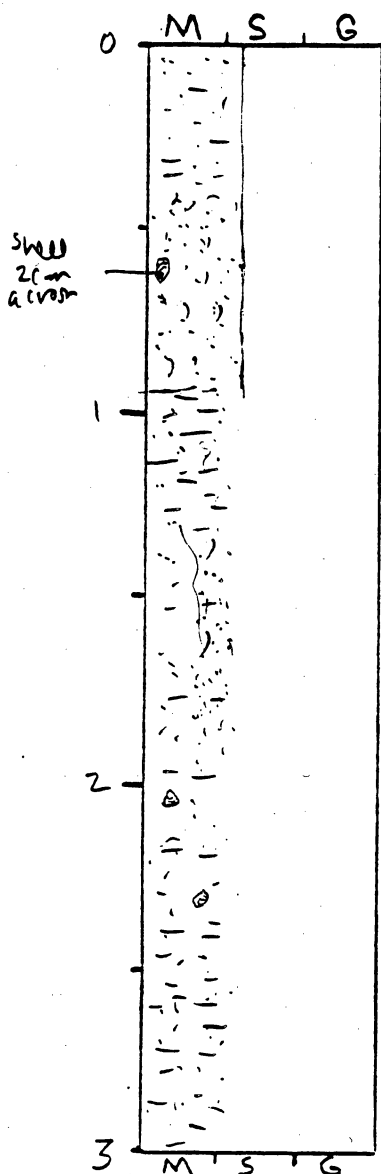
mottled lt gray, dark
 and small streaks of dark gray

General Comments:

CORE LOG

CORE # SBV-10(A) TYPE Vibracore LOCATION Sabine Bank
 LATITUDE 29° 29.72' LONGITUDE 93° 48.43' SURFACE ELEVATION -42'
 DEPTH PENETRATED LENGTH RECOVERED 18.5' % COMPACTION 2,
18.6"
 OBTAINED BY Gibson & R/V Kit Jones DATE 10/11/94
 DESCRIBED BY White DATE 2/3/95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



muddy sand (v. fine qtz sd)

Dark yellowish Brown

scattered shell frags & whole shells

Gravels & pebbles in size

shells more concentrated (to 100%) from 0.4' - 0.9' (higher conc. of sd at)

appears to be heavily burrowed

based on sand & mud relationships

(muddy sand)
 muddier and more olive gray in color
 from 0.9' - 1.4

burrows

Dark yellowish brown
 to
 olive gray

muddy sand but mud appears
 to be increasing at depth

color becoming more
 olive gray toward
 bottom (less
 brownish)

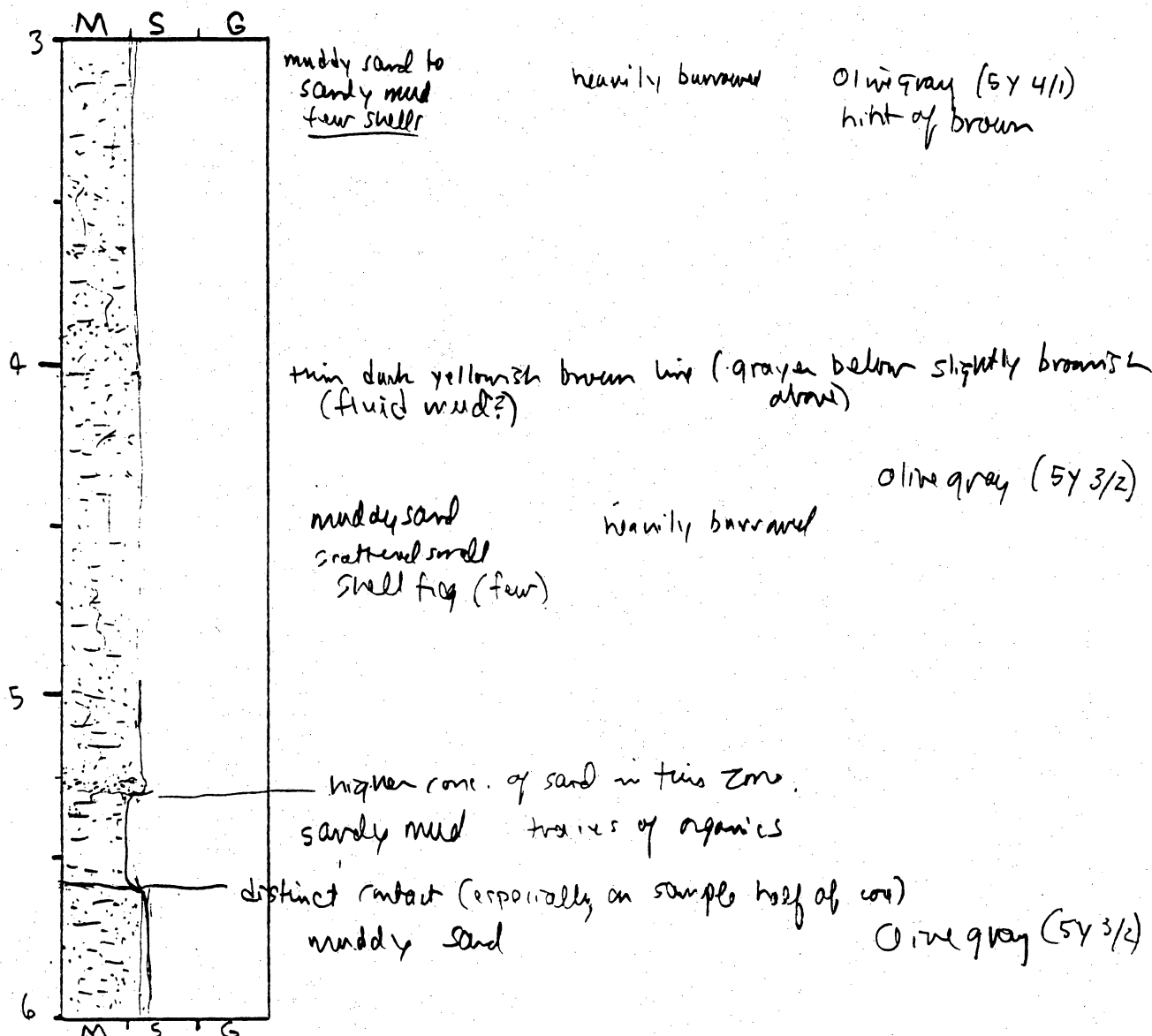
General Comments:

CORE LOG

CORE # SBV-10(13) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



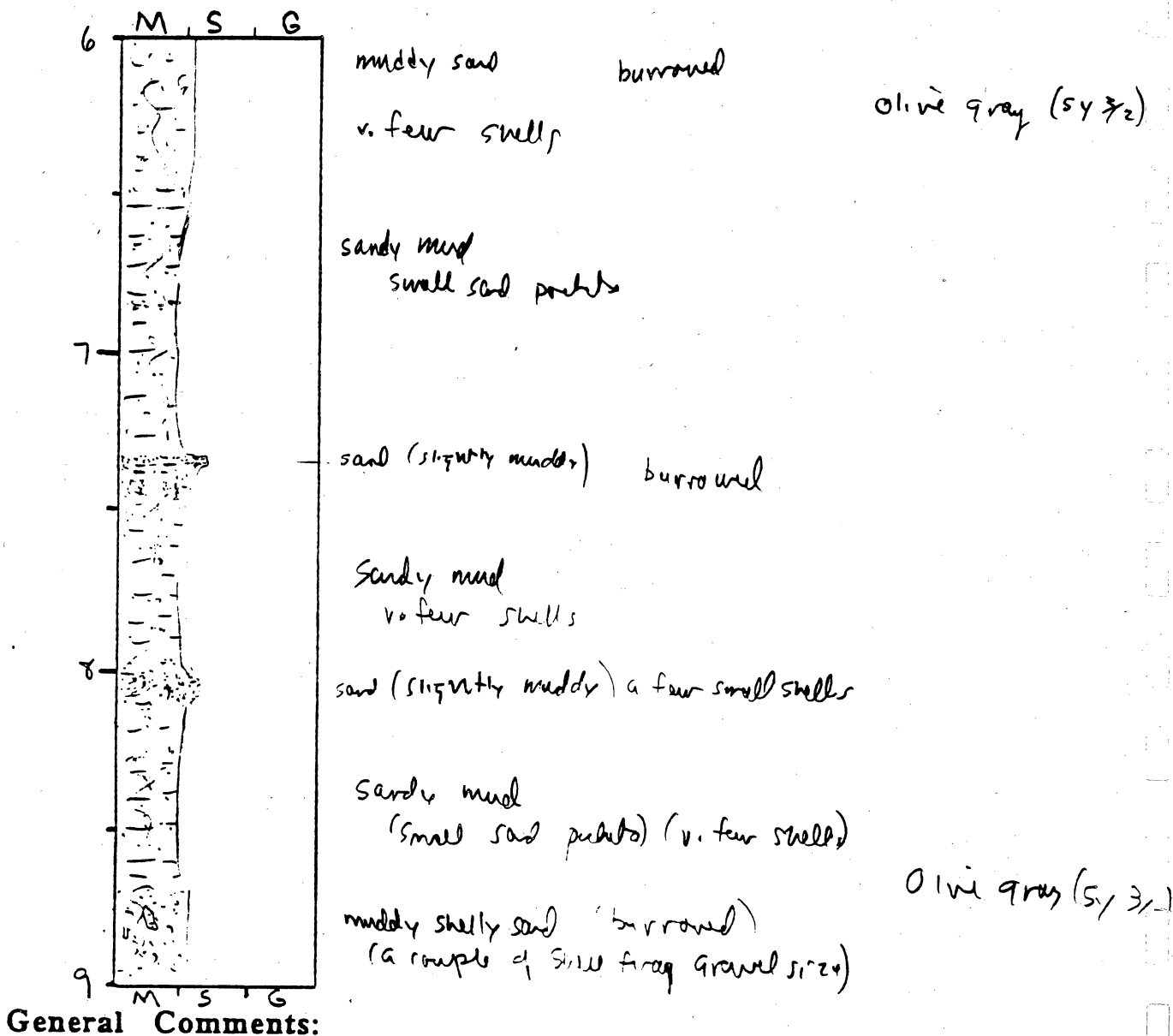
General Comments:

CORE LOG

CORE # SBV-10(9) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



CORE LOG

CORE # SBV-10D TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

| | | | | |
|----|-------|---|--|------------|
| 9 | M S G | muddy sand (v. fine sand) slightly shelly < 10% sand filled burrow discrete mud & sand zone | | olive gray |
| 10 | | distinct contact slightly sandy mud sandy pockets; v. scattered shells in sand | | |
| | | distinct contact muddy shelly sand (shell frags granule) | | |
| 11 | | organic mud w/ clay traces of sand or silt (Olivine = ... in a mud with organic traces) | | |
| | | mud (no ... silt & sand in pockets) scattered ... shell frags (v. coarse to granule) | | |
| | | slightly more sand (sandy mud) (scattered ^{small} shell frags) | | |
| 12 | M S G | mud (organic traces) | | olive gray |

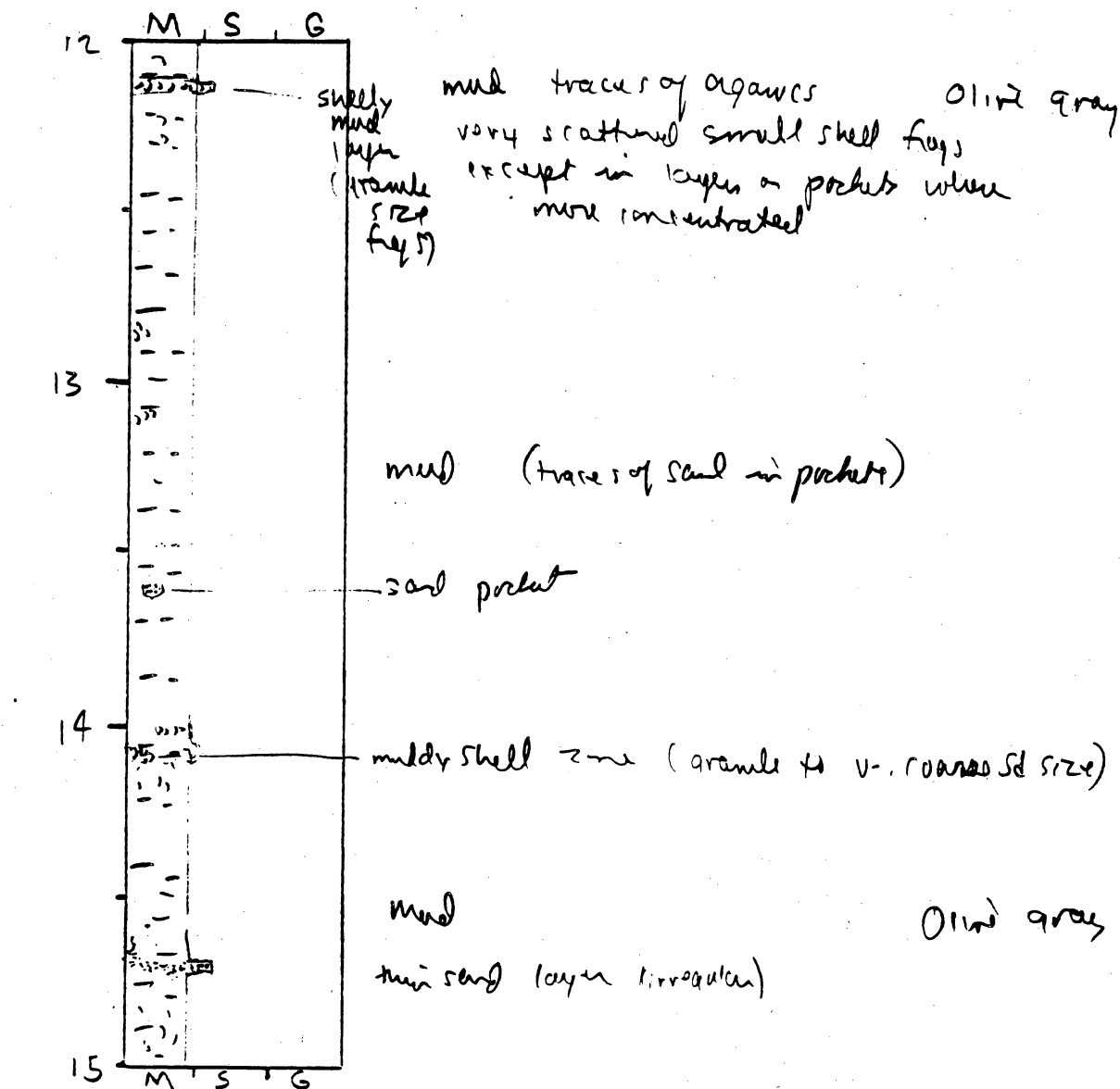
General Comments:

CORE LOG

CORE # SBV-10(E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH
 (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



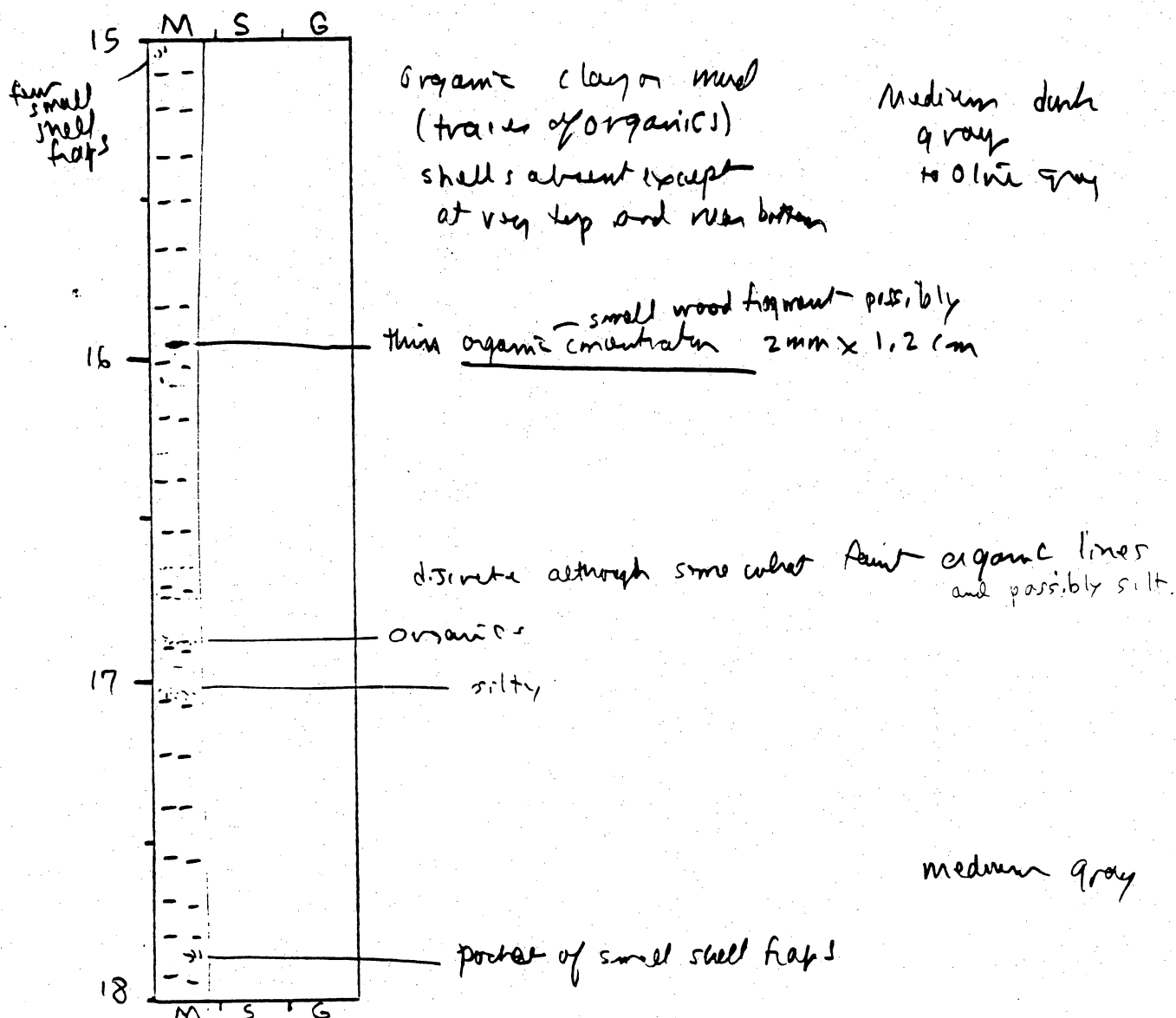
General Comments:

CORE LOG

CORE # SBV-10 (F) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



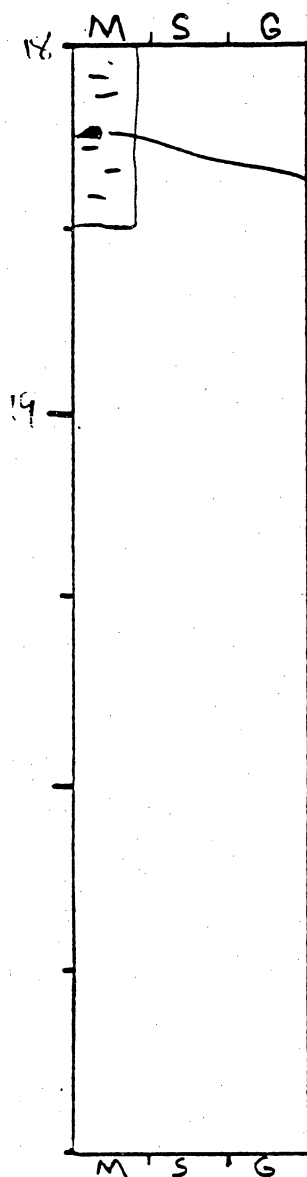
General Comments:

CORE LOG

CORE # SBV-10(G) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



soft mud (no shells) medium gray
 organic fragment (possibly could be dated)

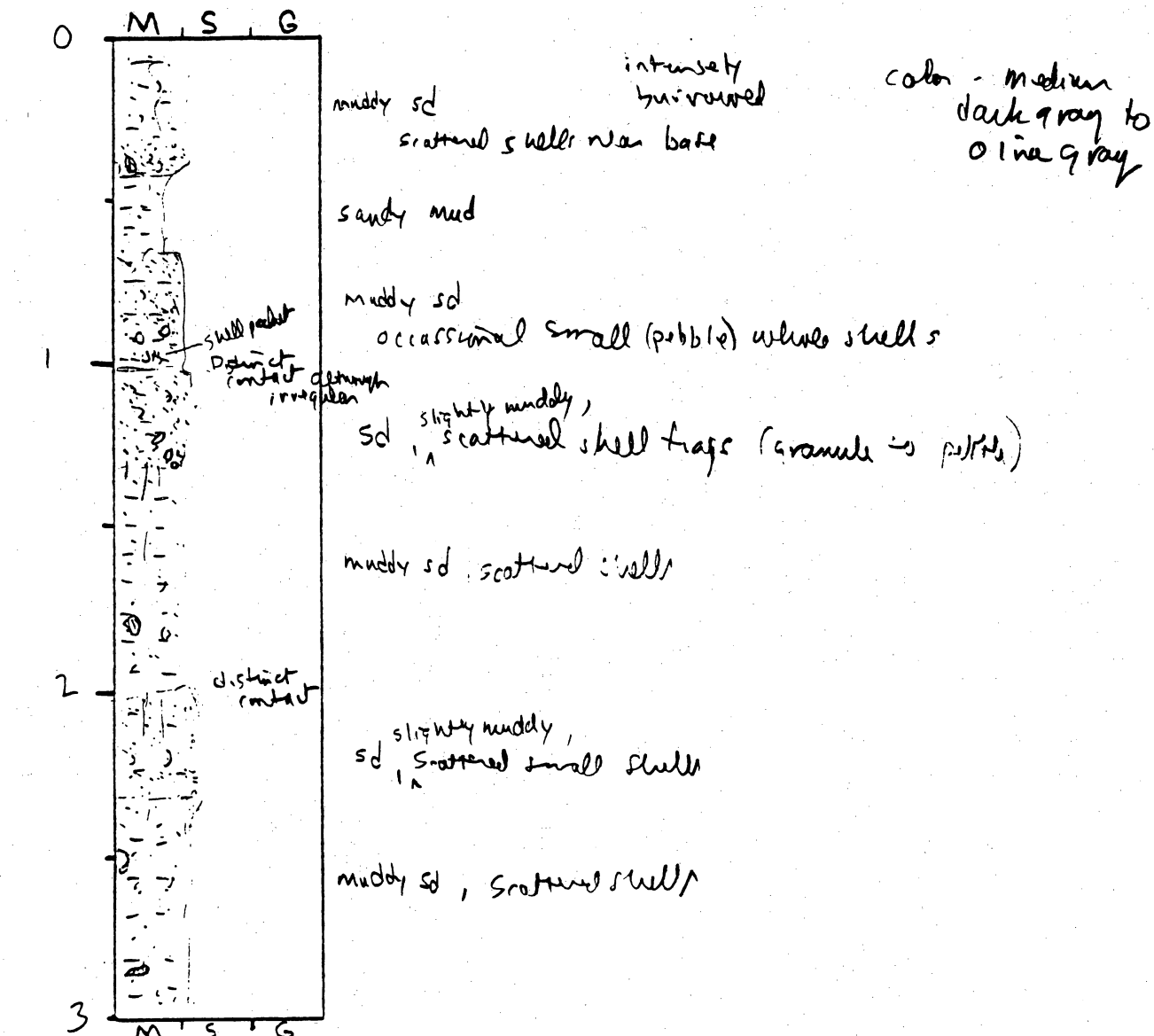
General Comments:

CORE LOG

CORE # SBV-11(A) TYPE Vibracore LOCATION Sabine Bank
 LATITUDE 29° 31.177' LONGITUDE 93° 25.649' SURFACE ELEVATION -37'
 DEPTH PENETRATED ? LENGTH RECOVERED 11' 3/4" COMPACTION ?

OBTAINED BY Gibeaut - R/V Kit Jones DATE 10-13-94
 DESCRIBED BY White DATE 3-6-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



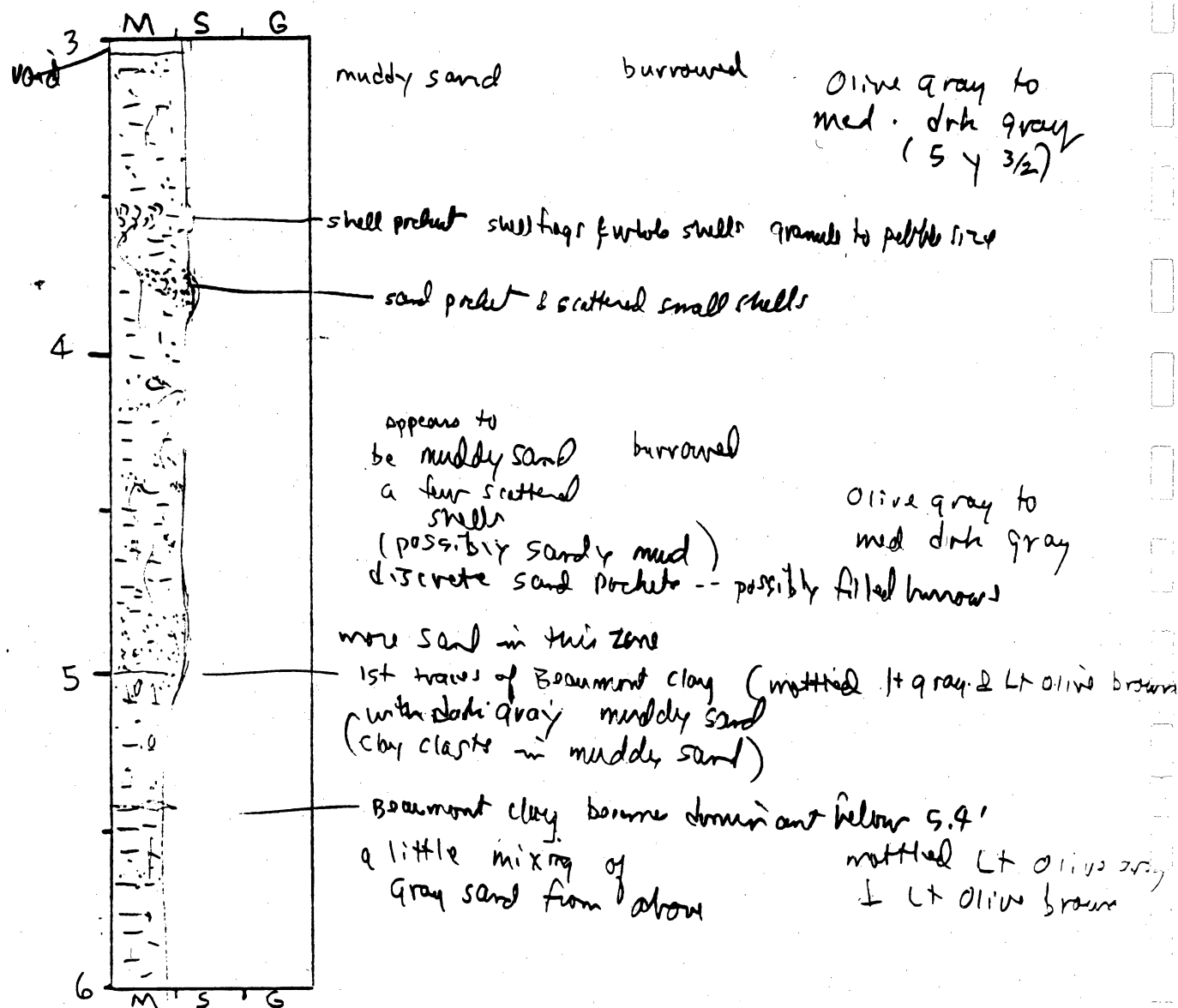
General Comments:

CORE LOG

CORE # SBV-11(B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, in) SKETCH LITHOLOGY STRUCTURE REMARKS



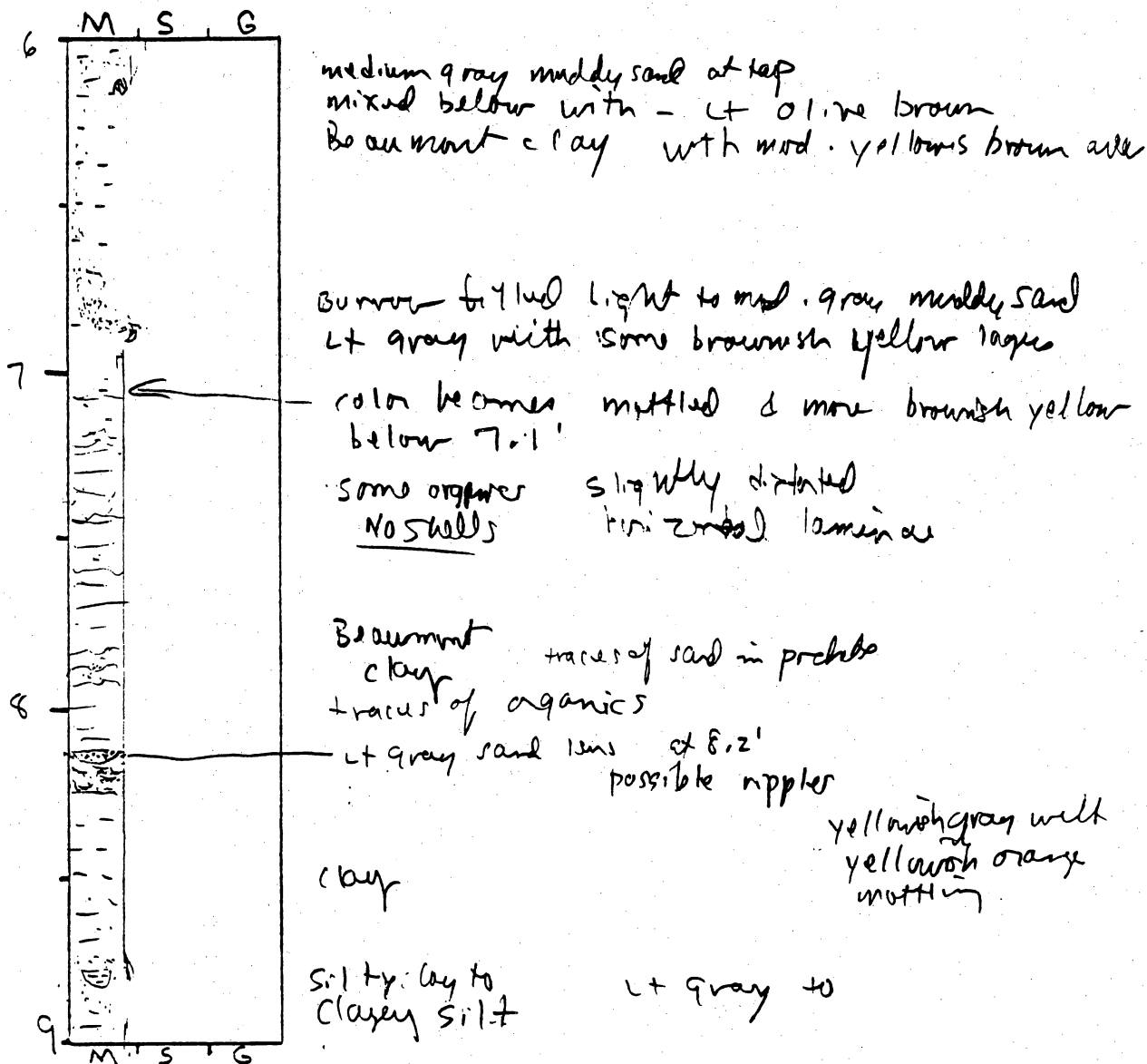
General Comments:

CORE LOG

CORE # SBV-11 (C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



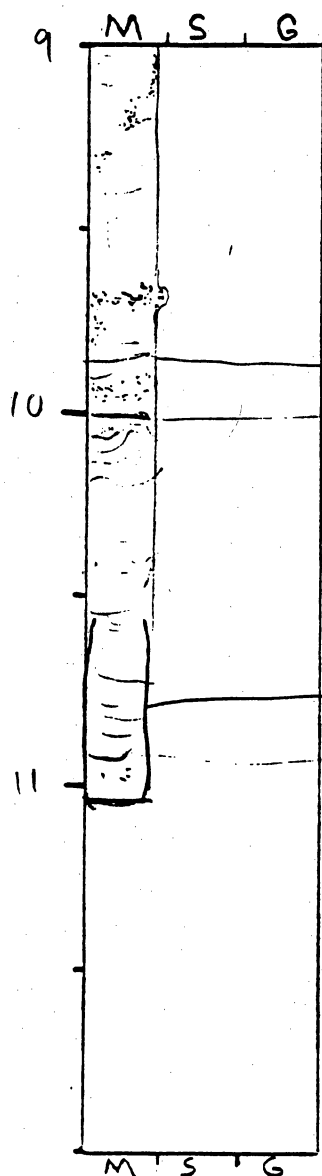
General Comments:

CORE LOG

CORE # SBV 11 (D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



Beaumont clay
 occasional thin v. fine sand or silt layers
 Organic layers

organic

Slightly disturbed laminar

thin dark brown organic layer

cone ratchet

organics

mottled colour
 from ^{olive} gray to
 drk yellow
 orange
 and grayish orange

General Comments:

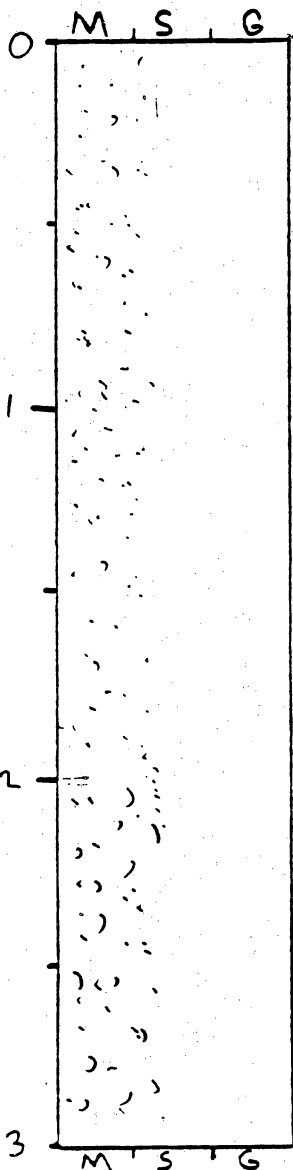
CORE LOG

CORE # SBV-12(A) TYPE Vibramore LOCATION Sabine Bank
 LATITUDE 29° 30.007 LONGITUDE 93° 35.317 SURFACE ELEVATION -25'
 DEPTH PENETRATED ? LENGTH RECOVERED 16.9" % COMPACTION ?

OBTAINED BY Gibeaut - R/V Kit Jones DATE 10-13-94
 DESCRIBED BY White DATE

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

Box of
fine
sand
from
top
12



Fine quartz sand, subrounded, well sorted
 5-10% shell frags - ^{to very coarse} coarse sand size

lt olive gray
 (SY 5/2)
 to olive gray
 hint of brown

Fining upward sequence

Fine quartz sand with increasing
 amounts of shell fragments, also
 coarsening of shell fragments -- granule in
 fragments approaching 25% size
 below $\approx 2'$

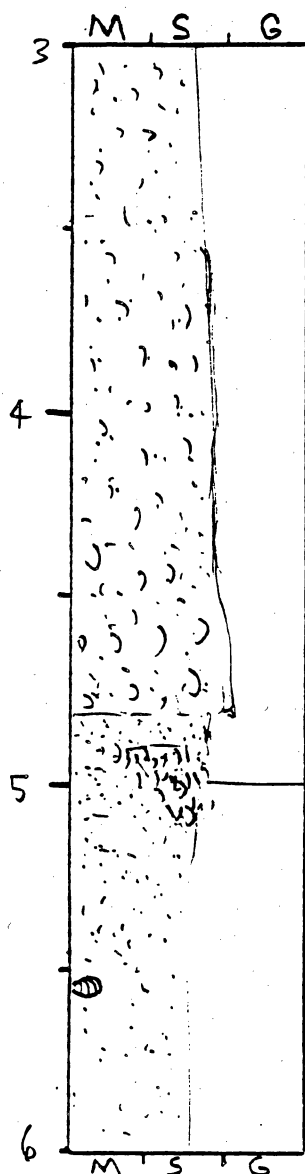
General Comments:

CORE LOG

CORE # SBV 12 (5) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



shelly sand

lt Olive gray (5Y 5/2)
 to Olive gray (5Y 4.1)

gradational increase in shell frags.
 quantity & size with depth

fining upward

sandy shell

coarsening of shells
 pebble size
 some whole shells

shell pocket

fine sand, scattered small shell frags.

olive gray sd
 (5Y 5/2)

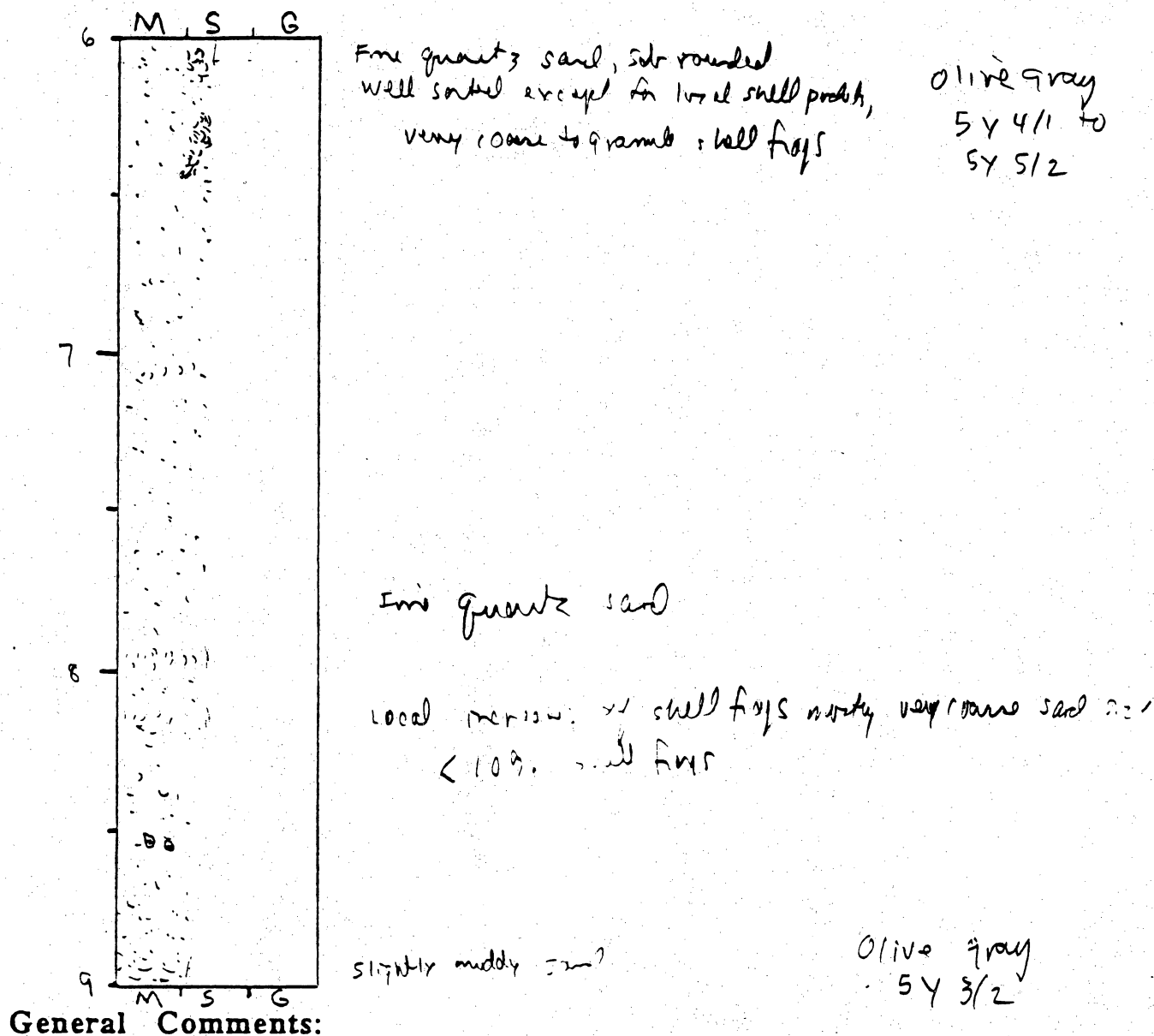
General Comments:

CORE LOG

CORE # SBV-12(c) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

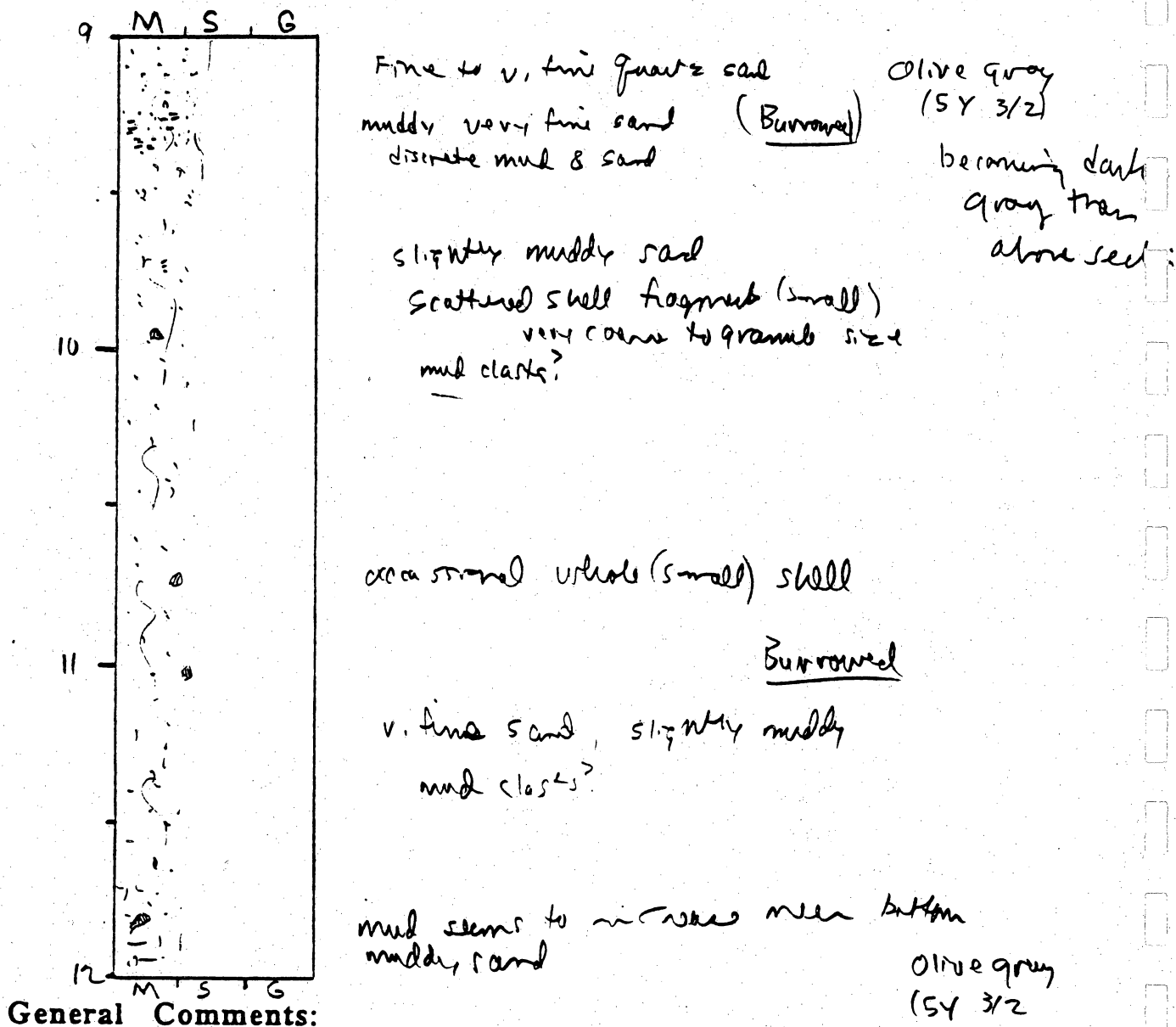
| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



CORE LOG

CORE # SBV-12(D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



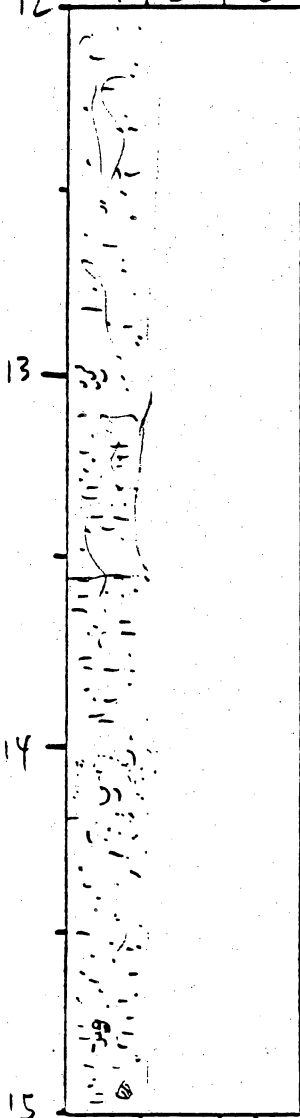
CORE LOG

CORE # SAV-12(E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

12 M S G



muddy sand intensely
Burrowed

Olive gray
(5Y 3/2)

a few scattered shell frags 1 or 2%

becoming
darker
gray
than
above
section

13

discrete sand and
mud (clay) zones. Intensely
slightly muddier Burrowed
from 13.1 - 13.6

14

lt Olive gray (brownish) sd. laren
a few larger shells (pebbles 1/2")

muddy sand
occasional shell pebbles

Olive gray
(5Y 3/2)

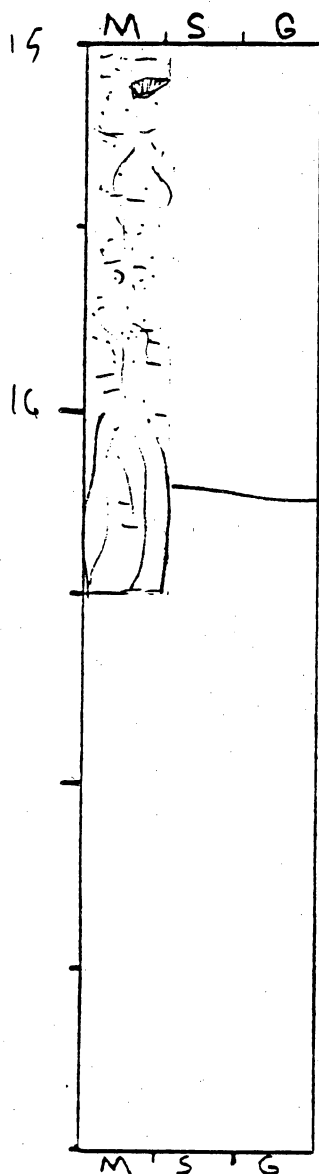
General Comments:

CORE LOG

CORE # SBV-12 F TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



muddy sand to sandy mud
 whole shell \approx 2 cm long
 < 1% shell frags

discrete sand
 pocket &
 clay zone

Intensely
 burrowed

olive gray
 (5 y 3/2)
 darker than
 above

core richer

General Comments:

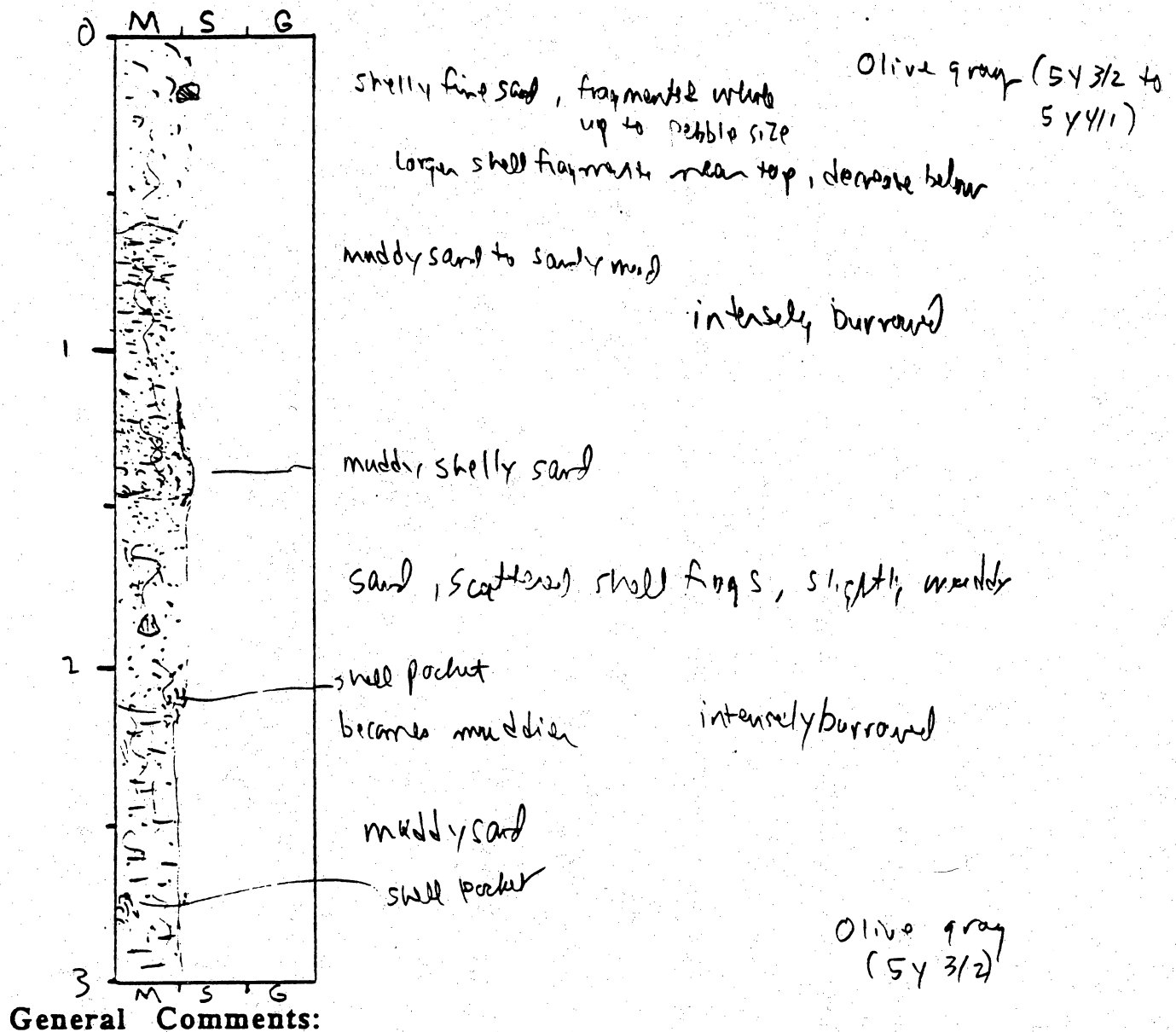
CORE LOG

CORE # 5BY-13(A) TYPE Vibro core LOCATION Sabine Bank
 LATITUDE 29° 28.729 LONGITUDE 93° 34.872 SURFACE ELEVATION -37'
 DEPTH PENETRATED 2 LENGTH RECOVERED 19' 4 1/2" COMPACTION ?

OBTAINED BY G. beaut - R/V Kit Jones
 DESCRIBED BY White

DATE 10-13-94
 DATE 2-7-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

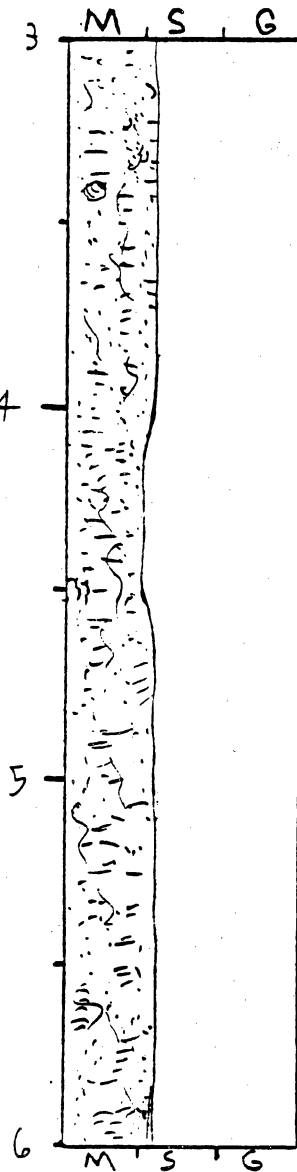


CORE LOG

CORE # SPV-13(B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



muddy sand

Olive gray
(SY 3/2)

very scattered shells
41%

Intensely
Burrowed

mudier muddy sand
to sandy mud

Intensely
Burrowed

muddy sand

Intensely
Burrowed

discrete
mud & sand
areas

Olive
gray
(SY 3/2)

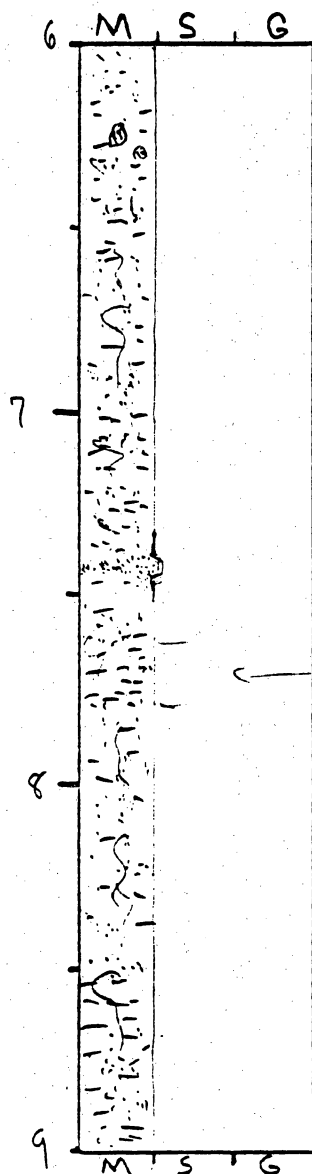
General Comments:

CORE LOG

CORE # SBV-13(C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



muddy sand to sandy mud
 mud became more
 abundant in this
 section, still lots
 of fine sand
 a few scattered shells
 discrete sand and mud over

Olive gray
 5Y 3/2

Intensely
Burrowed

discrete mud & sand zone
 thin sand layer (light olive gray to olive gray)

sandy mud

Intensely
Burrowed

muddy sand
 sandy mud
 very scattered shell frags
 < 1%

Olive gray (5Y 3/2)

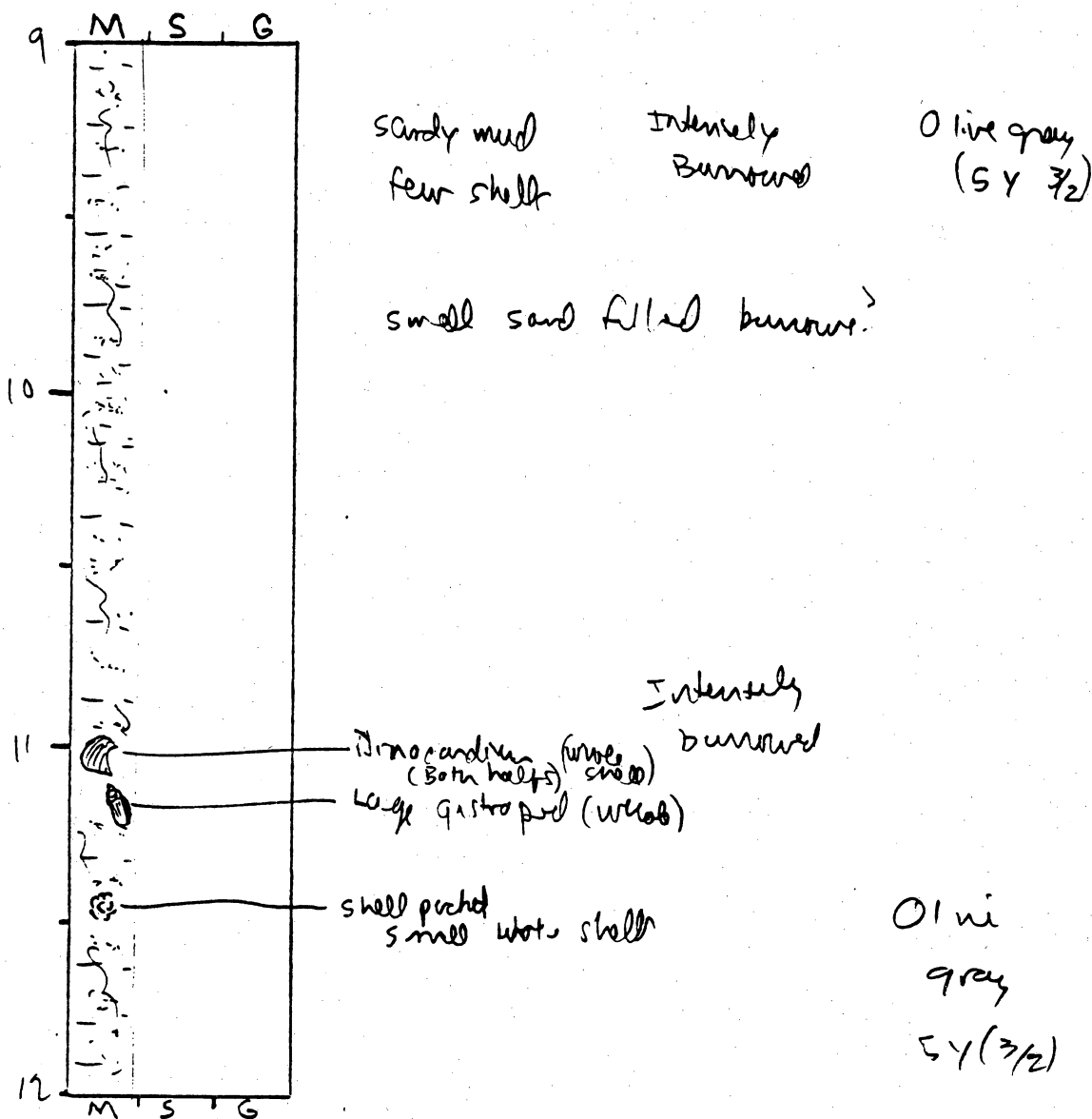
General Comments:

CORE LOG

CORE # SBV-131D TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

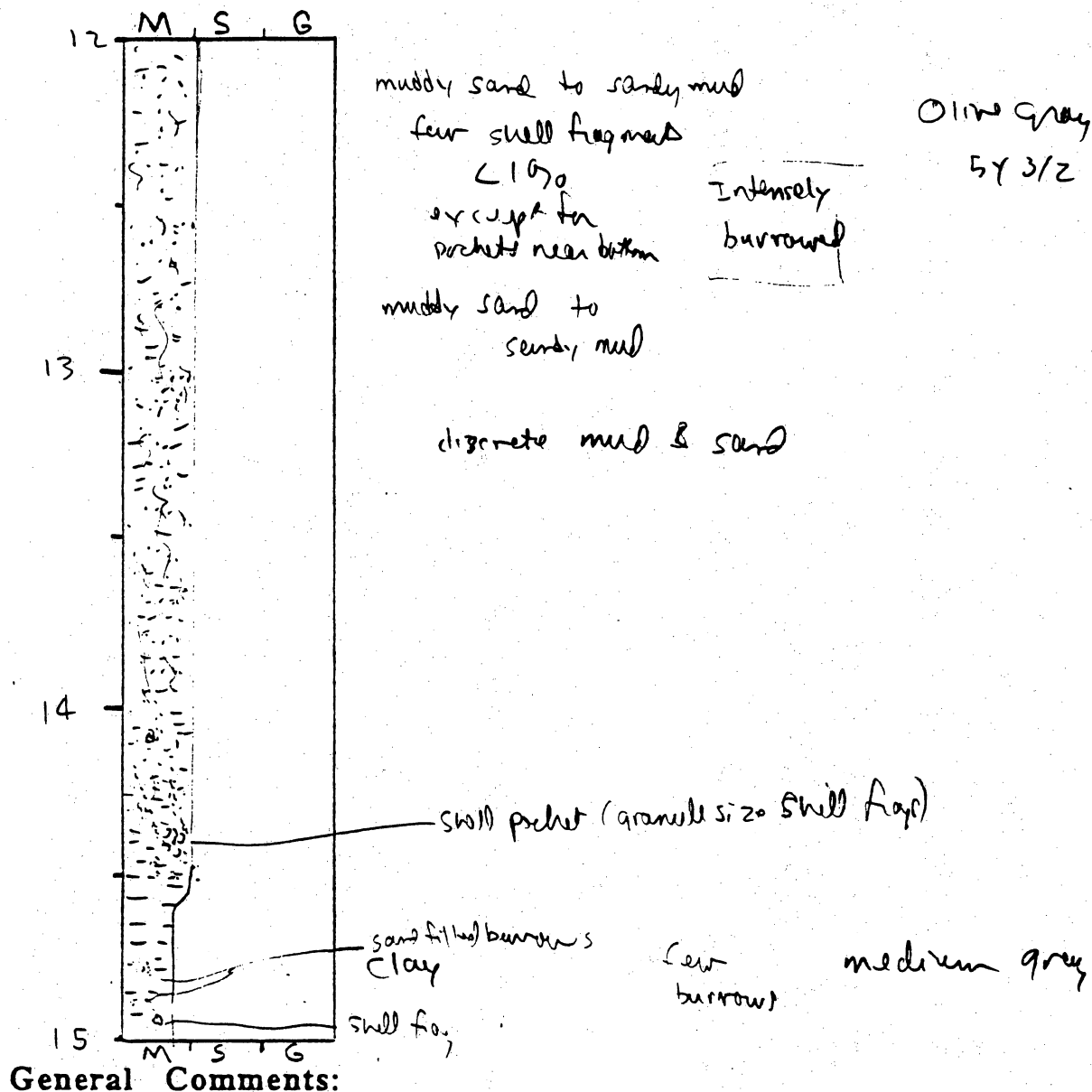


General Comments:

CORE LOG

CORE # SBV-13(E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

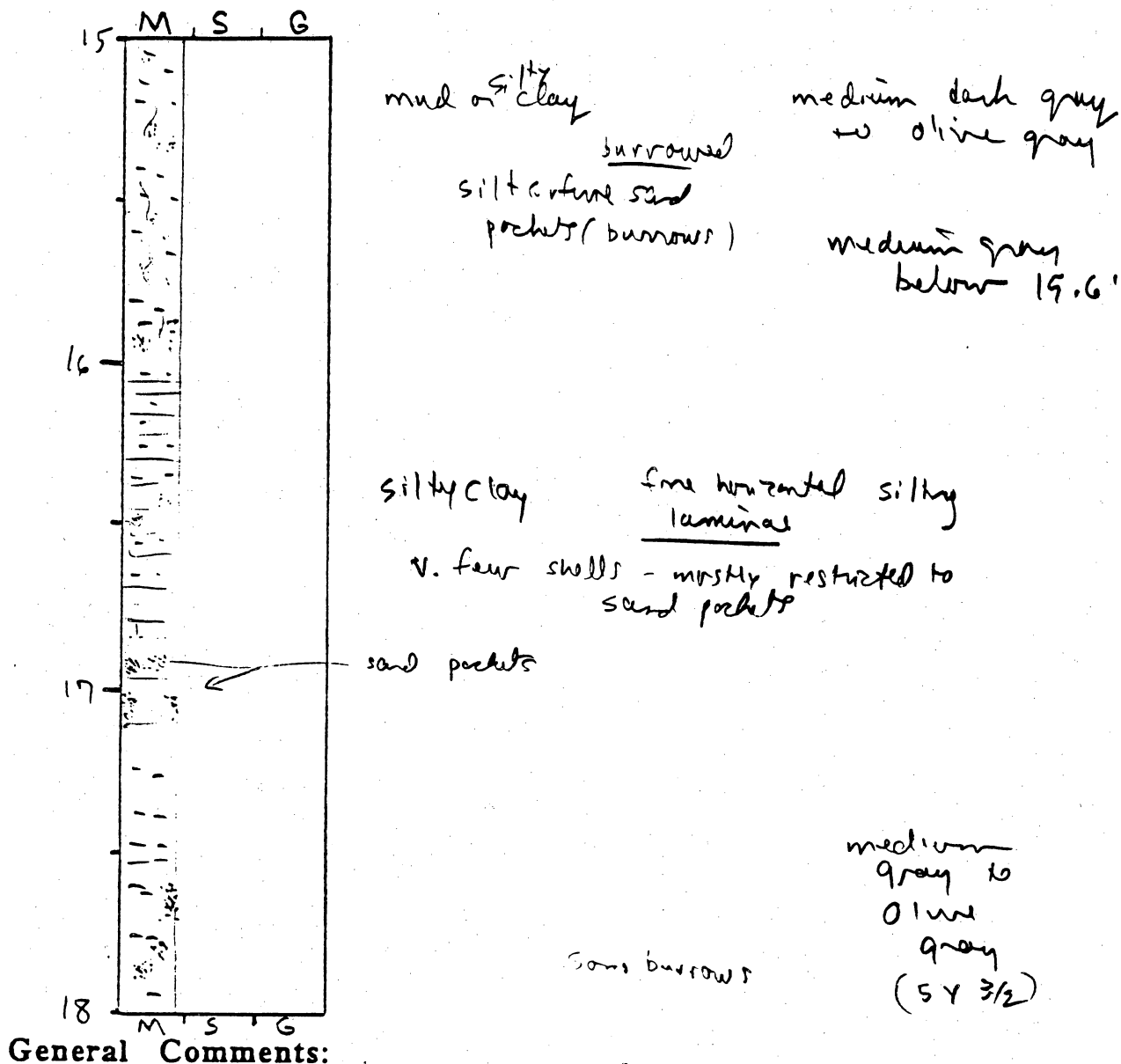


CORE LOG

CORE # SBV-13 (F) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

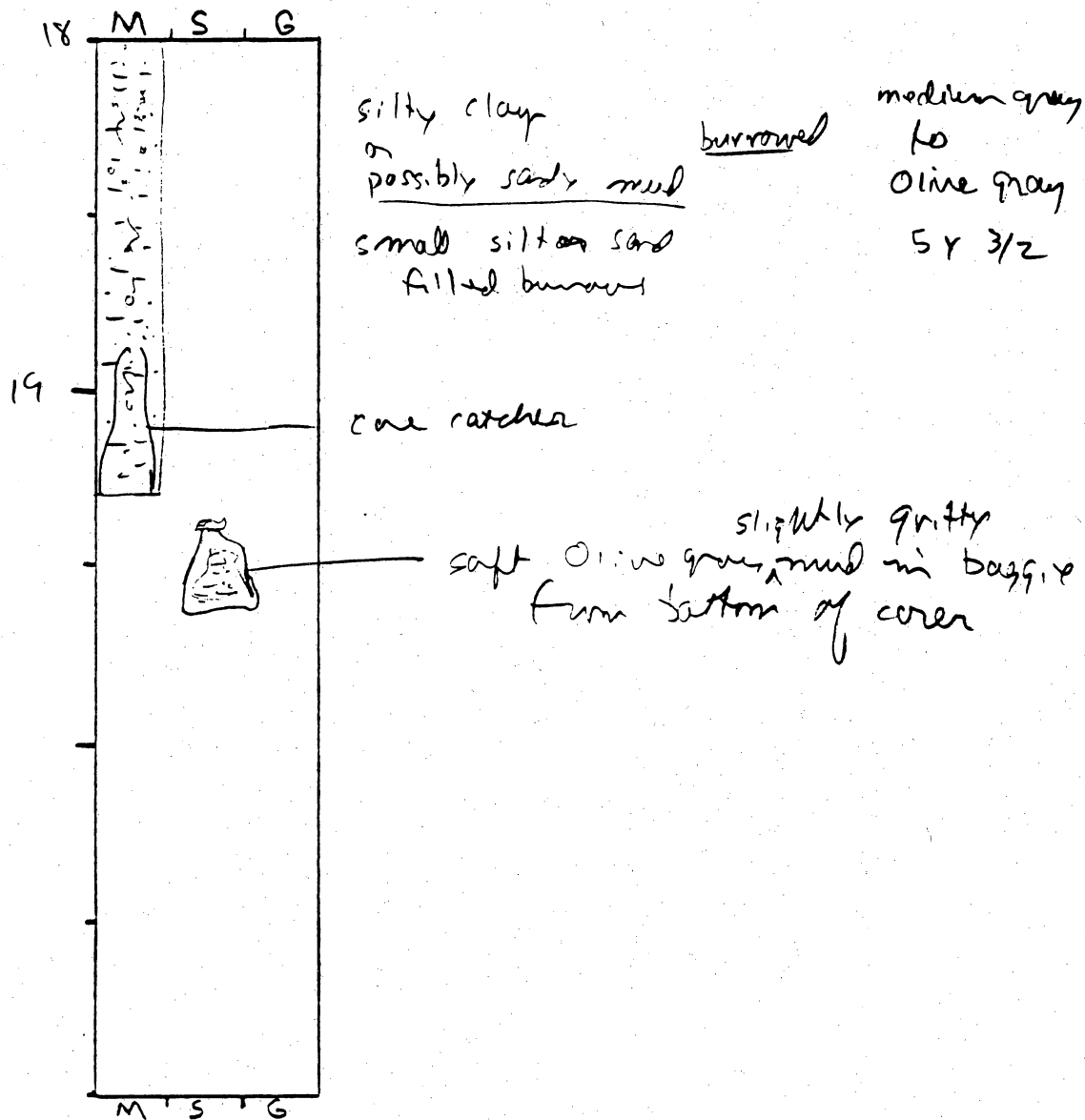


CORE LOG

CORE # SBX13(G) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



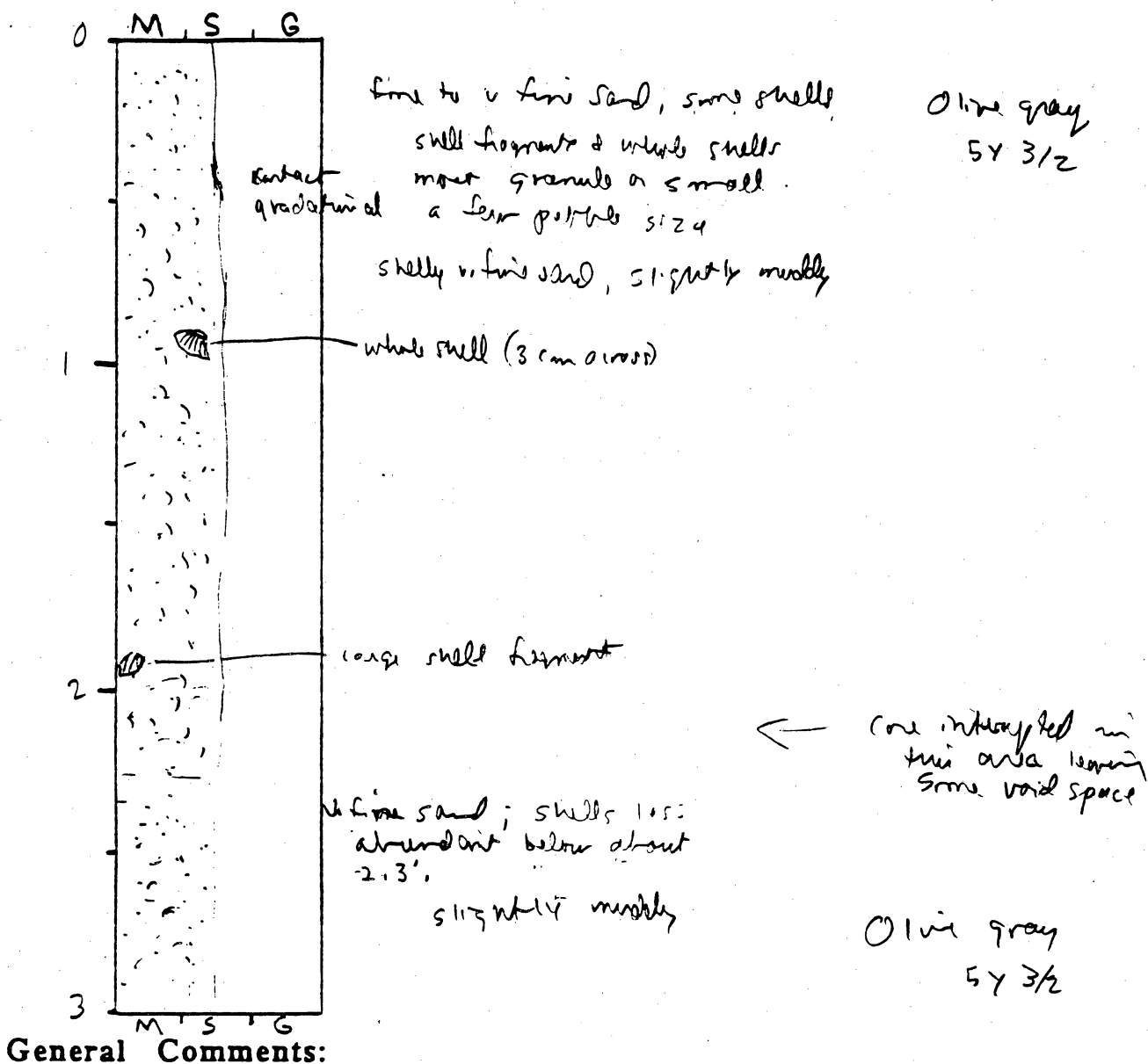
General Comments:

CORE LOG

CORE # SBV-14(A) TYPE Vibrocore LOCATION Sabine Bank
 LATITUDE 29° 29.283 LONGITUDE 93° 38.052 SURFACE ELEVATION -32'
 DEPTH PENETRATED ? LENGTH RECOVERED 19' 9 1/4" % COMPACTION 5

OBTAINED BY Gibson - R/V Ki+ Jones DATE 11-13-94
 DESCRIBED BY U. White DATE 2-7-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

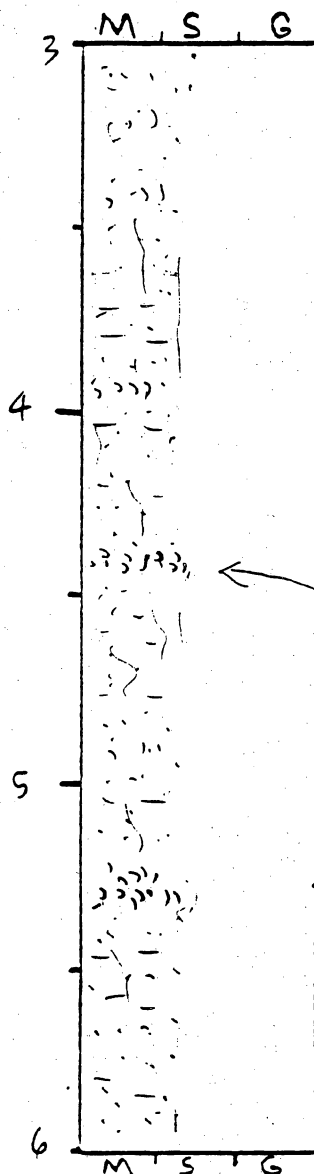


CORE LOG

CORE # SBV-14(B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



sand slightly muddy
 shells ~ 5%
 frags & whole
 local concentrations

Olive Gray

burrowed

becomes slightly
 more muddy
 below 3.6'

possibly
 muddy sand

← granule size shell concentration
 muddy shell & sandy

← shell packet - muddy
 shelly sand

muddy sand
 & few shells

Olive Gray

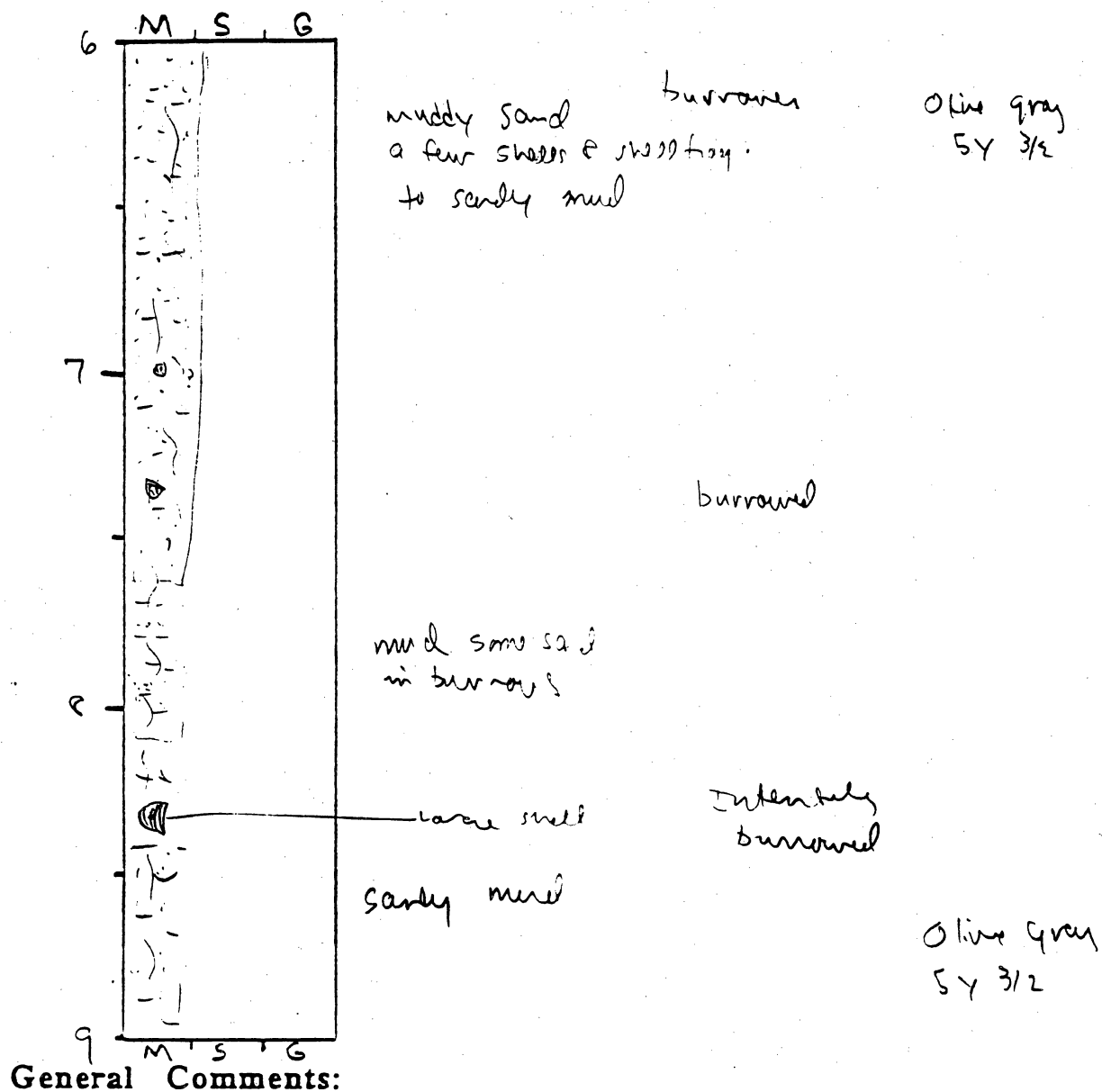
General Comments:

CORE LOG

CORE # SBV-14(C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

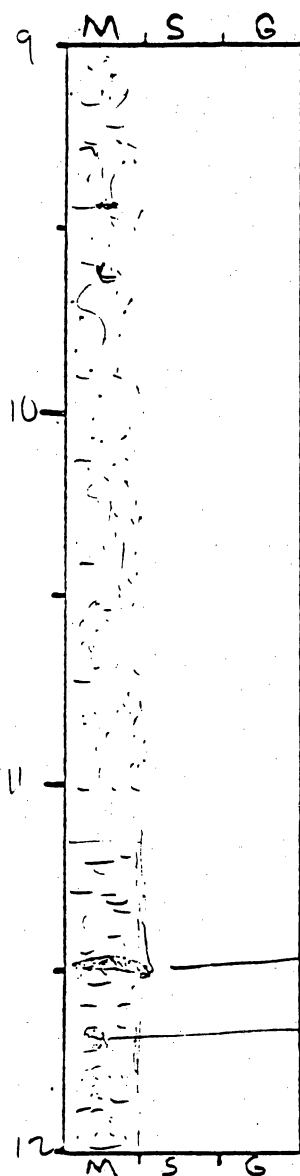


CORE LOG

CORE # SBV-14(D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



sandy mud Intensely
 a few shells Burrowed
 (very scattered < 1%)

Olive grey
 (5 Y 3/2)

(slightly more
 sand from 10-11.2')
 sandy mud

discrete sand &
 mud areas

sandy mud
 sandy unit not well defined
 sand filled burrows

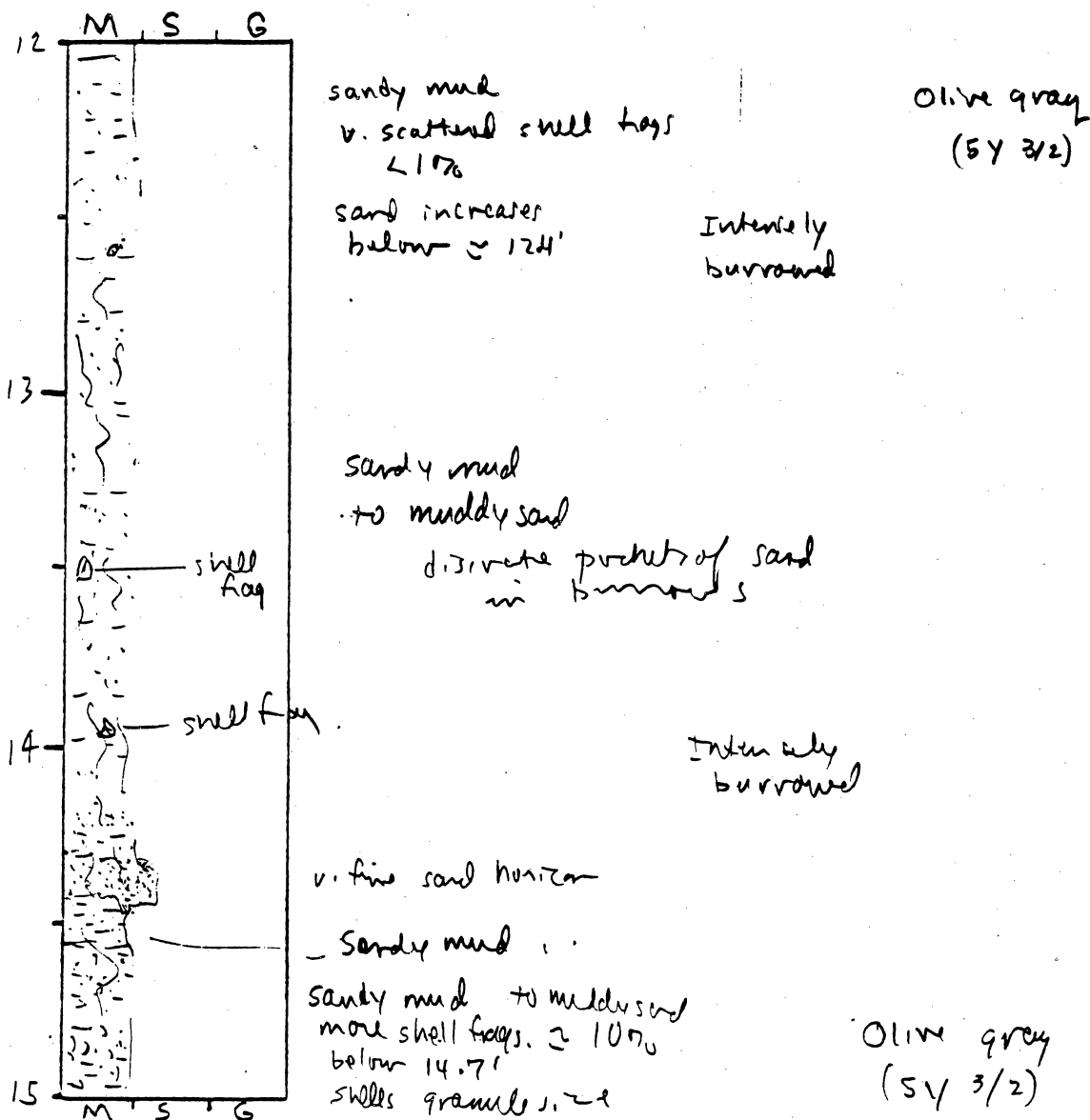
Olive grey
 (5 Y 3/2)

General Comments:

CORE LOG

CORE # SBV-14(E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



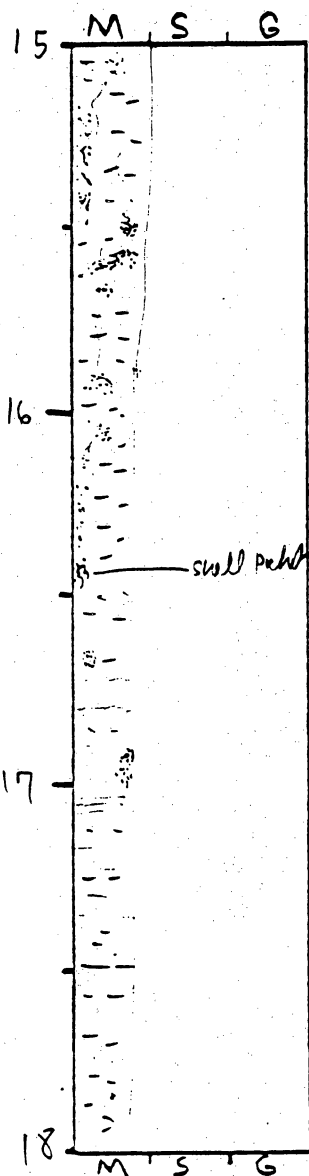
General Comments:

CORE LOG

CORE # SBV-14F TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



sandy mud (sand filled)
burrows

olive gray (5Y 3/2)
to medium gray

discrete sand filled burrows
a few v. coarse shell frags
in sandy areas

occasional burrows

clay

few burrows

medium gray

thin silty horizontal laminae
in clay

no burrows

clay

some organic
specks

medium gray

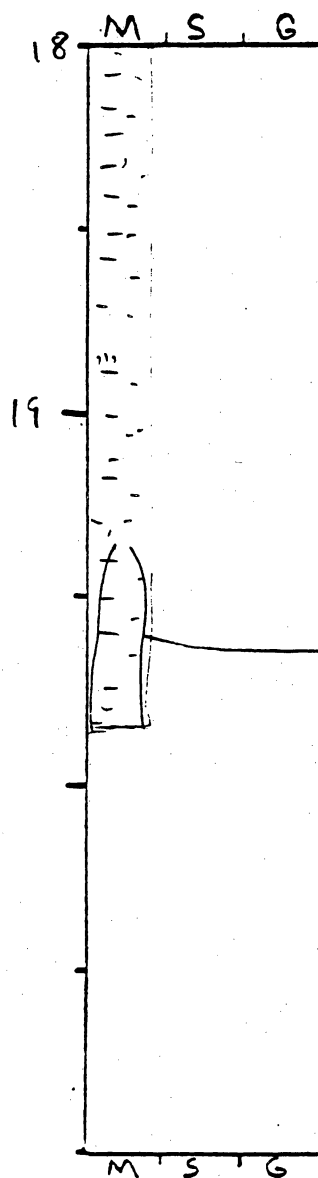
General Comments:

CORE LOG

CORE # SBV-14 (G) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



Clay some organic specks
 very scattered shell frags
 v coarse sand size

medium
 gray
 to olive gray

General Comments:

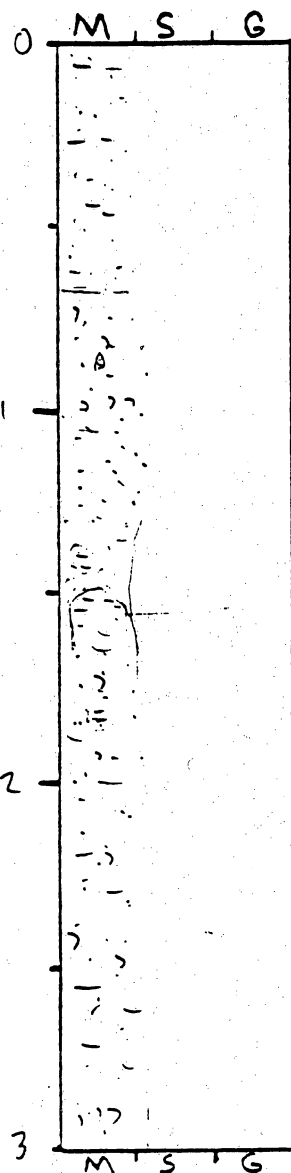
CORE LOG

CORE # SBV-15(A) TYPE Vibrocure LOCATION Sabine Bank
 LATITUDE 29° 25.34' LONGITUDE 93° 44.38' SURFACE ELEVATION -42'
 DEPTH PENETRATED ? LENGTH RECOVERED 5' 10 1/4" COMPACTION ?

OBTAINED BY Gibeaut - R/V Kit Jones
 DESCRIBED BY White

DATE 10-15-94
 DATE 2-8-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



muddy sand
 scattered shells < 50%

medium dk gray
 to olive gray
 (5Y 3/2)

sand, scattered shells ≈ 50%
 up to granule size
 slightly muddy

clayey sand
 v. scattered shell frags

mottled
 Lt olive gray & Lt olive brn
 in medium gray sand

mottled
 Greenish gray (SGY 6)
 to
 medium gray

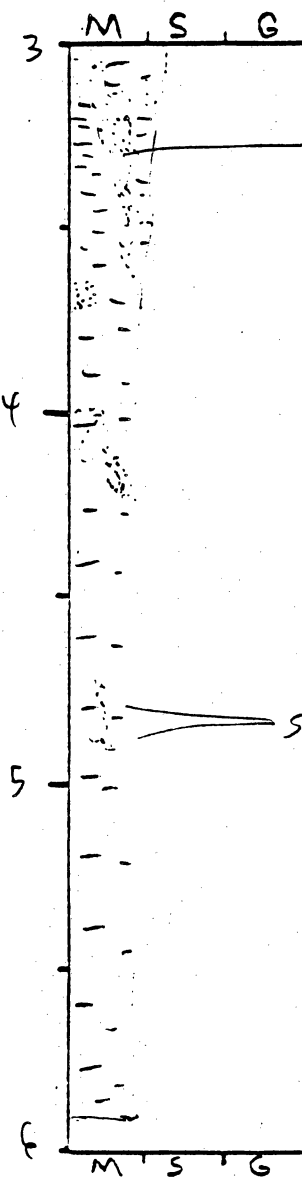
General Comments:

CORE LOG

CORE # SBV-15(B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



clayey sand
 sand filled burrows
 down into Beaumont clay

mottled
 greenish gray
 with some yellowish
 gray sand med gran.
 Beaumont clay
 Lt Olive brown to
 Dark yellowish gray

Beaumont clay
 occasional sand pocket mostly
 yellowish orange sand but
 some Lt gray sand in pockets
 No shells

mottled
 greenish gray,
 with oxidized
 sand pocket
 Lt brown to
 Dark yellow
 orange

sand pocket

Lt Olive gray
 with local
 Lt brown to
 Dark yellowish
 orange spots

General Comments:

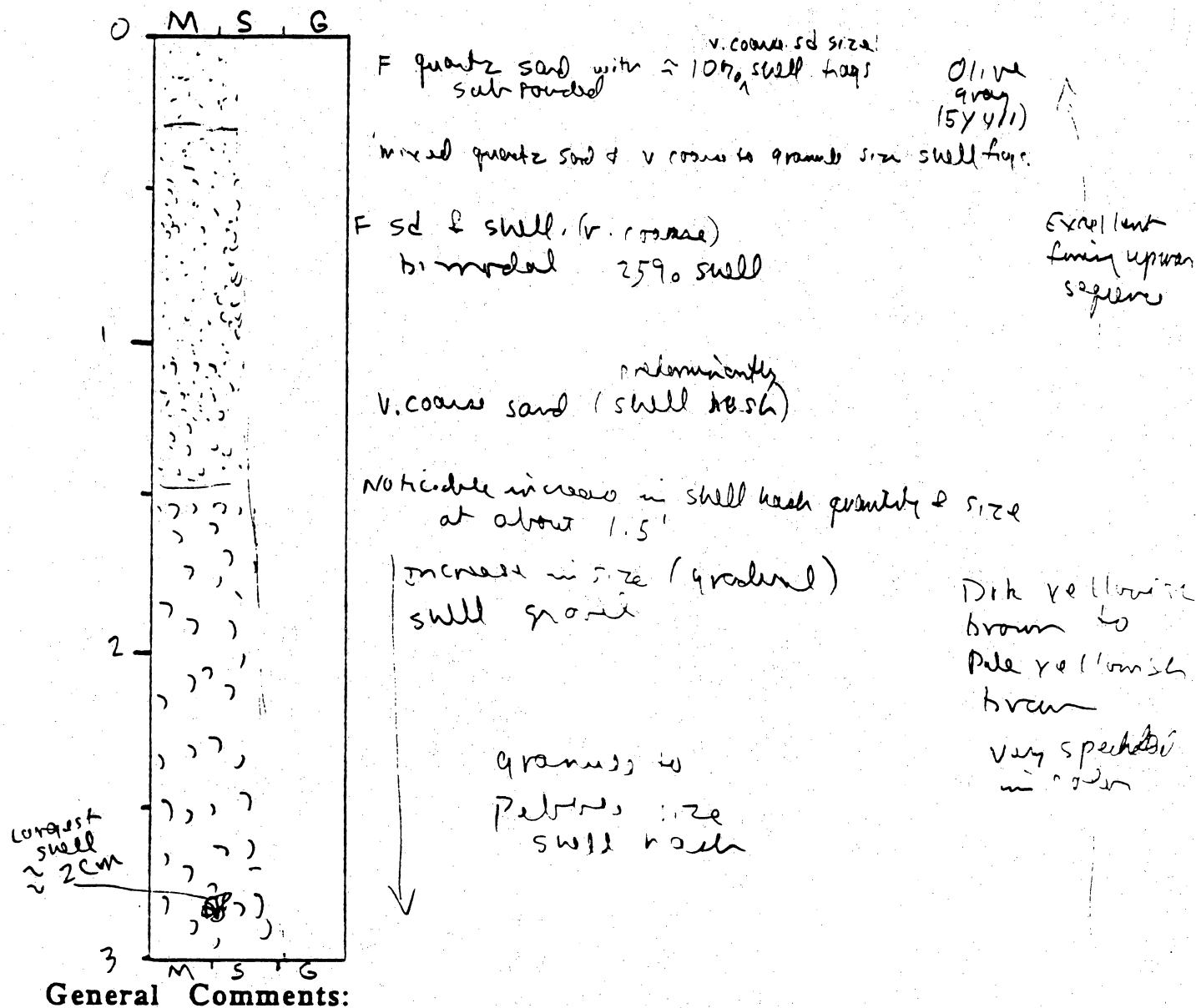
CORE LOG

CORE # SBV-16(A) TYPE Vibrocore LOCATION Sabine Bank
 LATITUDE 29° 26.13' LONGITUDE 93° 44.89' SURFACE ELEVATION -33'
 DEPTH PENETRATED ? LENGTH RECOVERED 15' 3 3/4" COMPACTION ?

OBTAINED BY Gibeaut - R/V Kit Jones
 DESCRIBED BY White

DATE 10-13-74
 DATE 2-2-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

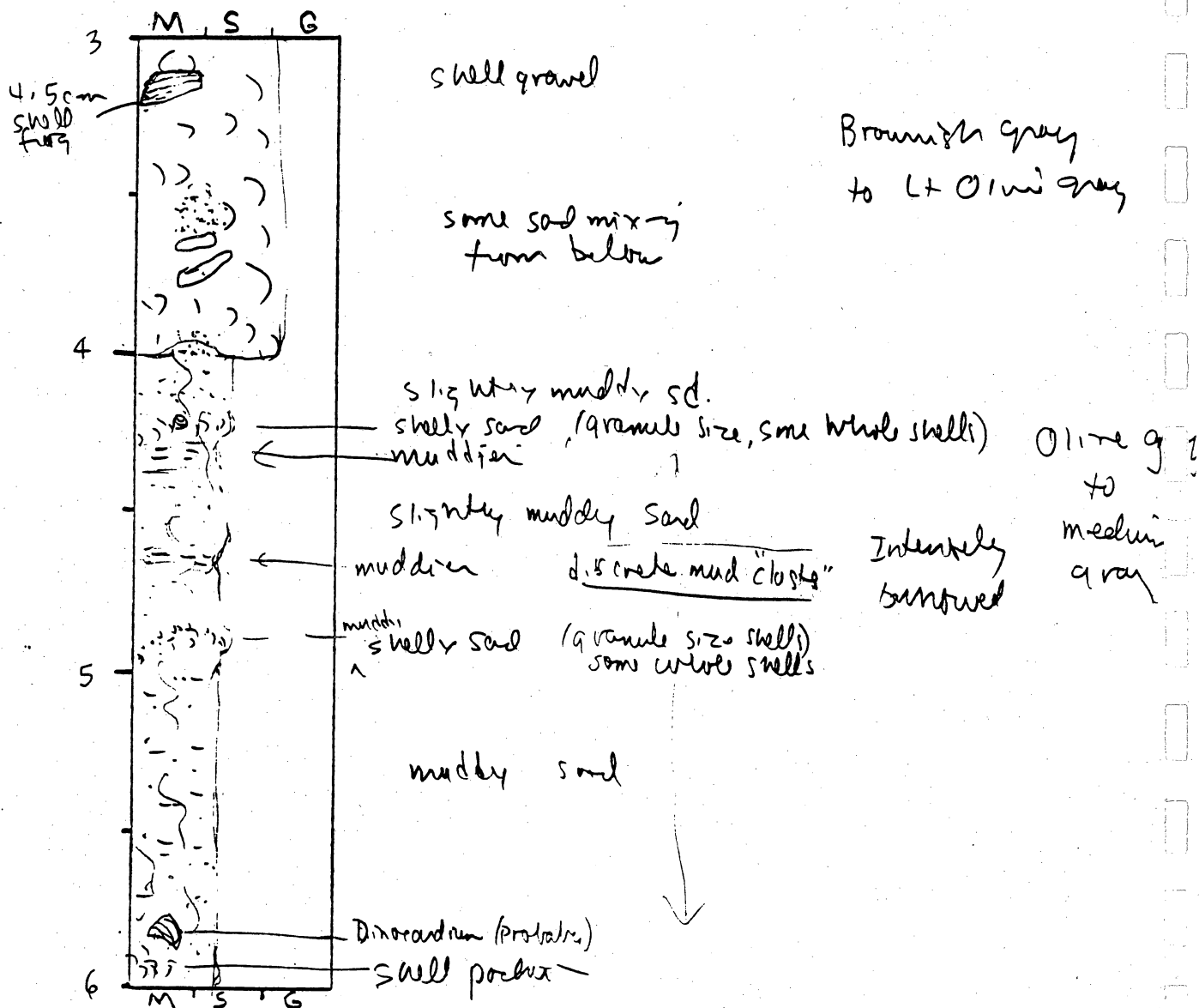


CORE LOG

CORE # SBV-16 (B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

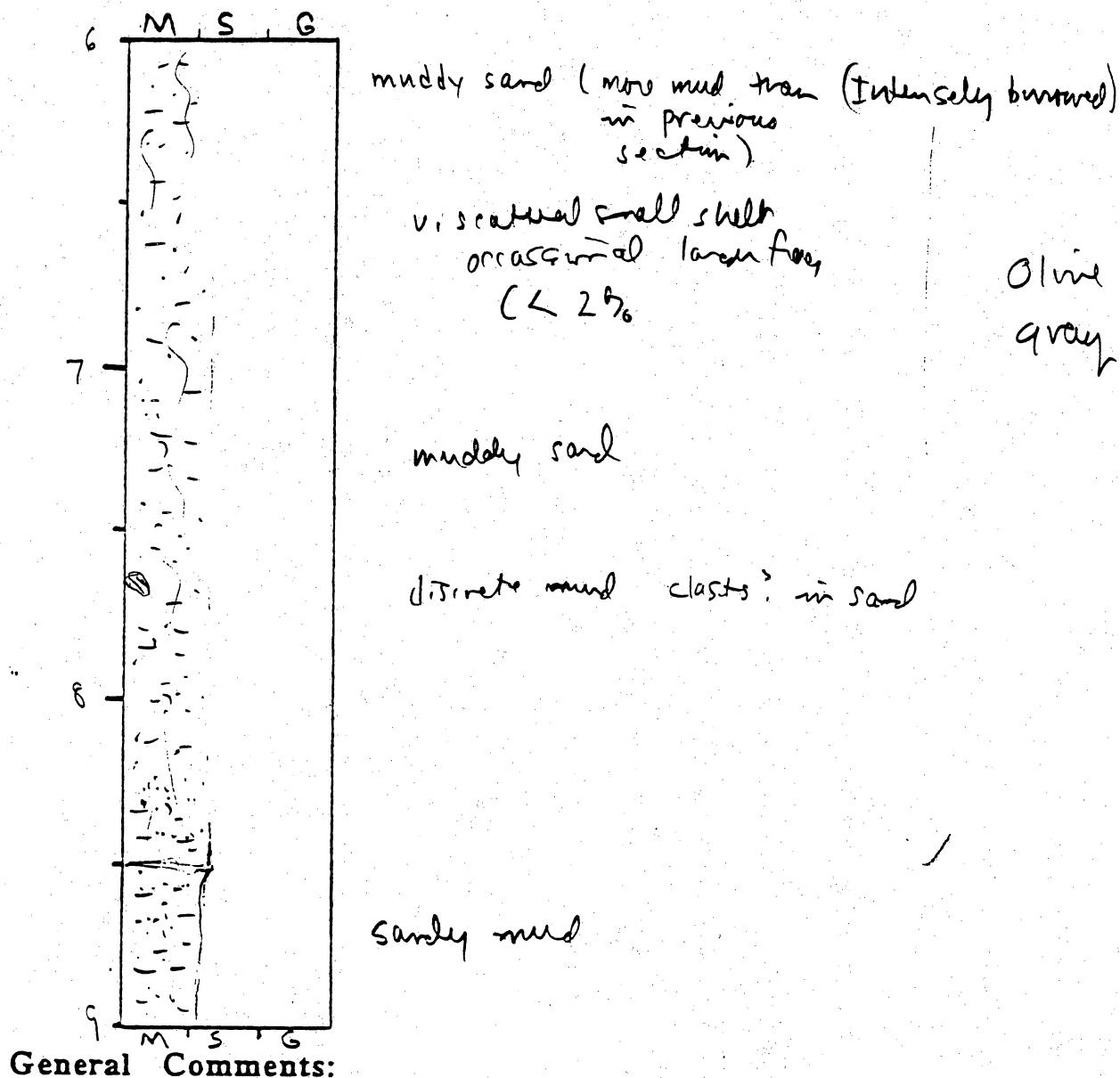


General Comments:

CORE LOG

CORE # SBV-16(C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

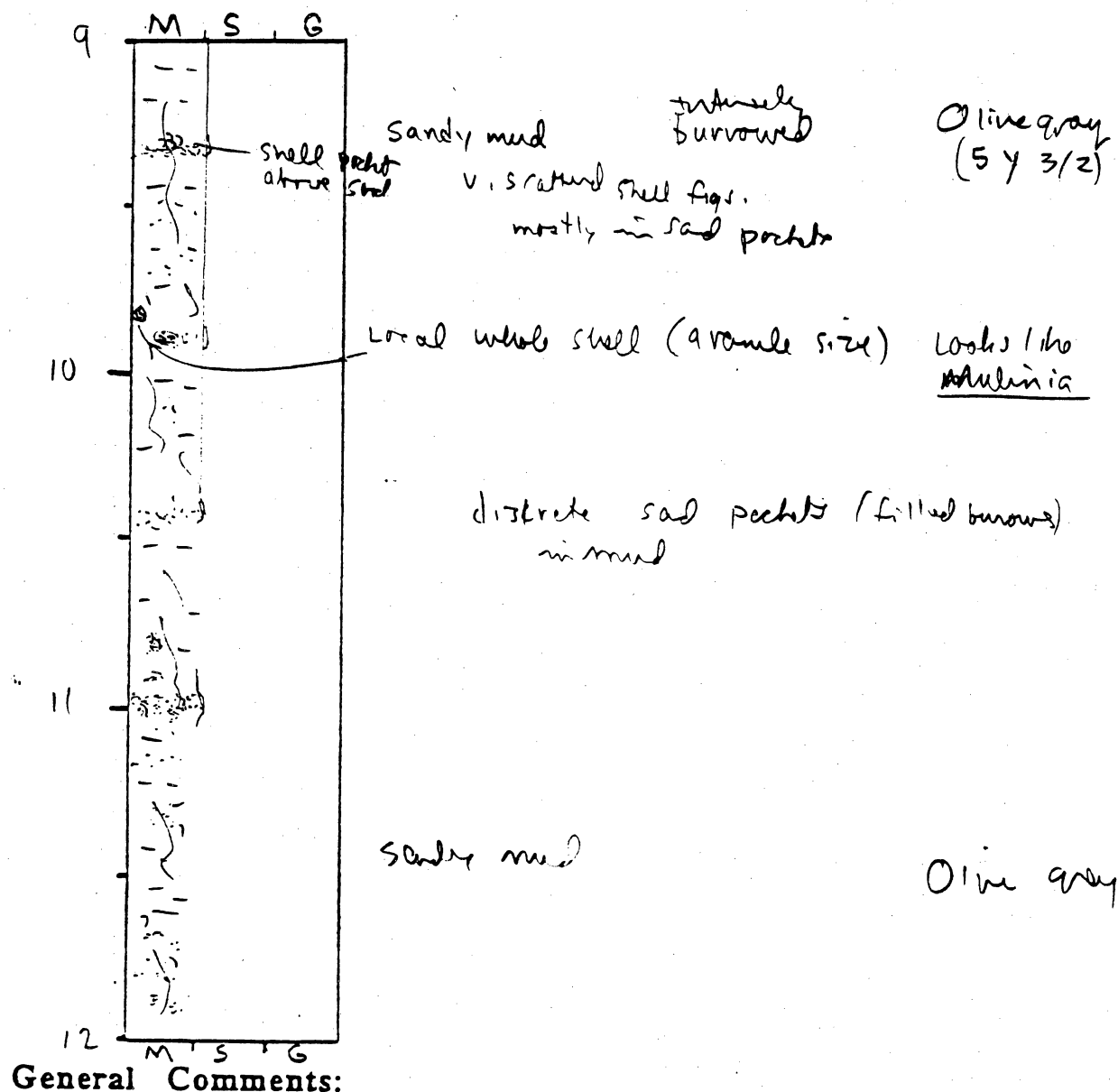


CORE LOG

CORE # SBV-16(D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

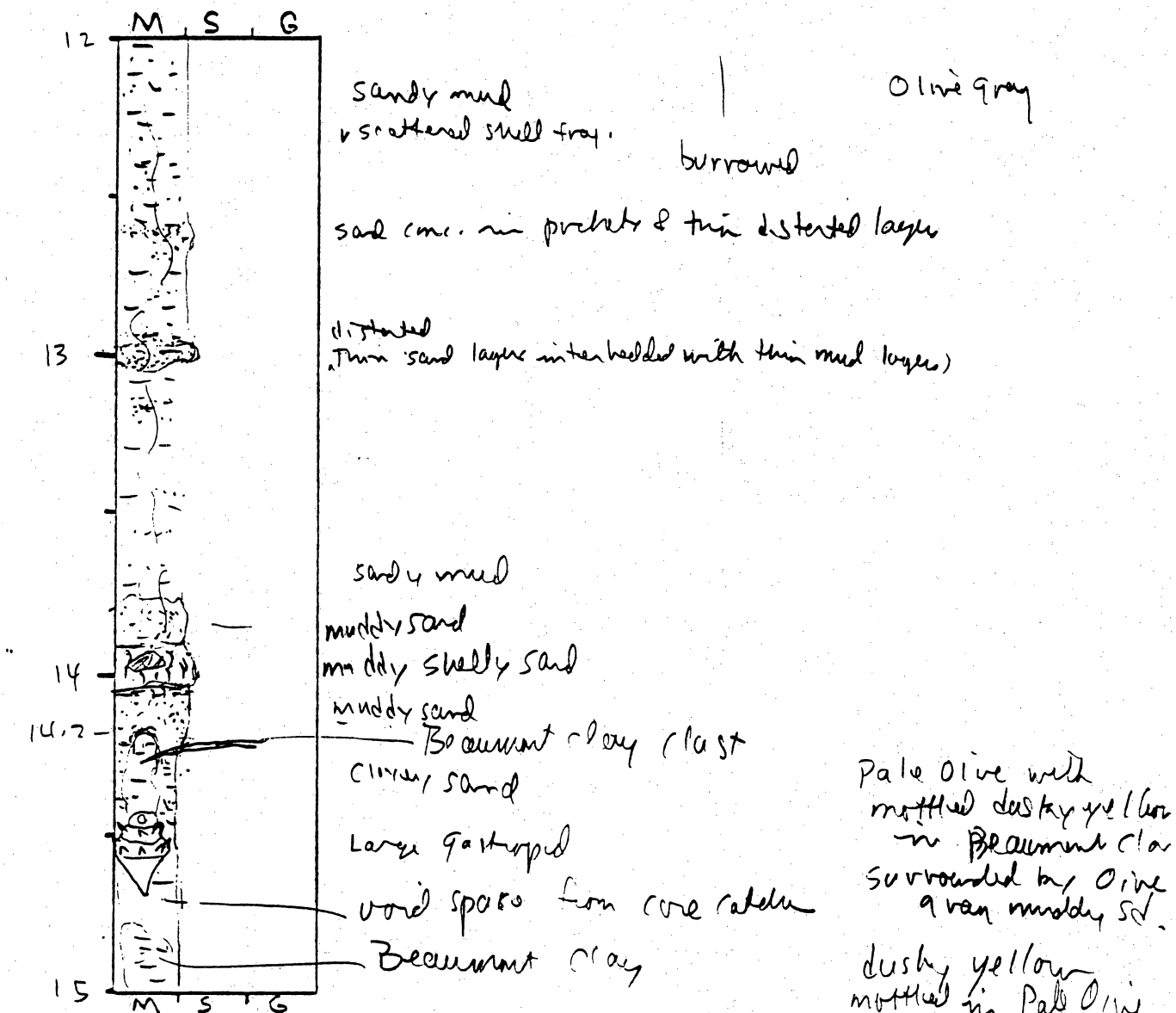


CORE LOG

CORE # SBV-16(E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



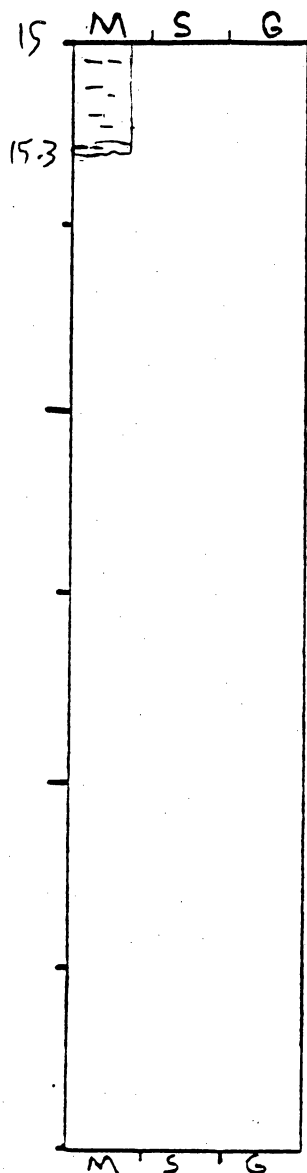
General Comments:

CORE LOG

CORE # SBV-16 (F) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



Beaumont clay

*Pale Olive
mottled with
dusky yellow to
lt Olive brown.*

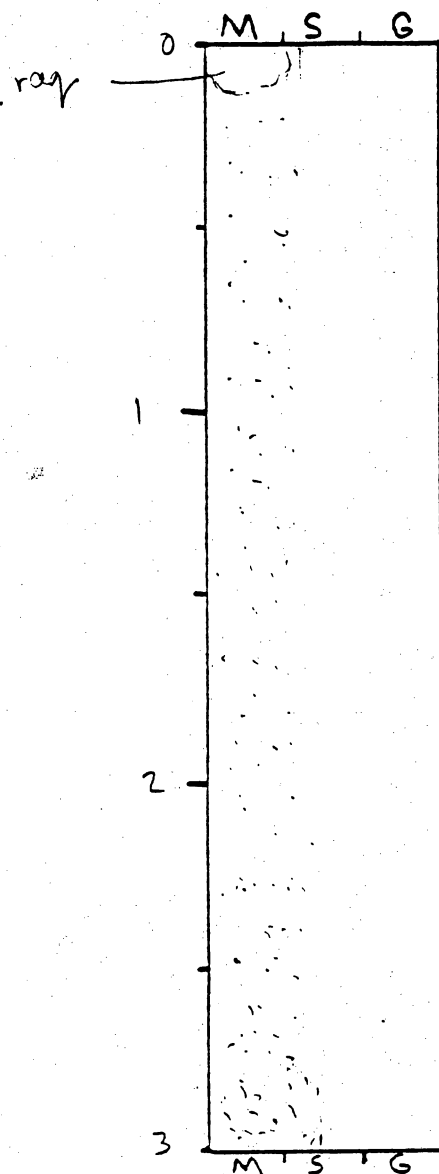
General Comments:

CORE LOG

CORE # SBV-17(A) TYPE Vibrocore LOCATION Sabine Bank
 LATITUDE 29° 28.318 LONGITUDE 43° 45.257 SURFACE ELEVATION -23.5'
 DEPTH PENETRATED ? LENGTH RECOVERED 14' 7 1/4" COMPACTION ?

OBTAINED BY Gibeault - R/V Kit JonesDATE -DESCRIBED BY WhiteDATE 2-8-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



Fine quartz sand with
 v. coarse sand size
 shell frags. \approx 10-20%
 quartz sub-rounded, well sorted

Light olive gray
 SY 5/2

part of fining upward sequence

lt olive gray
 SY 5/2

increase in
 shell frags near base to \approx 20%-25%
 v. coarse sand size
 bimodal with fine qtz sand

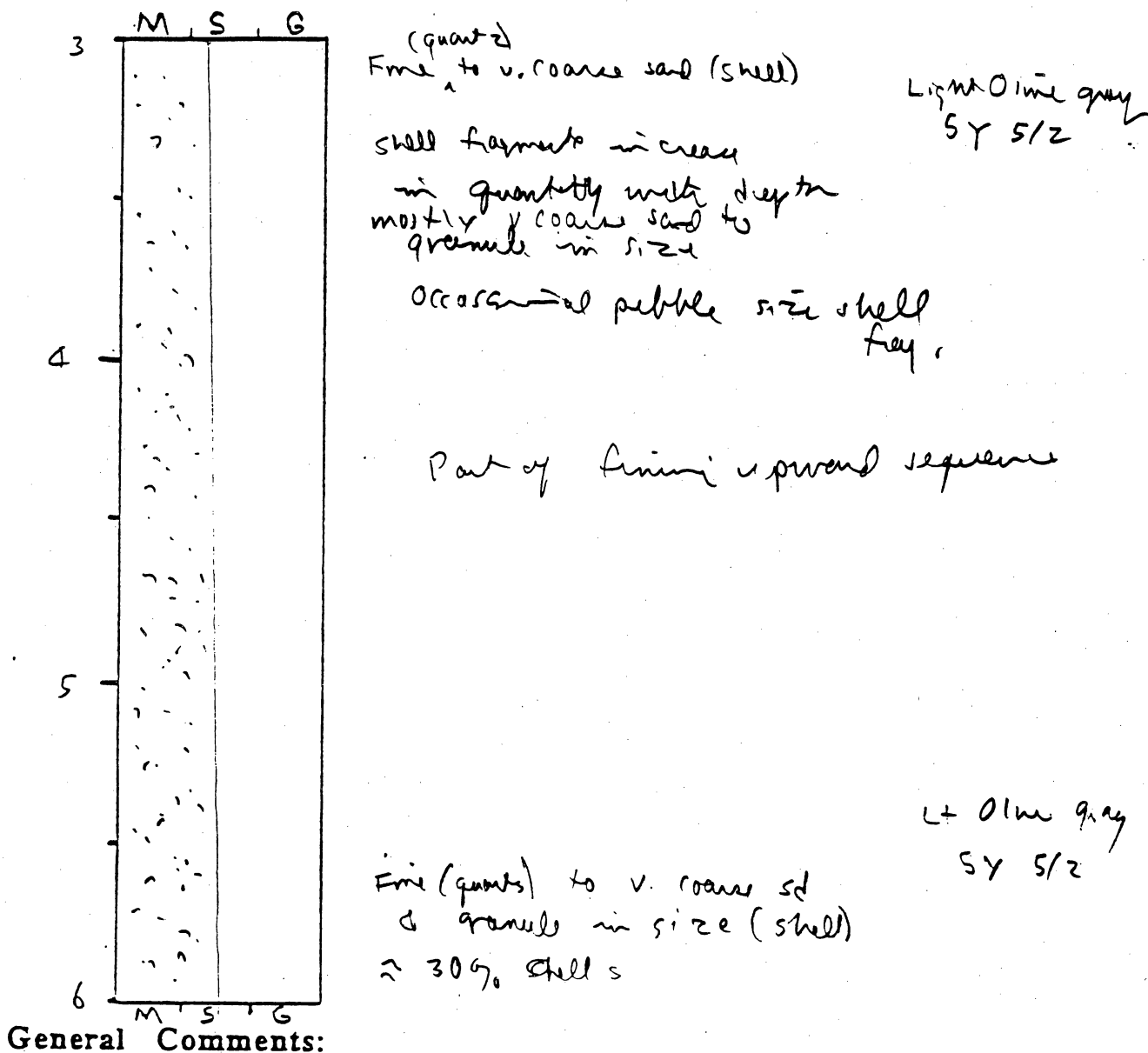
General Comments:

CORE LOG

CORE # SBV-17(B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS

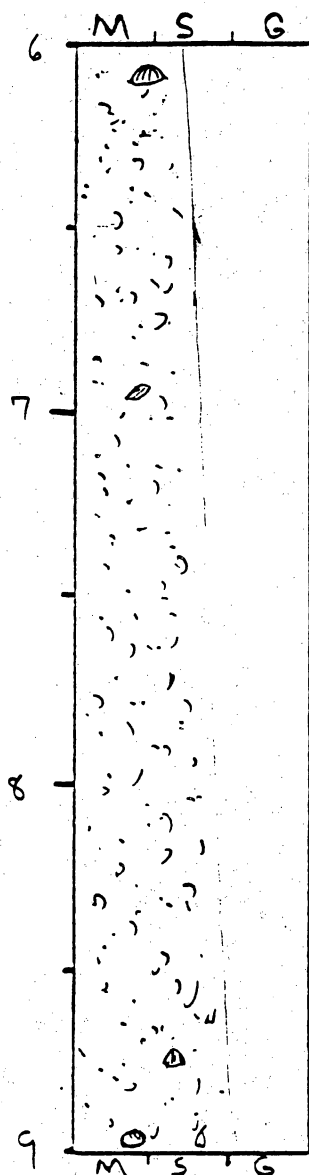


CORE LOG

CORE # SBV-17(c) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



Fine quartz sand & shell frags
 V coarse to granule in size
 local pebble size shell
 Bimodal grain size

lt Olive gray

part of
 Fining upward
 sequence

shell fragments become more abundant
 & slight layers with depth

shelly sand

~ 40% shell fragments

lt Olive gray

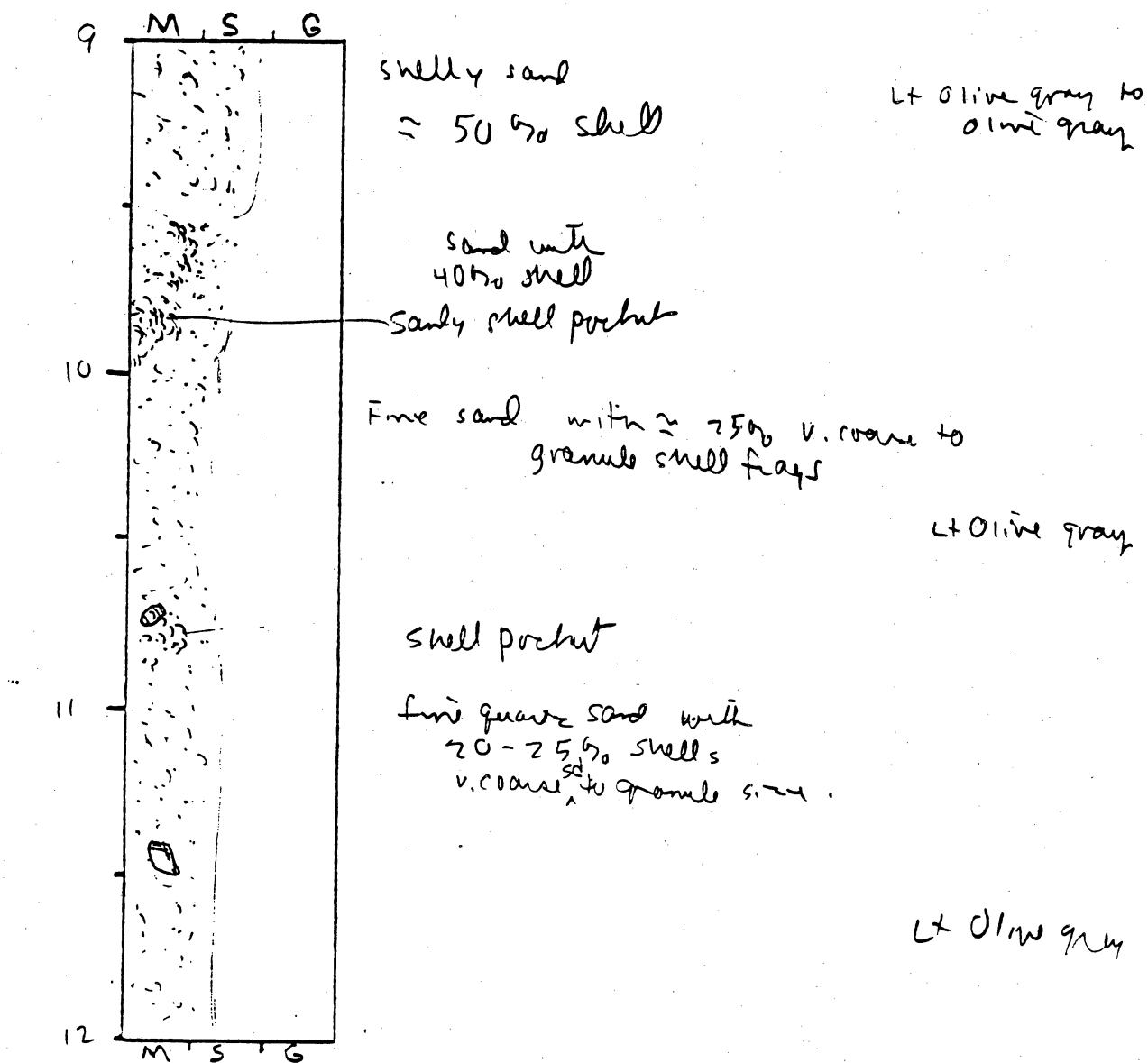
General Comments:

CORE LOG

CORE # SBV-17 (D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



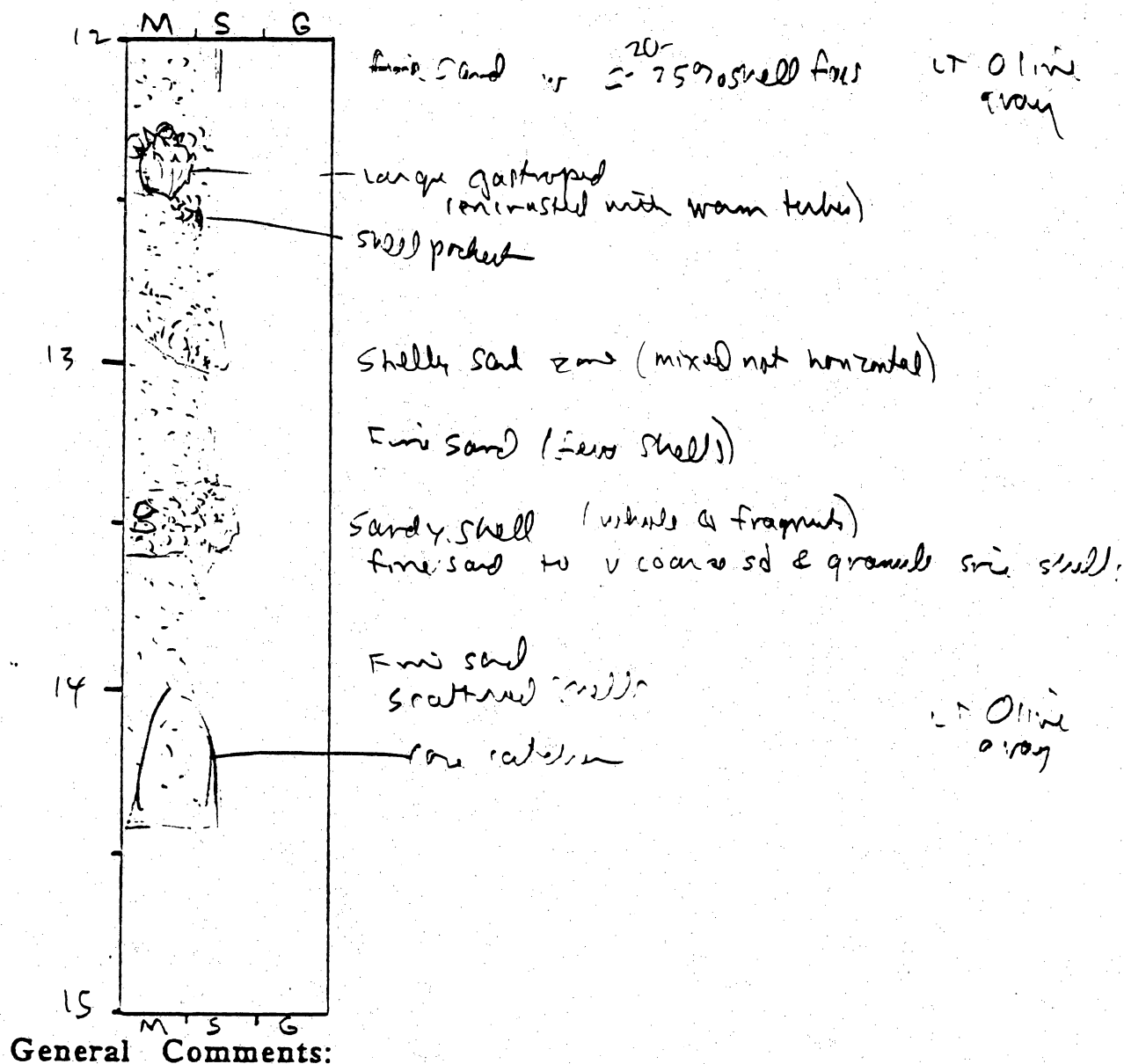
General Comments:

CORE LOG

CORE # SBV-17(E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

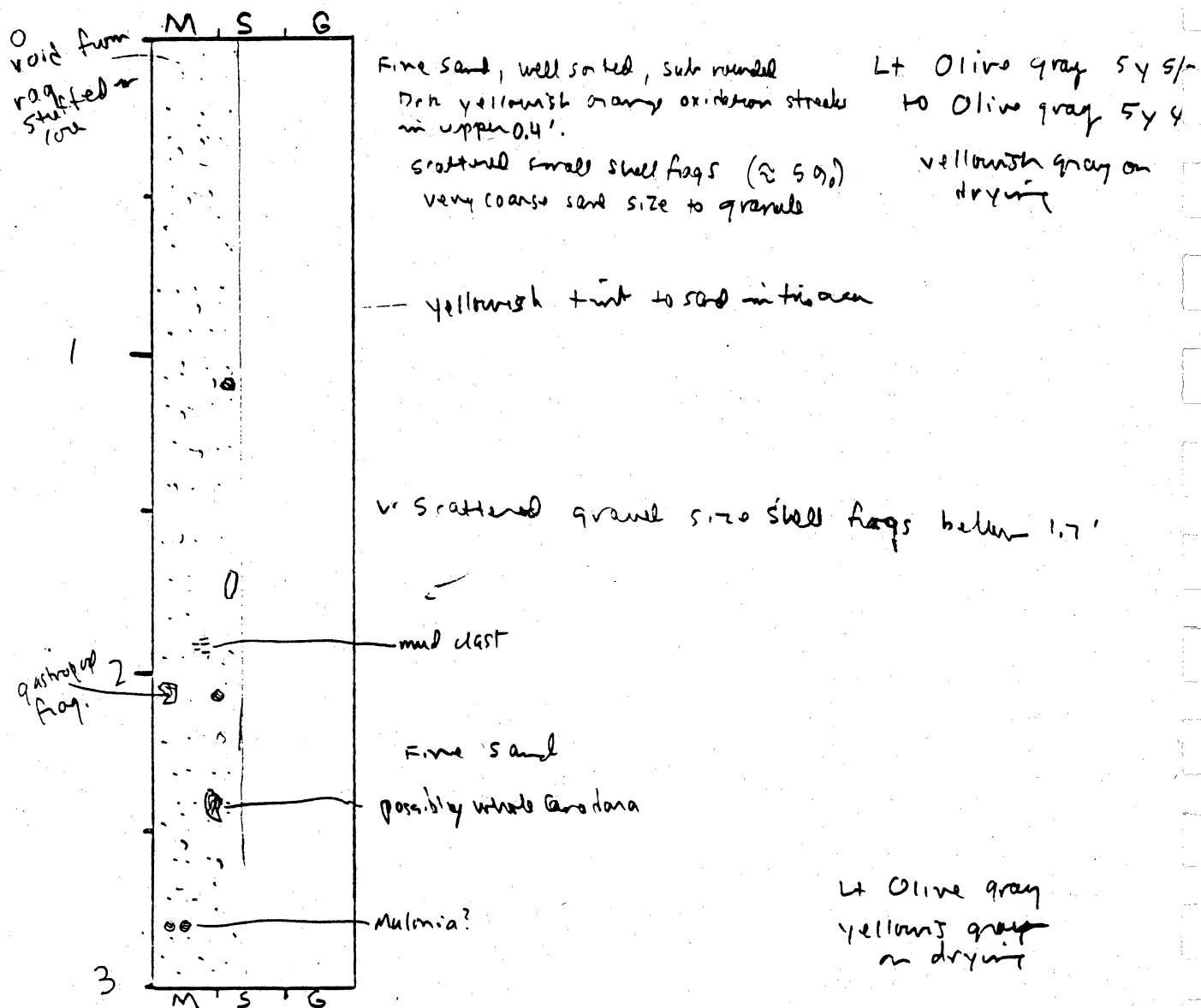


CORE LOG

CORE # SBV-18 (A) TYPE Vibrocore LOCATION Salina Bank
 LATITUDE 29° 27.692' LONGITUDE 92° 48.413' SURFACE ELEVATION -30.5'
 DEPTH PENETRATED 2' LENGTH RECOVERED 19.4' COMPACTION 2'

OBTAINED BY Gibson - R/V K. Jones DATE 10-14-94
 DESCRIBED BY Viv, Jr DATE 2-9-95

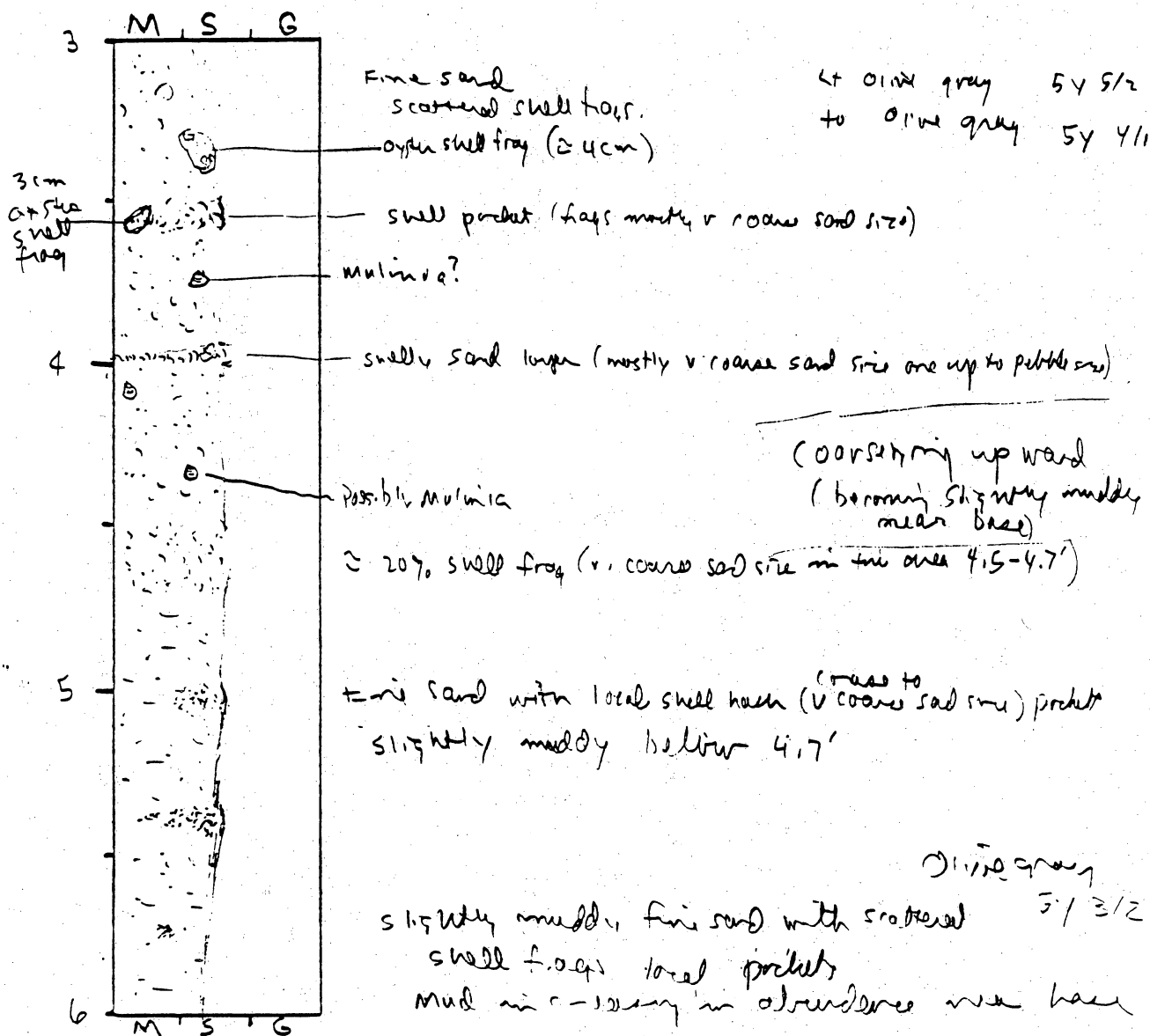
| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



CORE LOG

CORE # SBV-R (B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



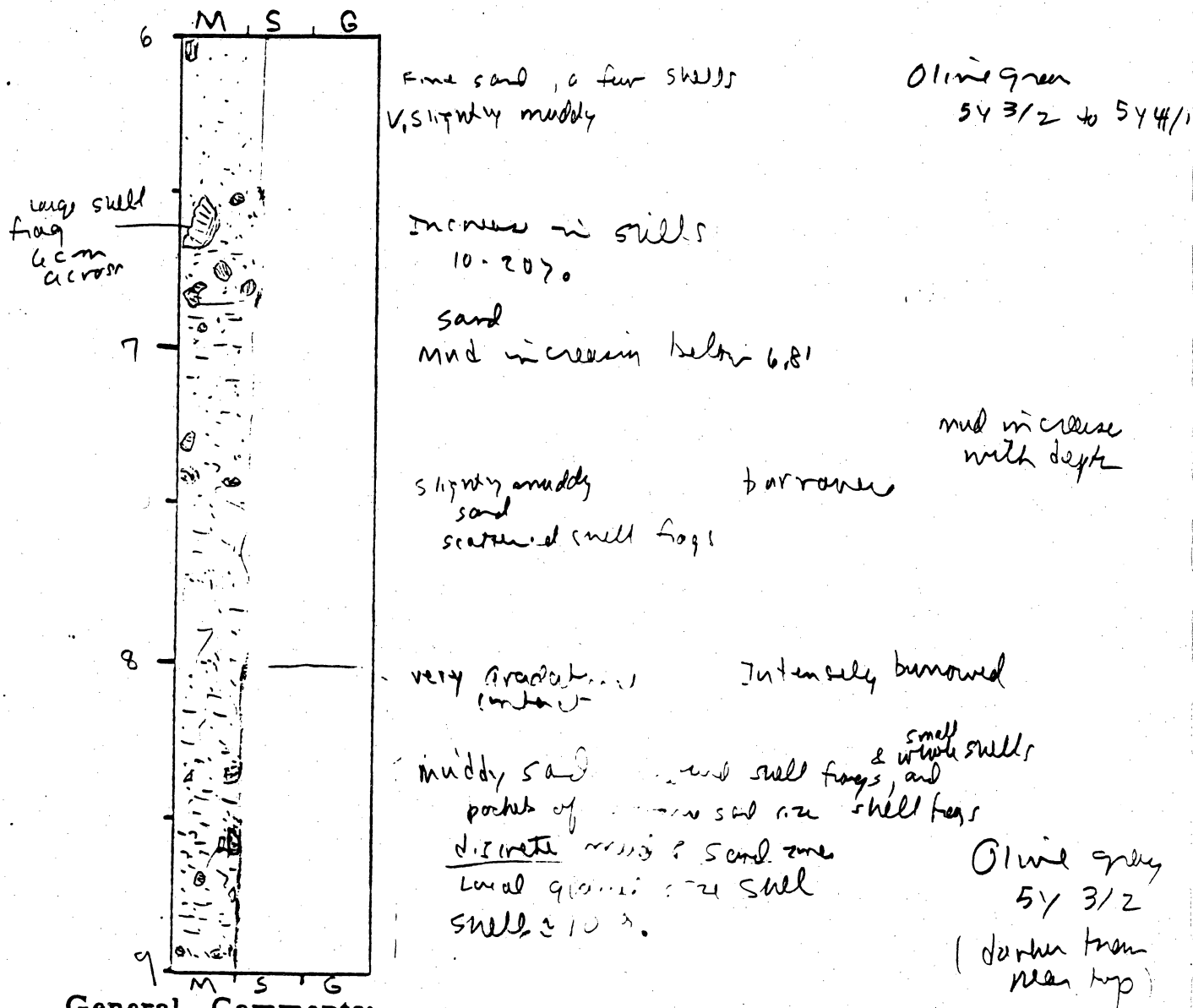
General Comments:

CORE LOG

CORE # SBV-8(C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS

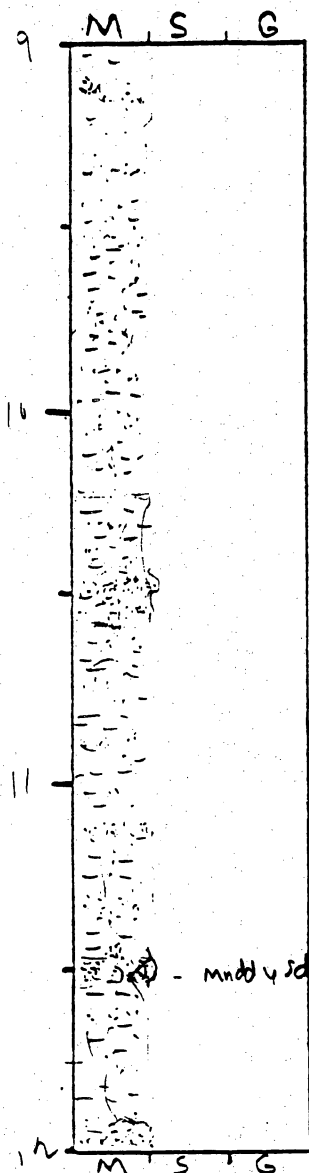


CORE LOG

CORE # SBV-18(1) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



muddy sand
 sand in pockets and
 irregular layers include
 coarse sand size
 shell hash locally
 Intensely
 burrowed
 Distinct mud & sand zone

(5y 3/2)
 Olive gray to
 dark gray

sandy mud
 muddy sand

Mud increases
 with depth

Color change
 in this
 core to
 darker gray

Overall mud
 appears to become
 more abundant than
 sand below
 10.2'

sandy mud to
 muddy sand
 scattered small shell fragments associated
 with sand pockets
 Intensely
 Burrowed

Dark gray to
 olive gray 5y 3/4

muddy sand to sandy mud

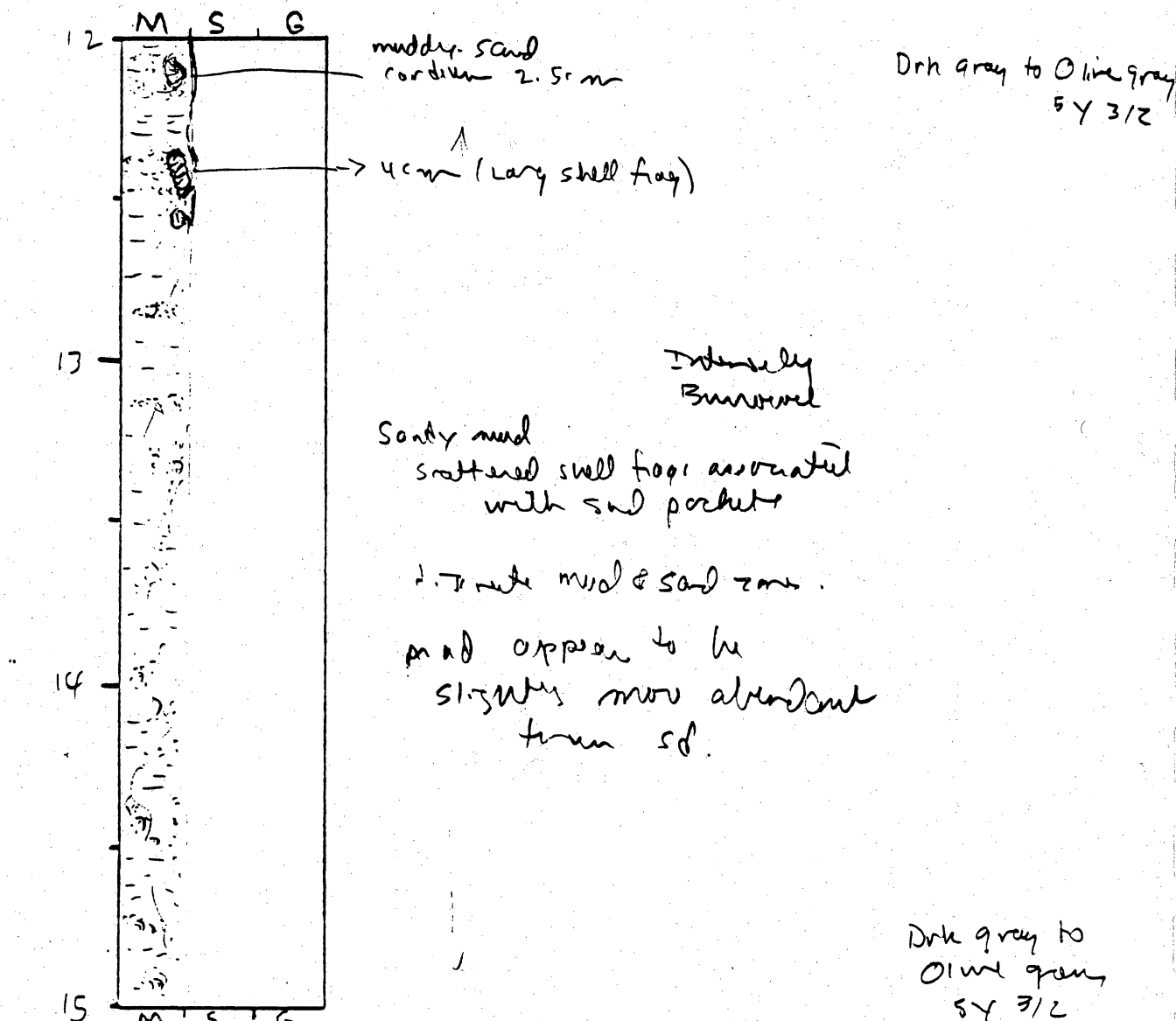
General Comments:

CORE LOG

CORE # SBV-18 (E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



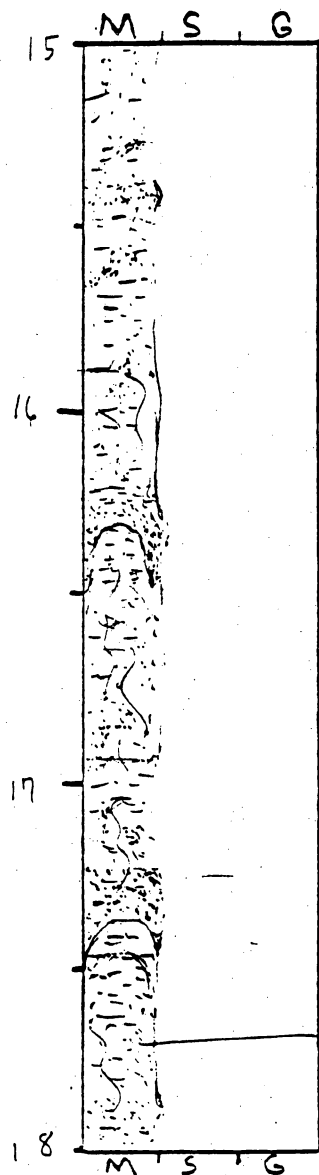
General Comments:

CORE LOG

CORE # SBV-18 F TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft. m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



sandy mud

Dark gray to
 Olive gray
 SY 3/2

muddy sd discrete sand & mud zone
 scattered shell frags
 associated with
 sand pockets

sandy mud

muddy sand

disturbed sand (disturbed by coring)
 larger

muddy sand
 to sandy mud

Intensely
 Burrowed

sandy mud to distinct sand zone
 sand to
 muddy sand (disturbed by coring)

Sandy mud
 (urea)
 fine sand mud to muddy sand zone

muddy sand

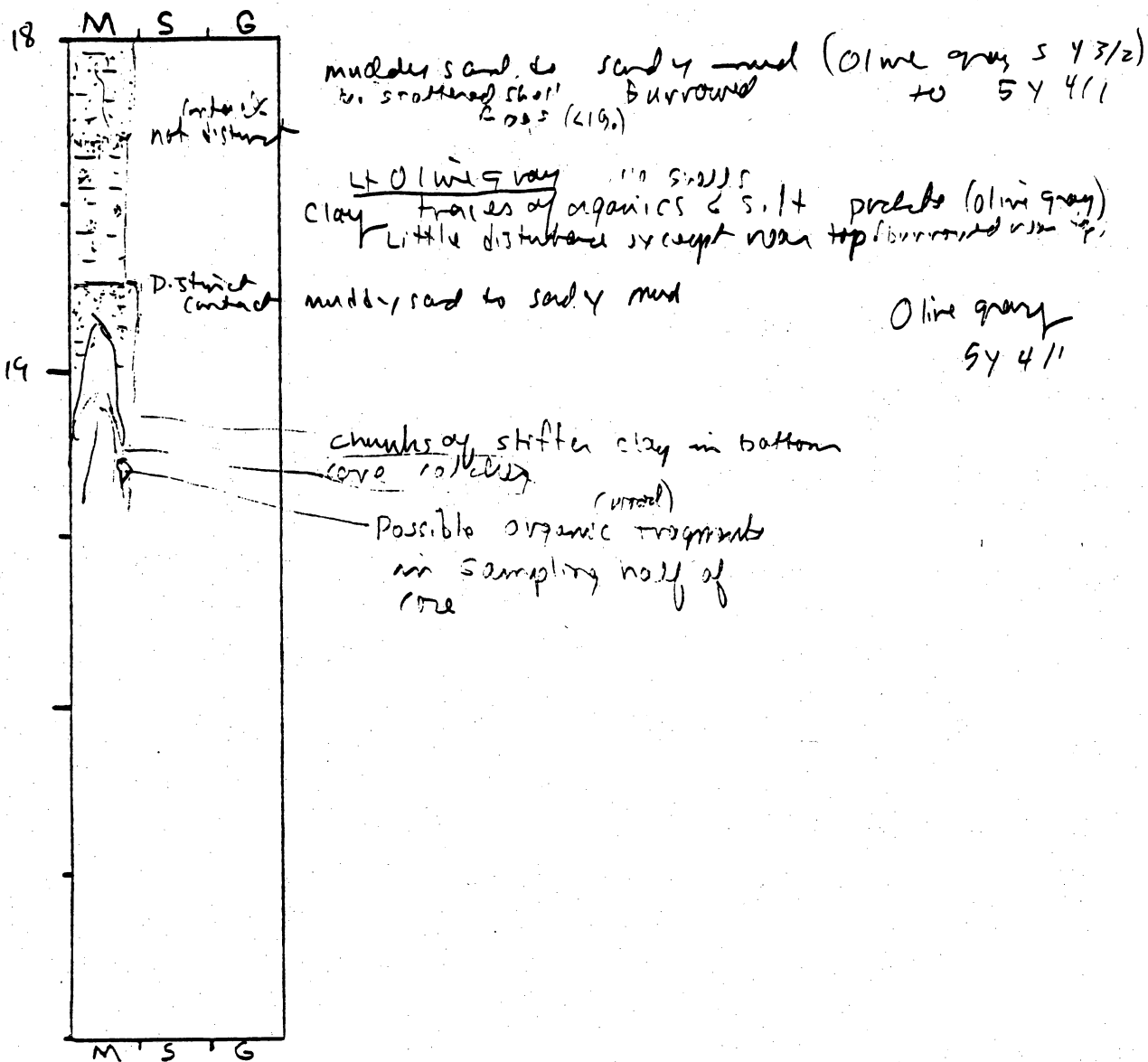
Olive gray
 SY 3/2

General Comments:

CORE LOG

CORE # SBV-18(G) TYPE Vibrocure LOCATION Sabine Bank
 LATITUDE 29° 27.647 LONGITUDE 92° 48.413 SURFACE ELEVATION -39.5'
 DEPTH PENETRATED ? LENGTH RECOVERED 19' 4 1/2" % COMPACTION ?
 OBTAINED BY Gibbaut - R/V Kit Jones DATE 10-14-94
 DESCRIBED BY White DATE

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



General Comments:

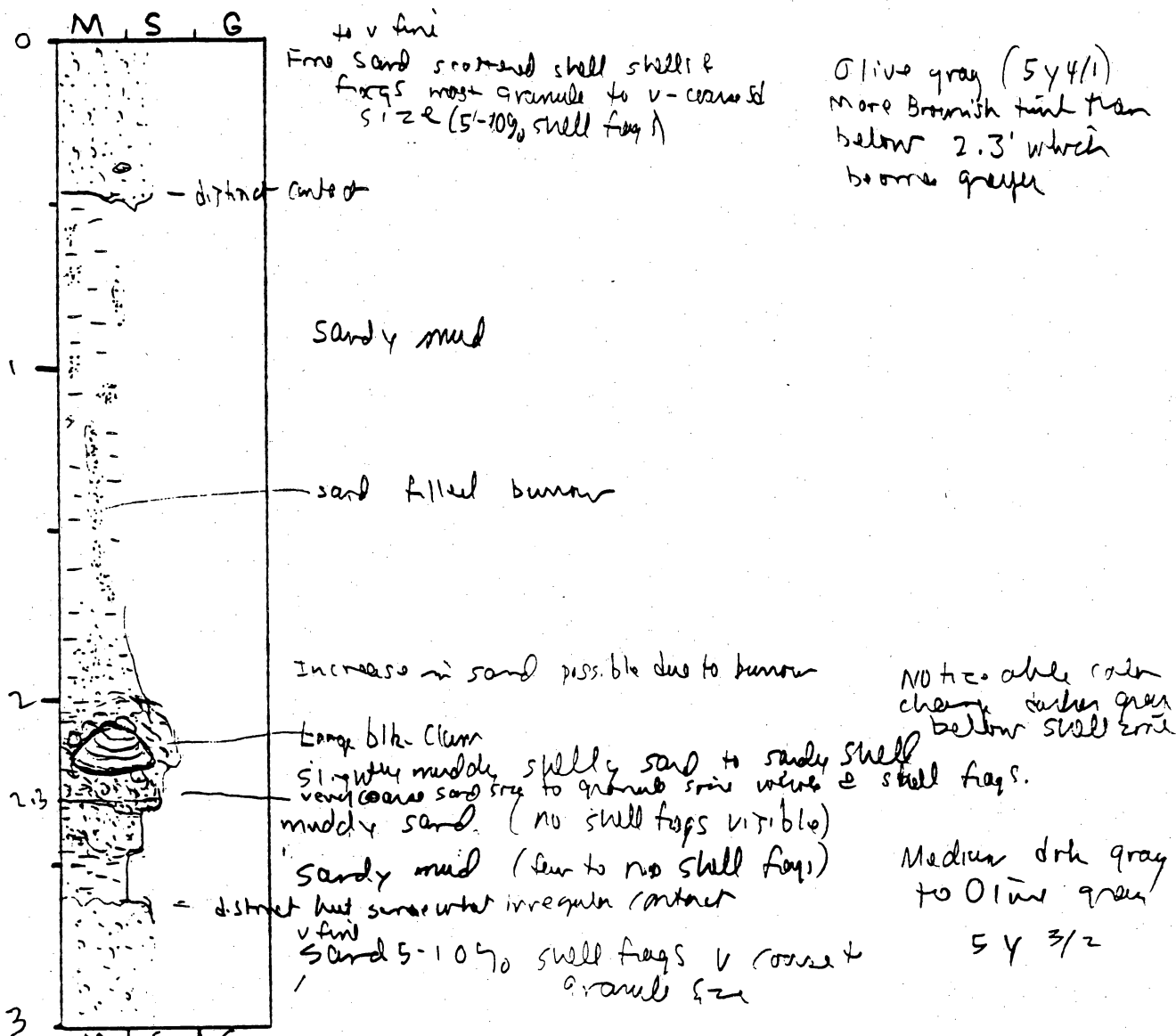
CORE LOG

CORE # SBV-19(A) TYPE Vibrocore LOCATION Sabine Bank
 LATITUDE 29° 26.41' LONGITUDE 93° 47.78' SURFACE ELEVATION -31.5'
 DEPTH PENETRATED ? LENGTH RECOVERED 19' 4 1/2" % COMPACTION ?

OBTAINED BY Gibson - R/V Kit Jones
 DESCRIBED BY White

DATE 10-14-94
 DATE 2-9-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



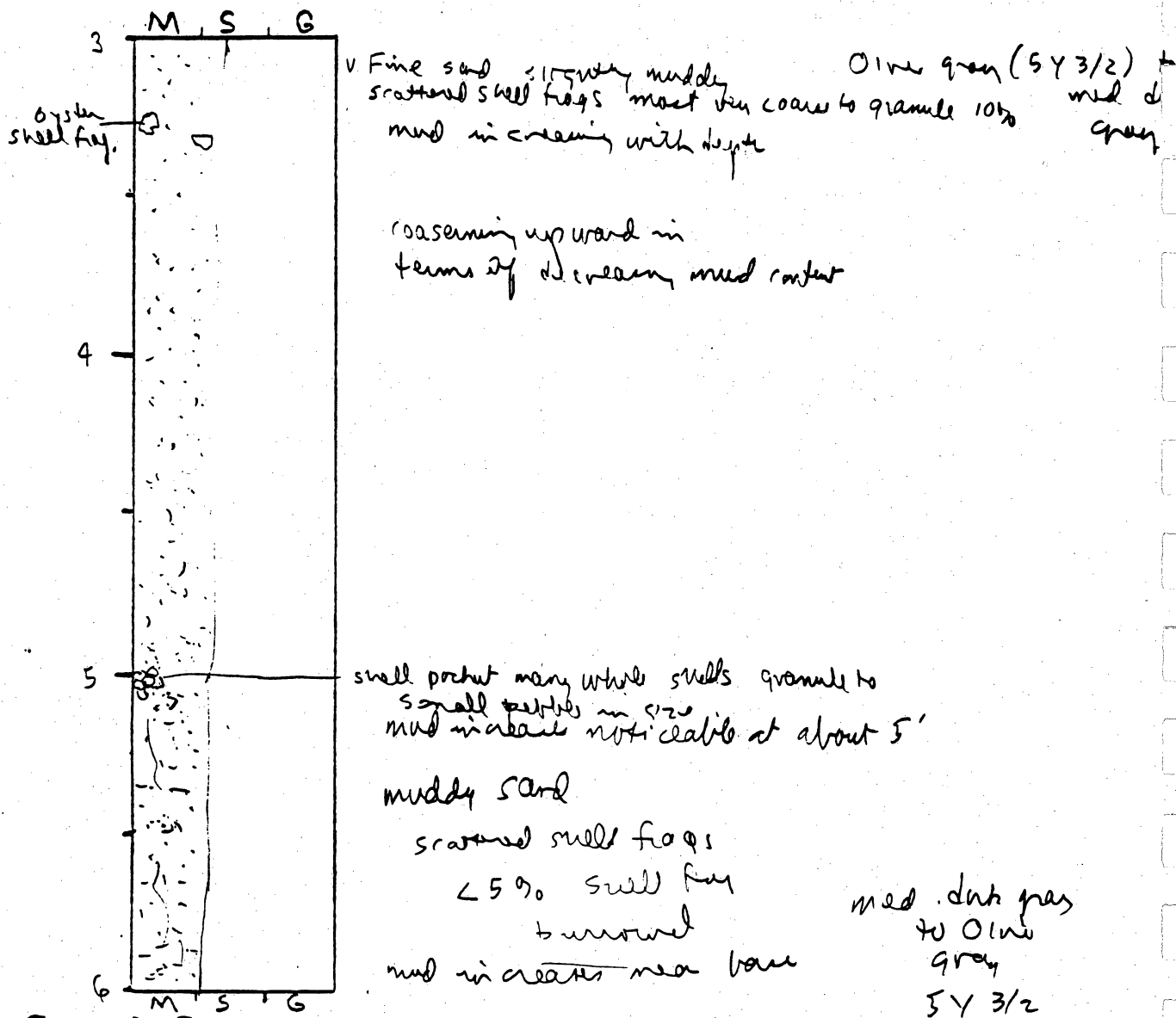
General Comments:

CORE LOG

CORE # SBV-19(B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS

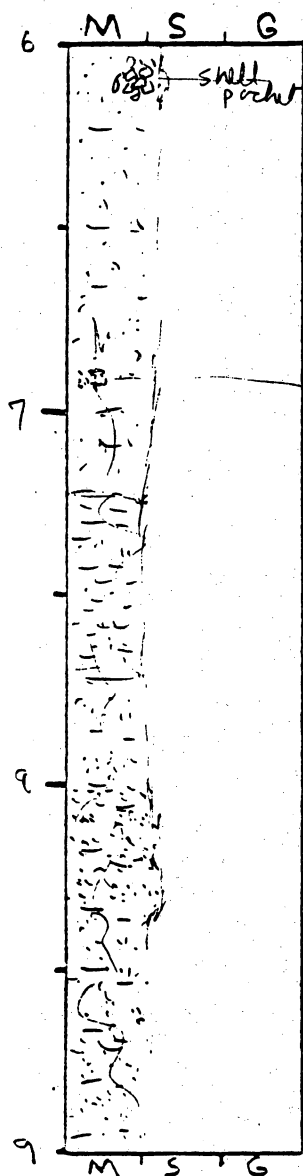


CORE LOG

CORE # SBV-19 (C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



muddy sand
 ↓ scattered shell frags -- < 5%
 except in shell pocket

olive green
 5Y 3/2
 to mud
 dark gray

shell frag pocket (v coarse sand size)

mud increases noticeable below 7.3'
 wetter zone 7.3 - 7.8' intensely burrowed
 sandy mud to muddy sand
 Discrete pocket of sand & mud
 < 1% shell frags

sand increases slightly below 8'
 Muddy sand

muddy sand to sandy mud

intensely burrowed olive green
 5Y 3/2
 to mud
 dark gray

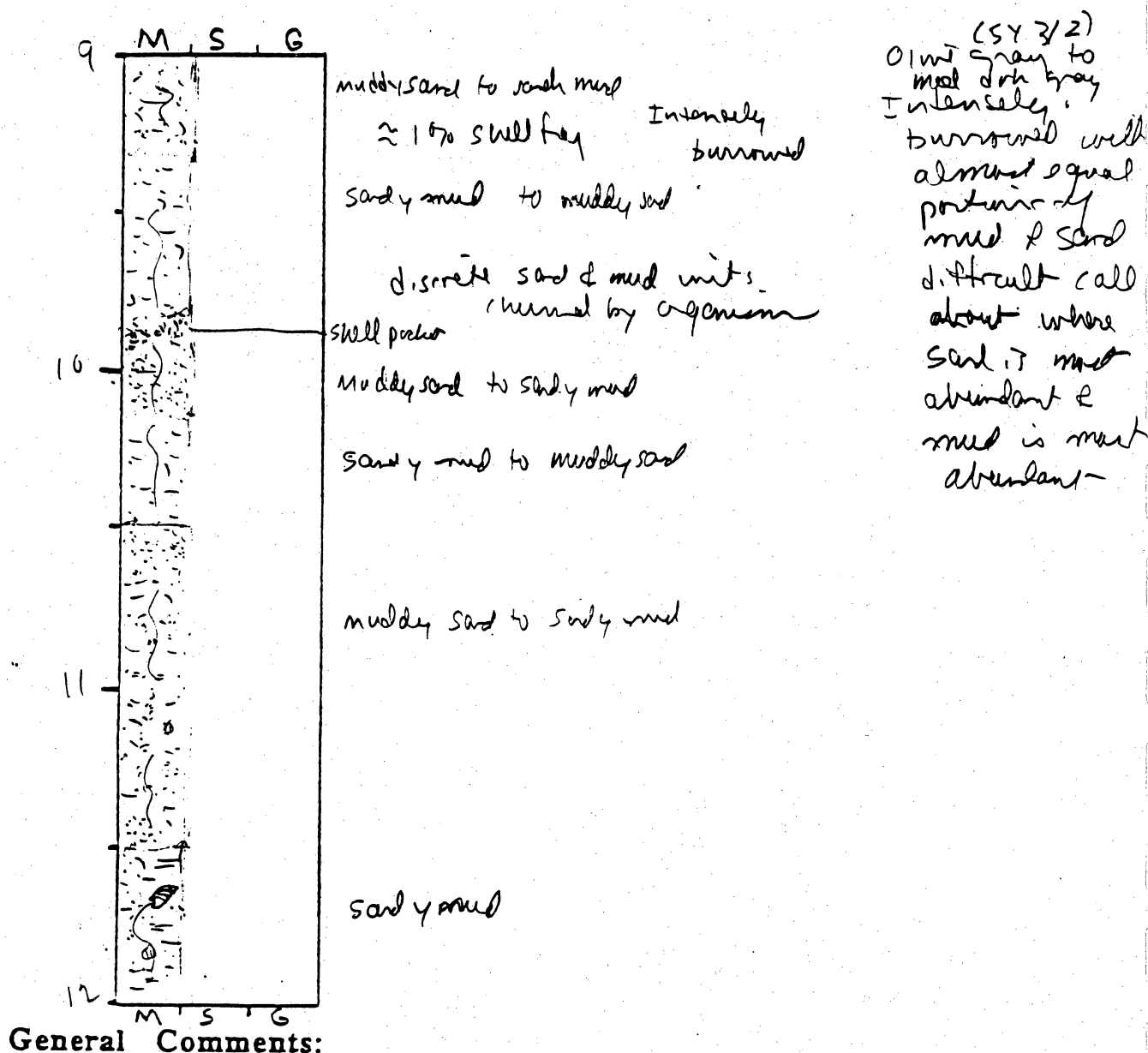
General Comments:

CORE LOG

CORE # SBV-19 (D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS

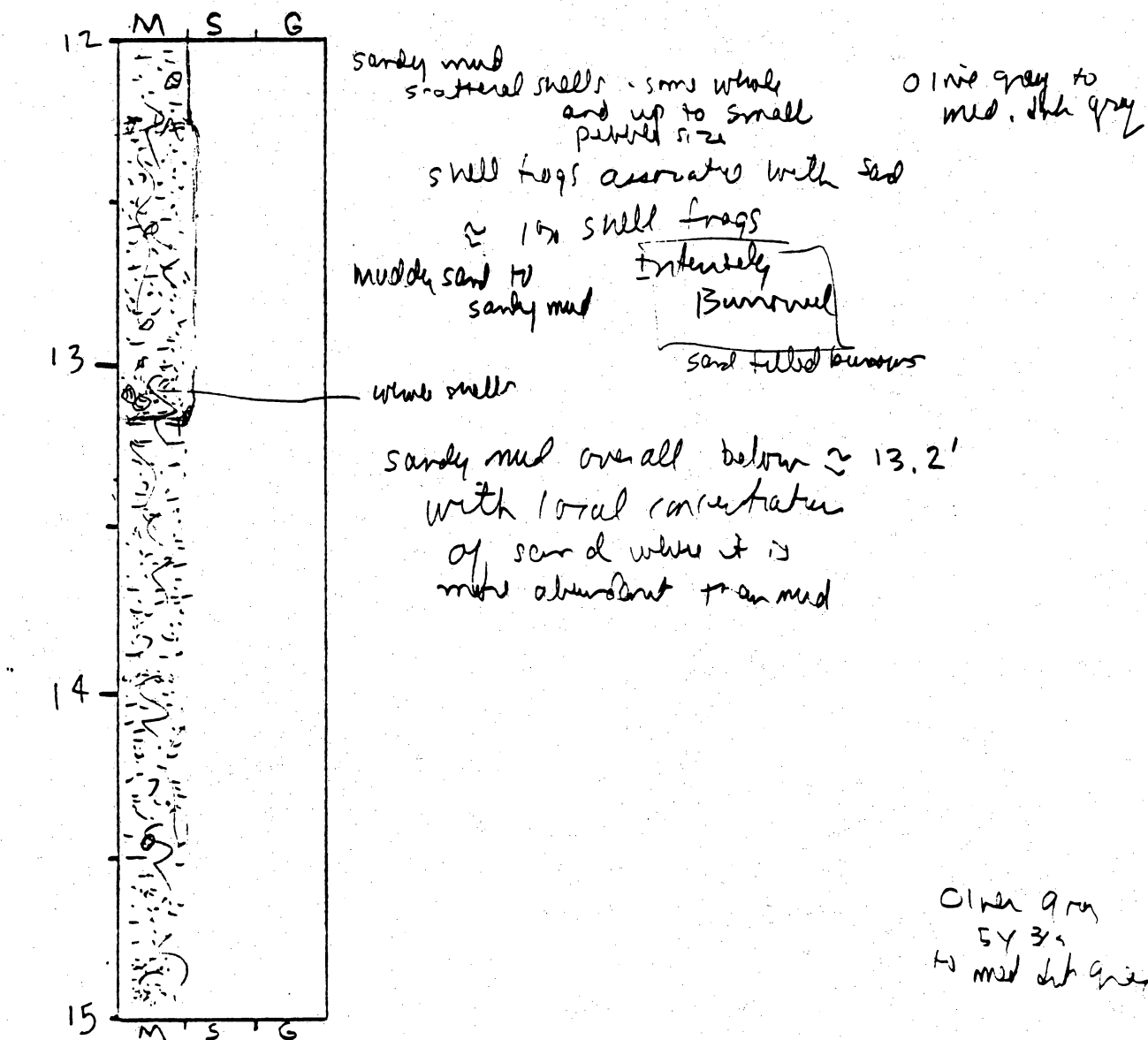


CORE LOG

CORE # SBV-19 (E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



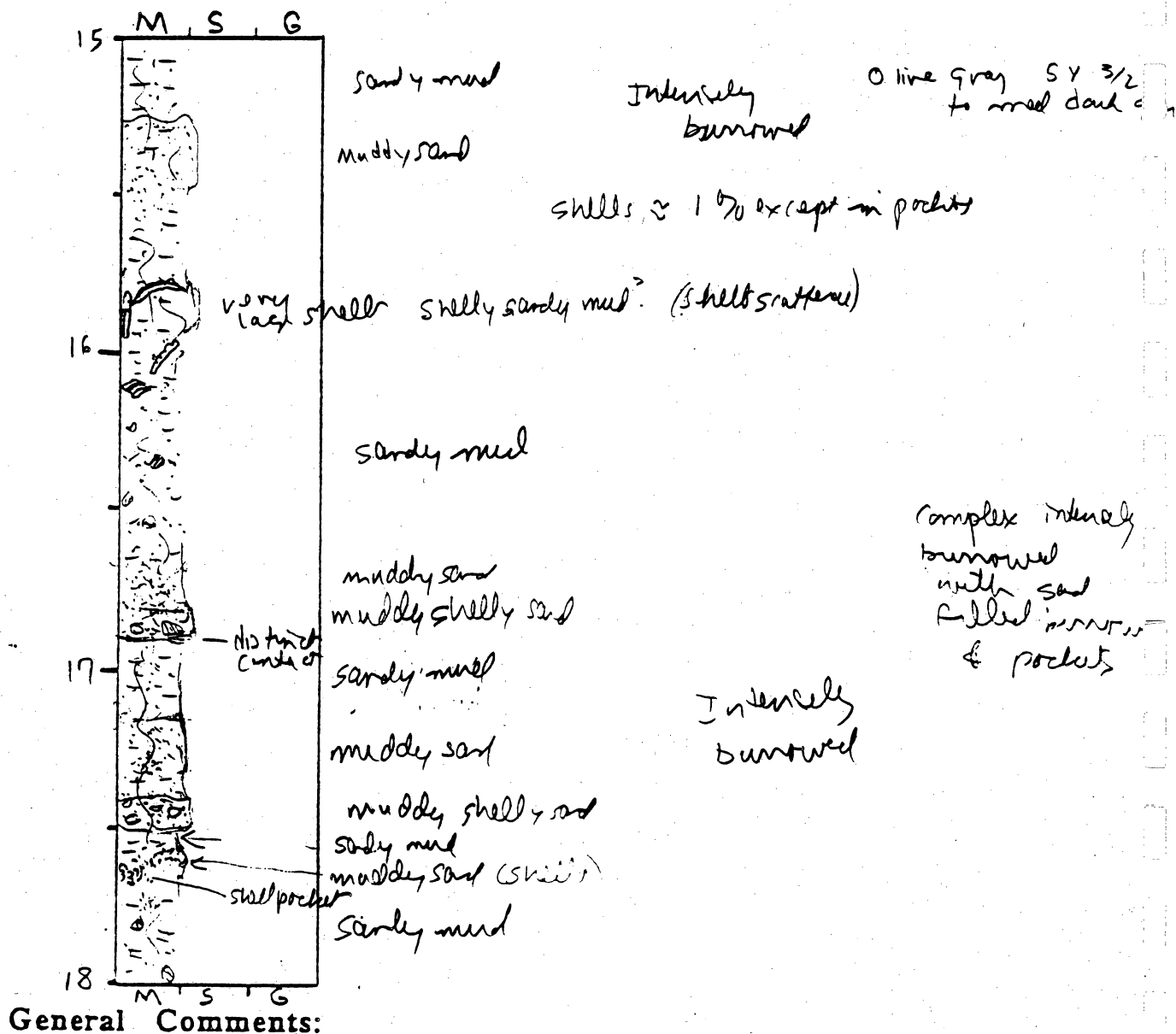
General Comments:

CORE LOG

CORE # SBV-19 (F) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS

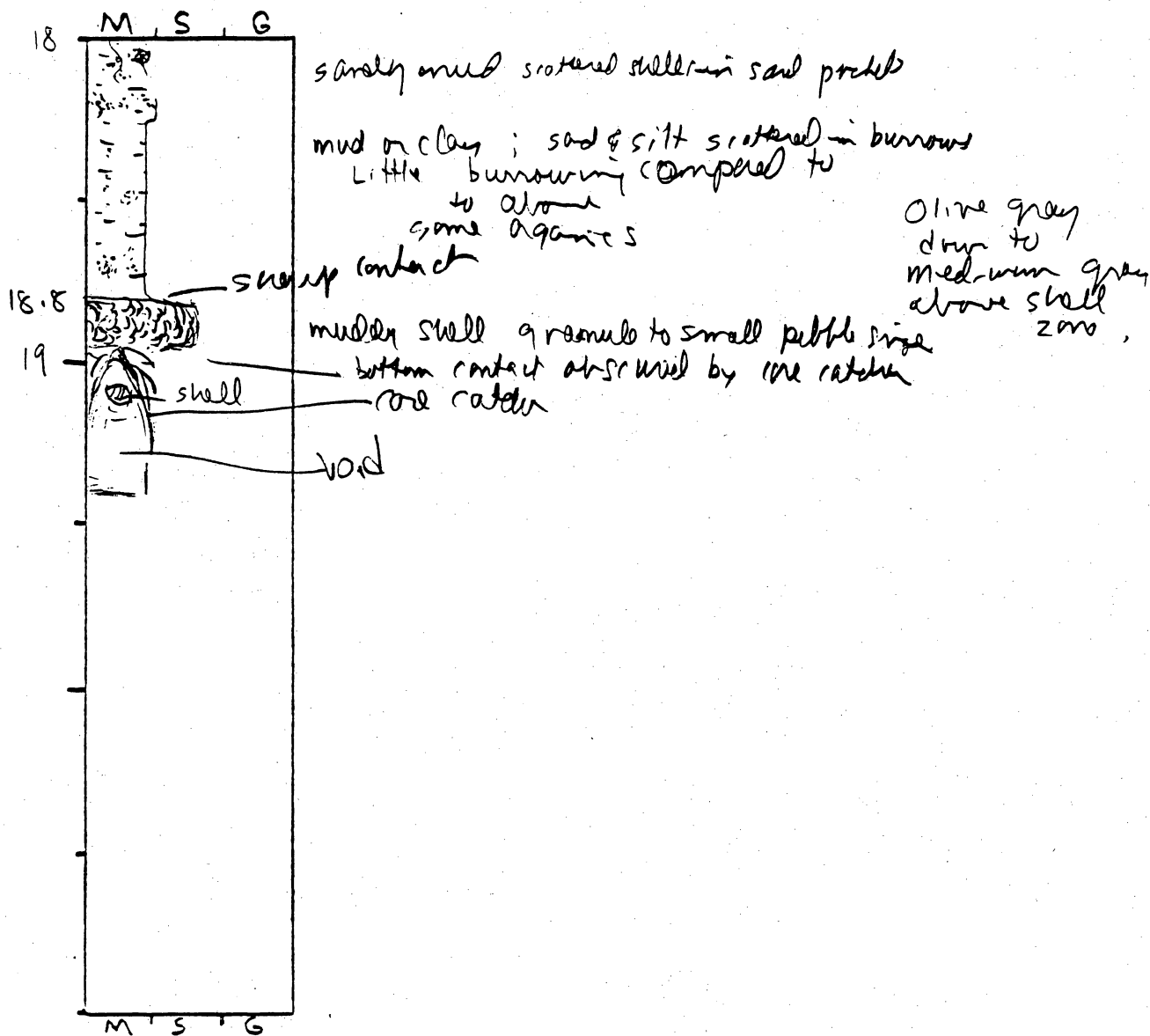


CORE LOG

CORE # SBV-19(G) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



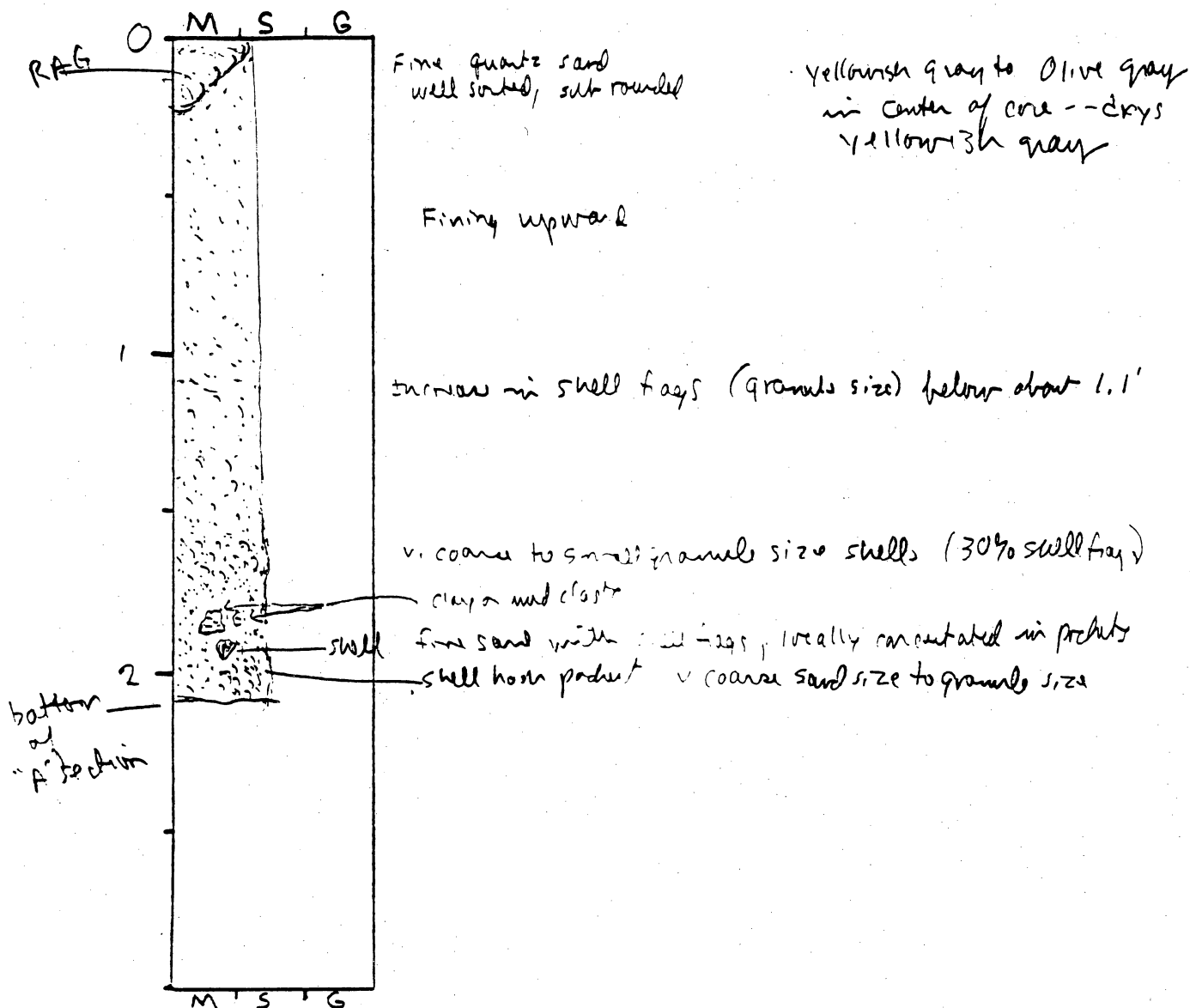
General Comments:

CORE LOG

CORE # SBV-201A TYPE Vibrocure LOCATION Sabine Bank
 LATITUDE 29° 25.035 LONGITUDE 93° 47.144 SURFACE ELEVATION -35.5'
 DEPTH PENETRATED ? LENGTH RECOVERED 5' 2" % COMPACTION ?

OBTAINED BY Gibeaut - R/V Kit Jones DATE 10-14-94
 DESCRIBED BY White DATE 2-22-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

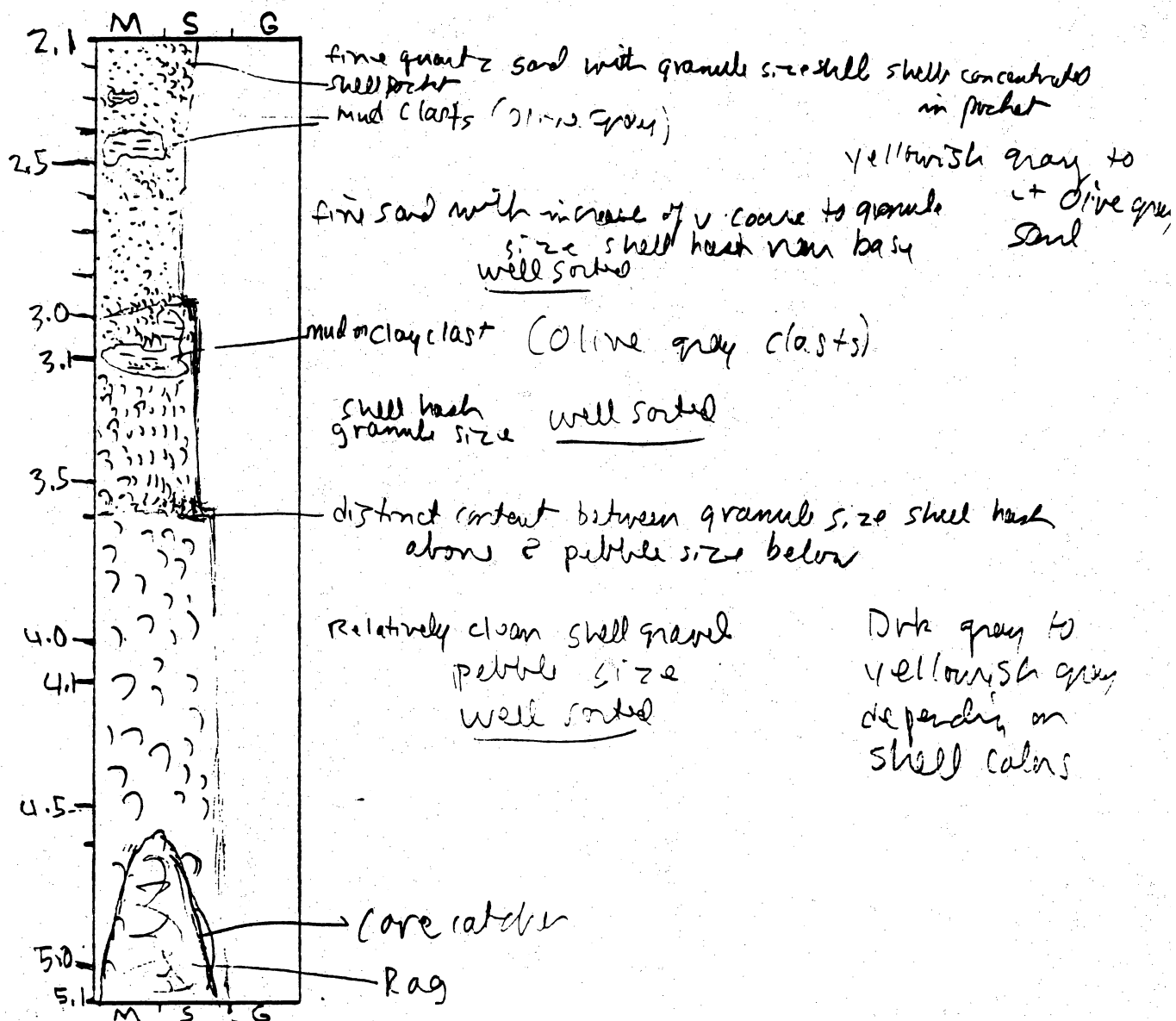


General Comments:

CORE LOG

CORE # SBV-20 (B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



General Comments: _____

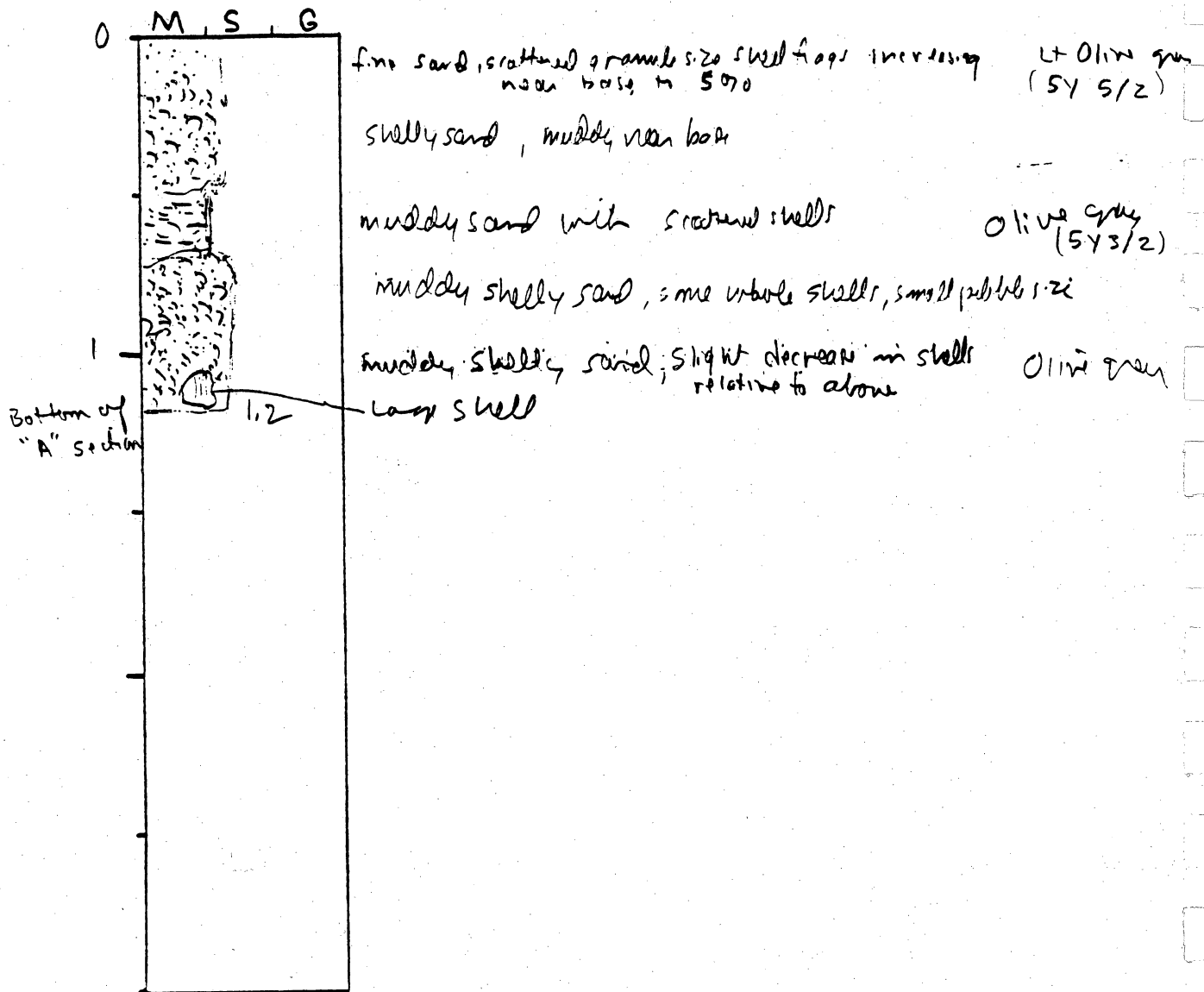
CORE LOG

CORE # SBV-21(A) TYPE Vibracore LOCATION Sabine Bank
 LATITUDE 29° 23.800' LONGITUDE 93° 46.516' SURFACE ELEVATION -42.5'
 DEPTH PENETRATED ? LENGTH RECOVERED 7' 2 1/2" % COMPACTION 9

OBTAINED BY Gibeaut - R/V Kit Jones
 DESCRIBED BY White

DATE 10-12-94
 DATE 2-22-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



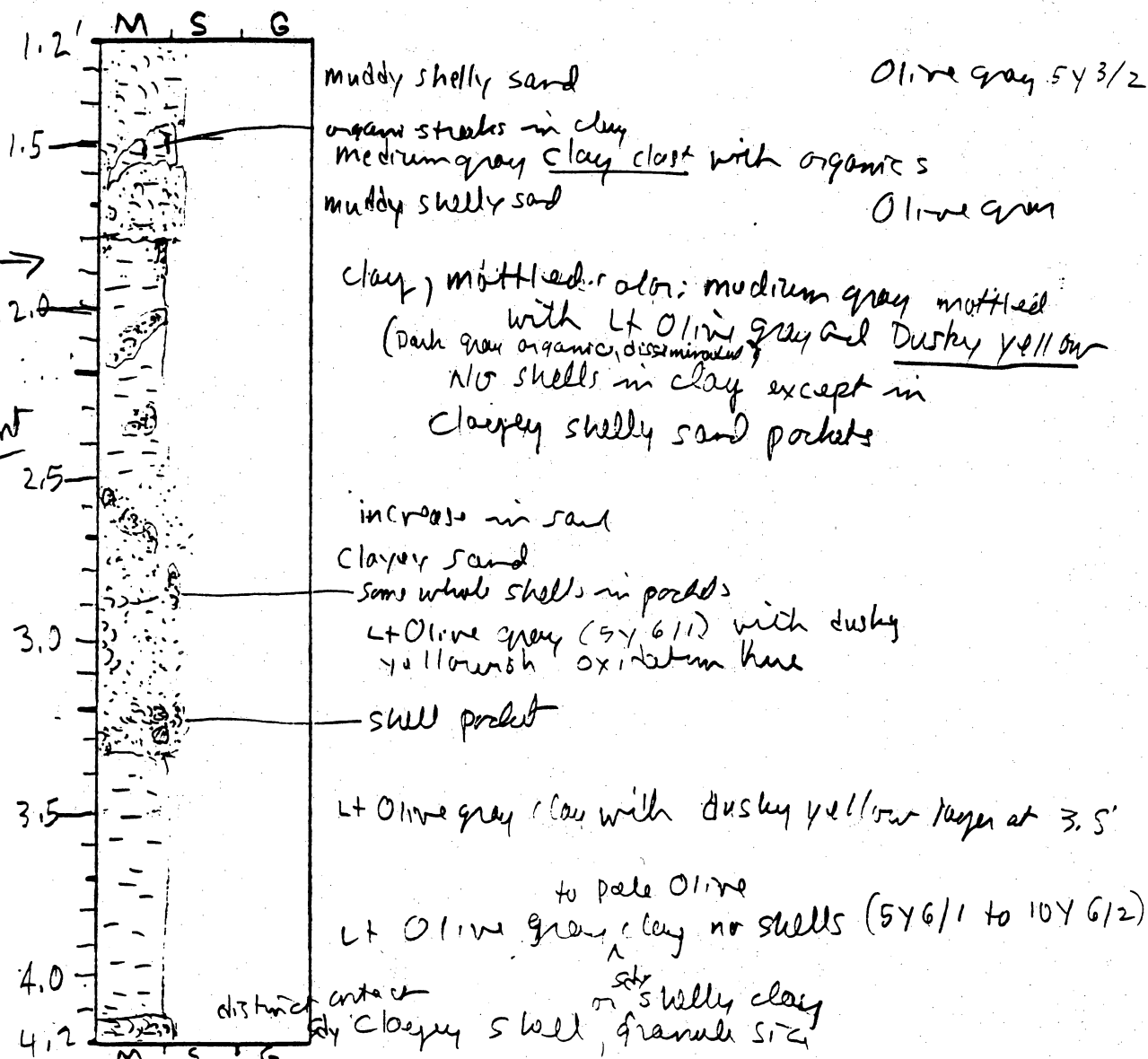
General Comments:

CORE LOG

CORE # SBV-2(B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft. m) SKETCH LITHOLOGY STRUCTURE REMARKS



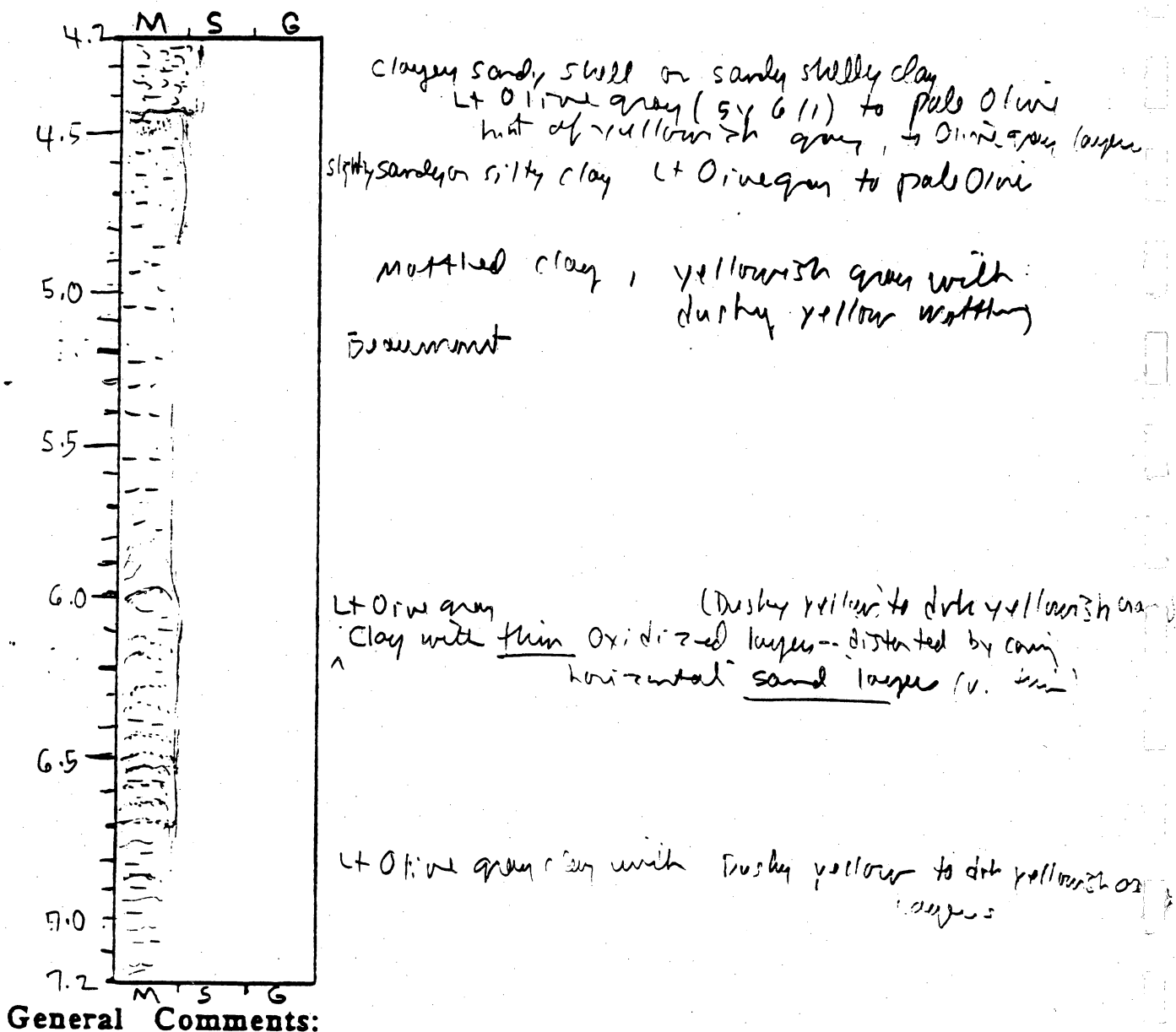
General Comments:

CORE LOG

CORE # SBV-21(C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH
 (ft. m) SKETCH LITHOLOGY STRUCTURE REMARKS

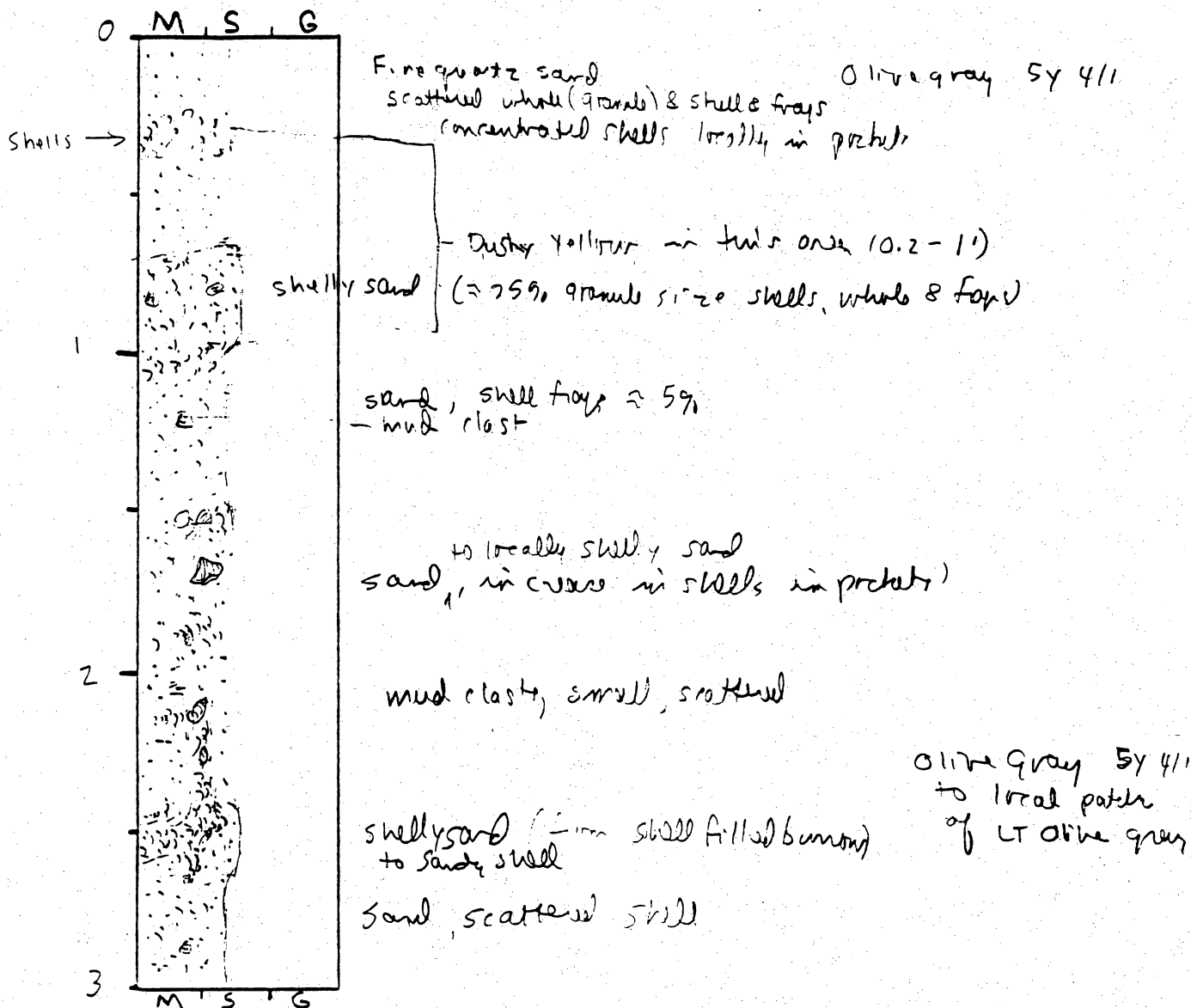


CORE LOG

CORE # SBV-22 (A) TYPE Vibrocore LOCATION Sabine Bank
 LATITUDE 29° 25.163 LONGITUDE 93° 52.618 SURFACE ELEVATION -31.5'
 DEPTH PENETRATED ? LENGTH RECOVERED 19' 3 1/2" % COMPACTION ?

OBTAINED BY Gibeaut - R/V Kit Jones DATE 10-14-94
 DESCRIBED BY White DATE 2-17-95

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



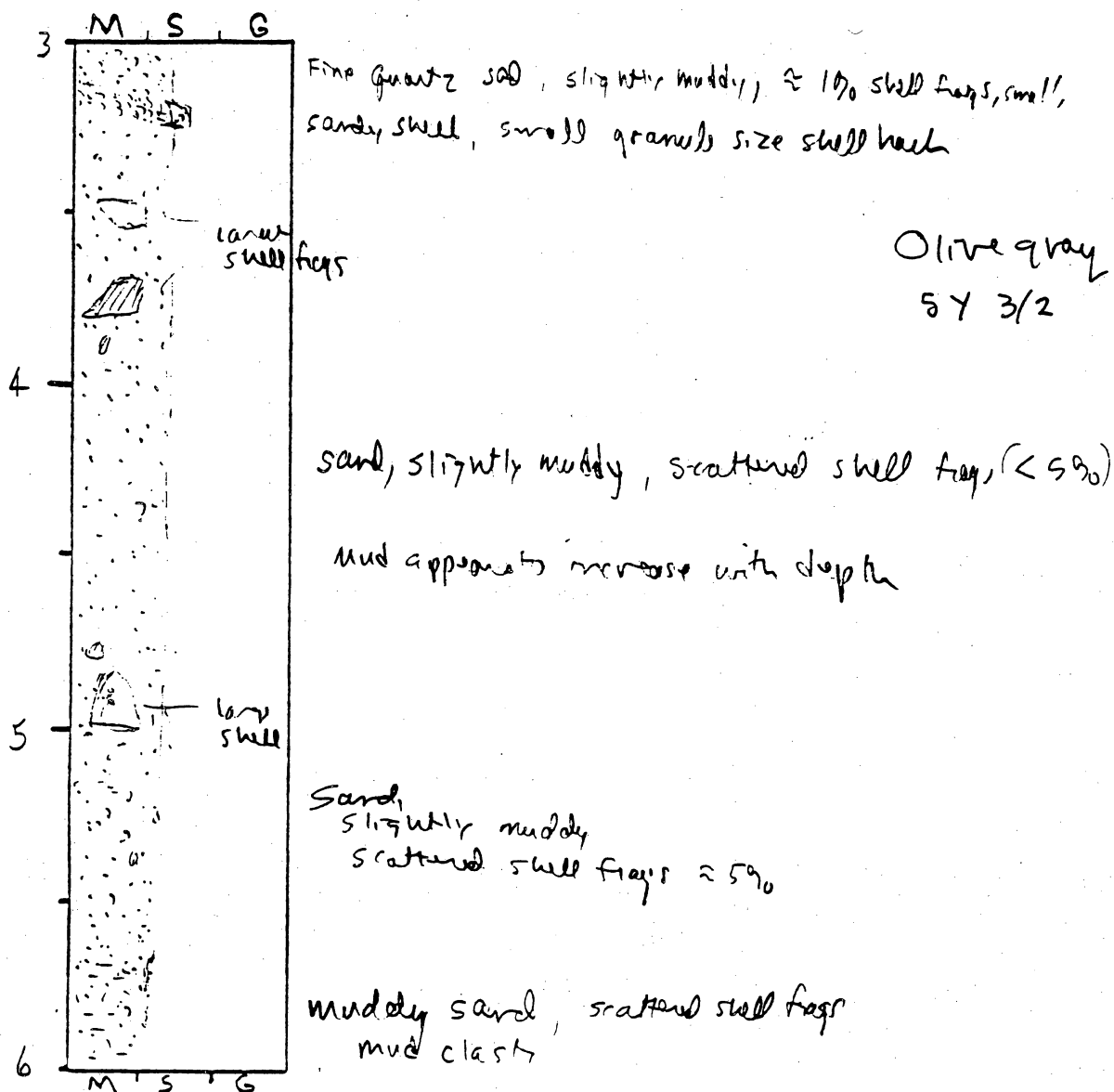
General Comments:

CORE LOG

CORE # SBV-22(B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



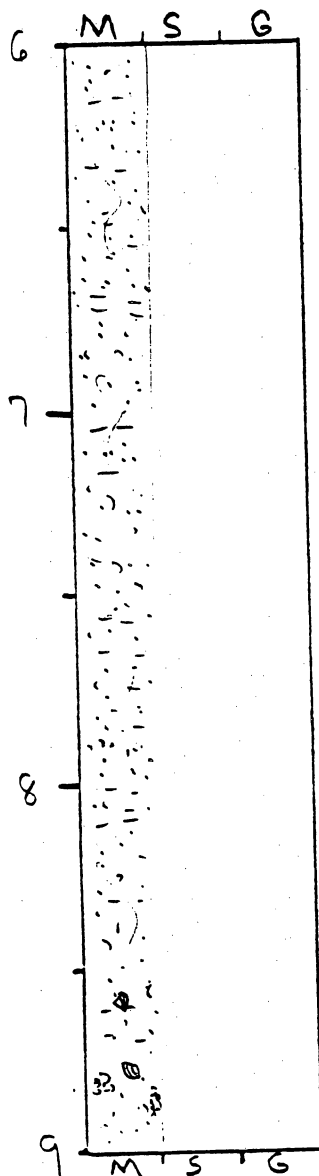
General Comments:

CORE LOG

CORE # SBV-22(C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



muddy sand
 mud clasts

scattered shells, vitals & faq.

5% locally 10% mostly gravel in size

Burrowed

Olive gray
 SY 3/2

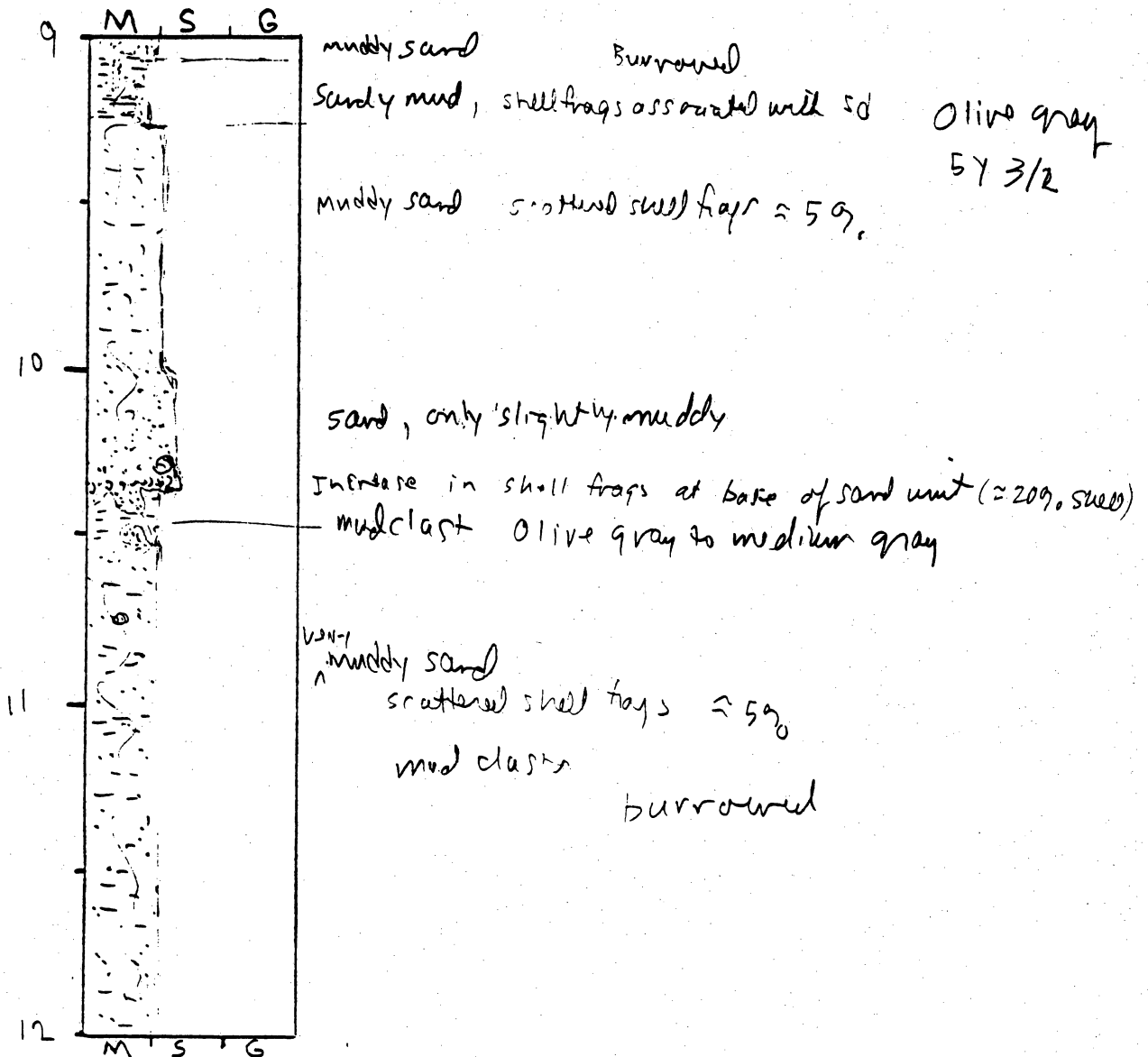
General Comments:

CORE LOG

CORE # SBV-22 (D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH
(ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



General Comments:

CORE LOG

CORE # SBV-22/E TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

| | | | | |
|------|-------|--|--------------------|-----------------------|
| 12 | M S G | v muddy sand sandy mud | Intensely burrowed | Olive gray 5 Y 3/2 |
| 12.4 | | sand, with thin shell hash lens (praker) | | |
| 12.6 | | distinct but burrowed contact | | |
| | | Sandy mud to ^{very} muddy sand | | |
| 13 | | scattered small shell fragments associated with sand | Intensely Burrowed | |
| | | Muddy sand to sandy mud | | |
| 14 | | | | |
| | | | | |
| 15 | M S G | Sandy mud to muddy sand | | |

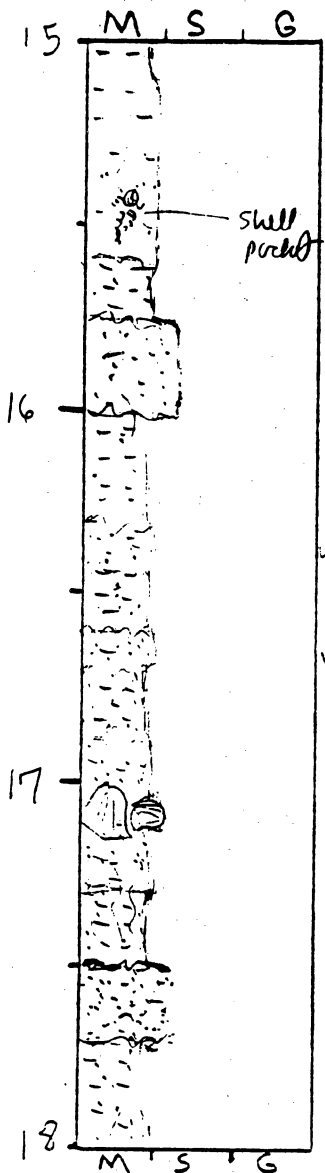
General Comments:

CORE LOG

CORE # SBV-22(F) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



sandy mud to muddy sand
 muddy sand

sandy mud
 sand, slightly muddy

sandy mud
 muddy sand
 sandy mud
 muddy sand
 sandy mud

2 large shells in muddy sand with shells

sandy mud
 sand slightly muddy
 sandy mud

Olive gray
 5Y 3/2
 to
 Olive gray
 5Y 4/1
 Intensely
 burrowed

Discrete
 mud &
 sand
 zone

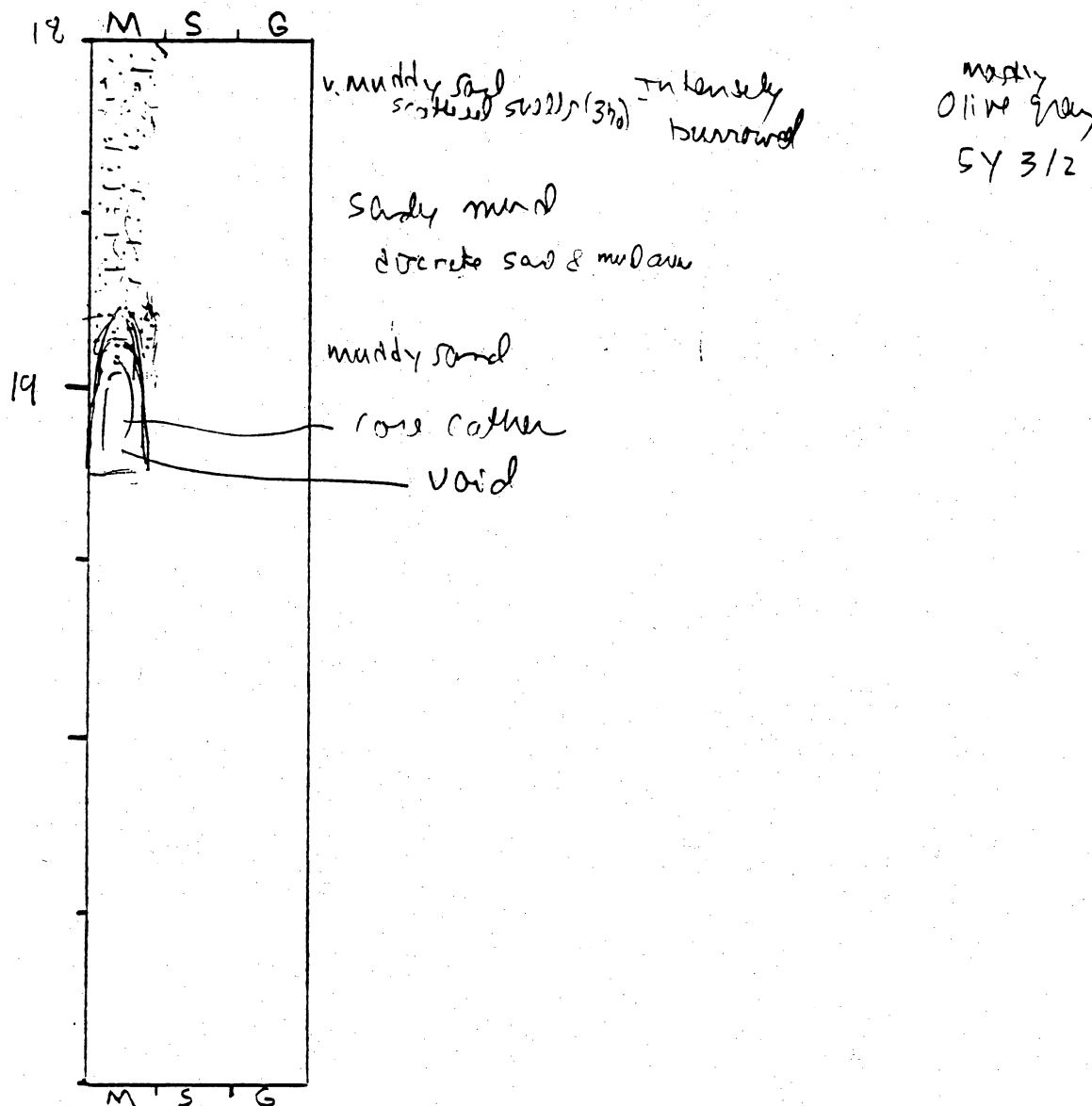
General Comments:

CORE LOG

CORE # BBV-22(G) TYPE LOCATION
LATITUDE LONGITUDE SURFACE ELEVATION
DEPTH PENETRATED LENGTH RECOVERED % COMPACTION

OBTAINED BY _____ DATE _____
DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



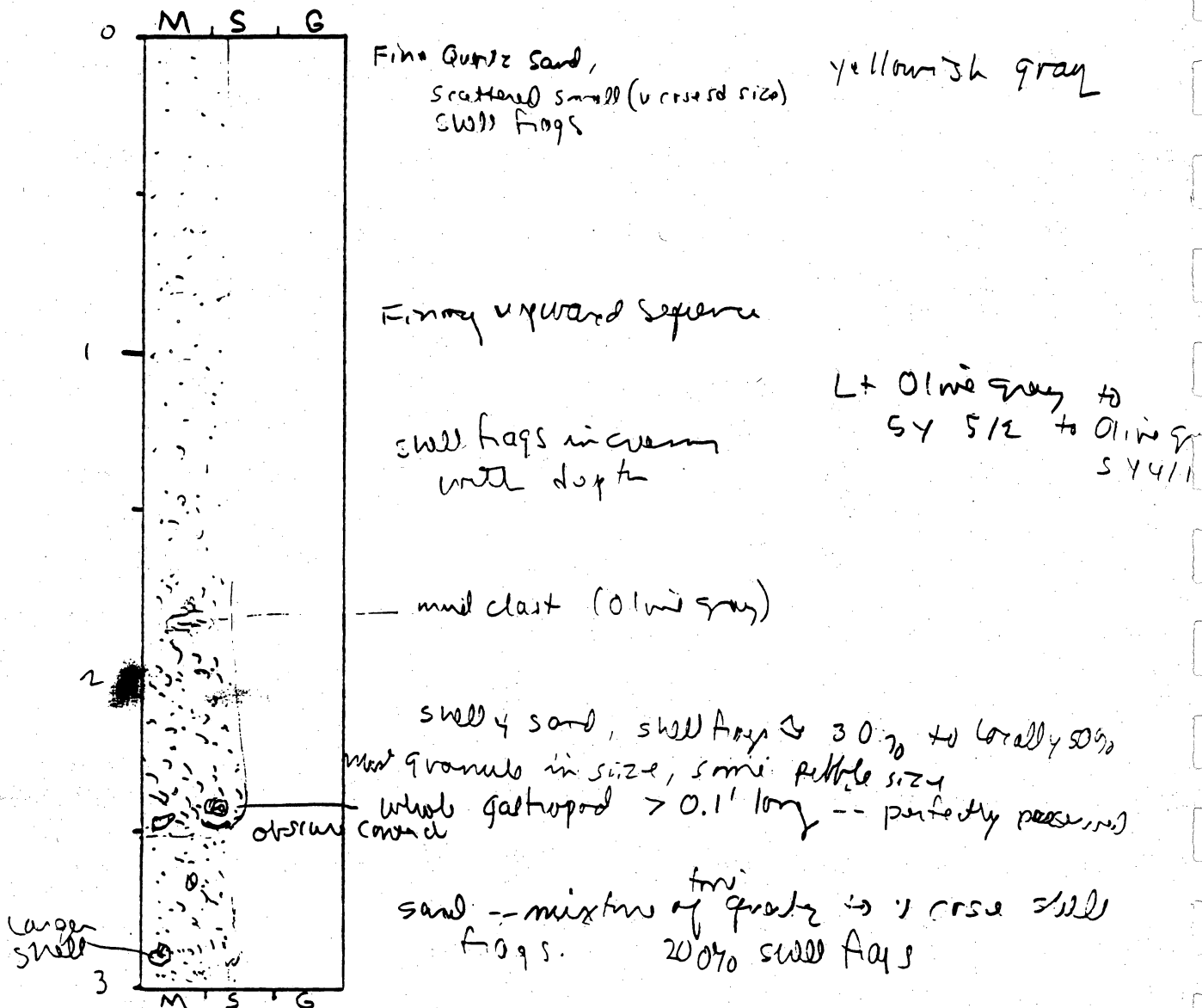
General Comments:

CORE LOG

CORE # SBV-23(A) TYPE Vibracore LOCATION Sabine Bank
 LATITUDE 29° 24.610 LONGITUDE 93° 54.21 SURFACE ELEVATION -32'
 DEPTH PENETRATED ? LENGTH RECOVERED 12' 11 1/2" % COMPACTION ?

OBTAINED BY Gibeault - R/V Kit Jones DATE 10-14-94
 DESCRIBED BY JJW DATE

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



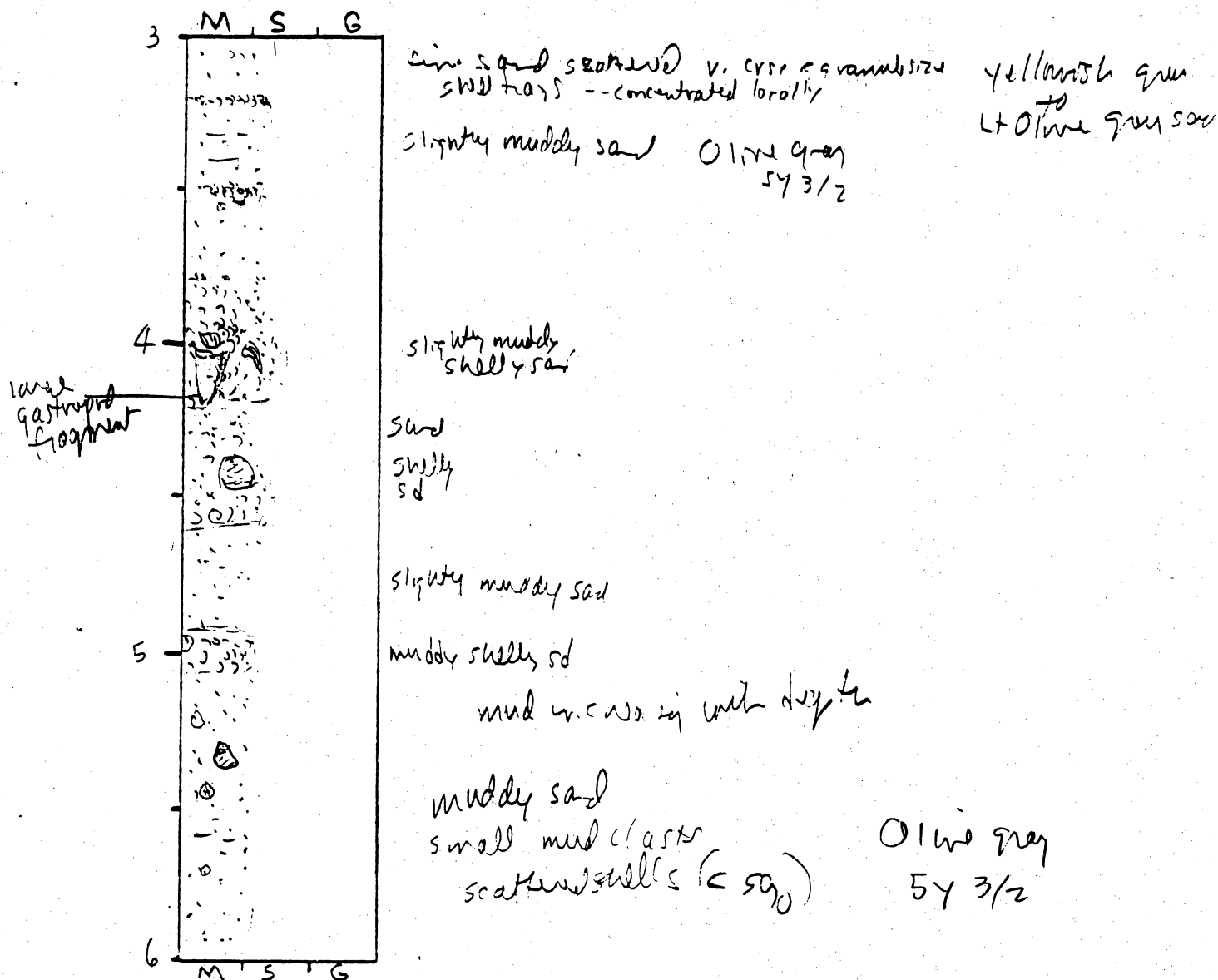
General Comments:

CORE LOG

CORE # SBV-73 (8) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



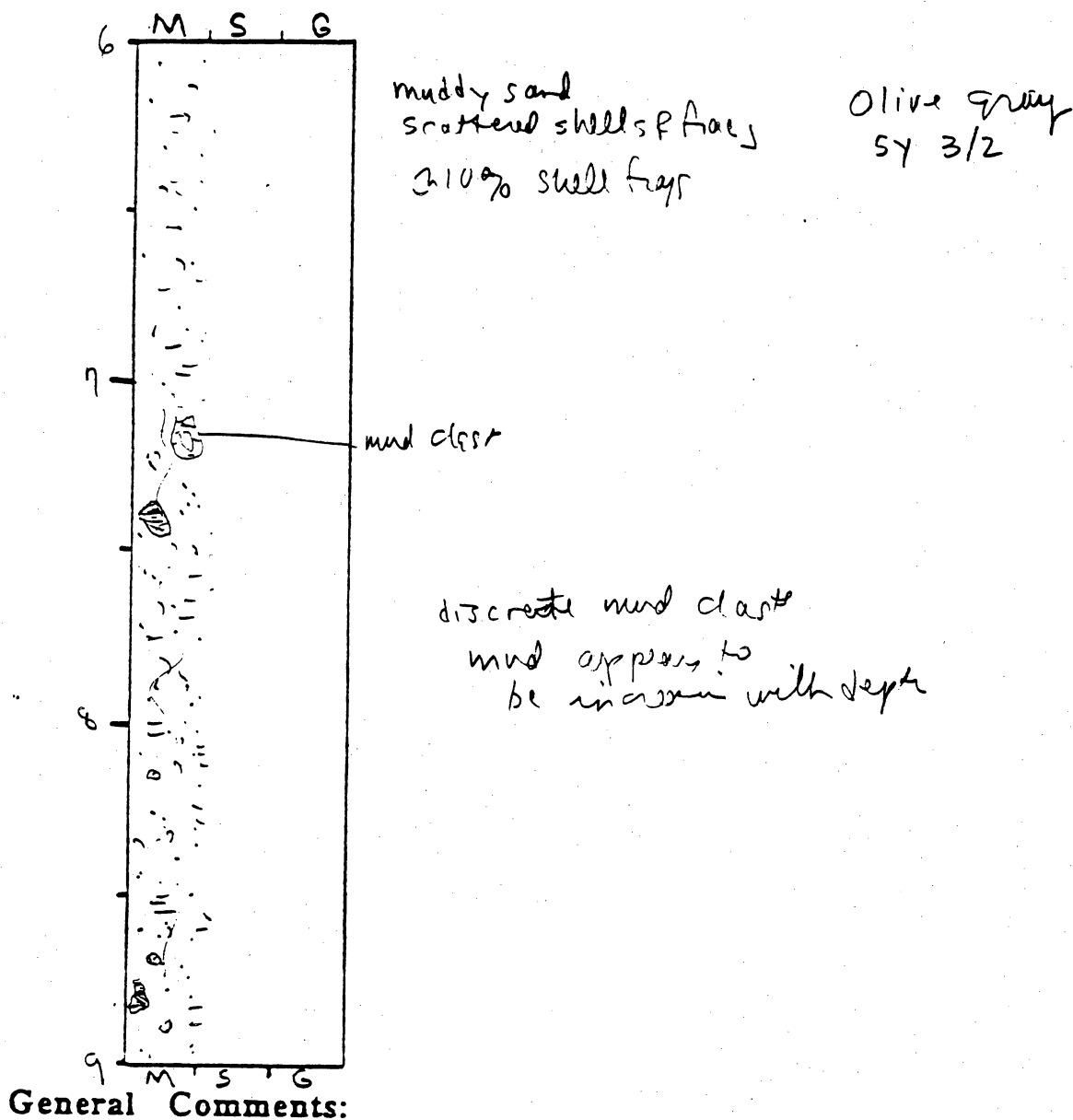
General Comments:

CORE LOG

CORE # SRV-23C TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

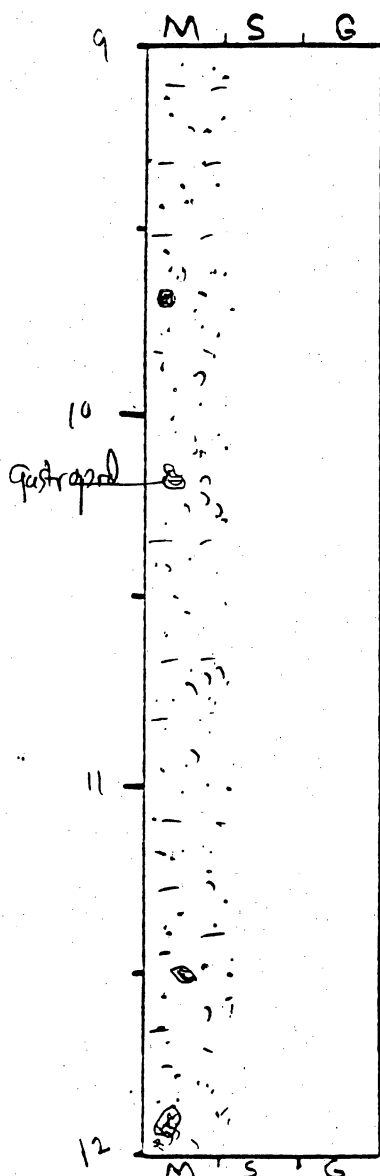


CORE LOG

CORE # SPV-13(D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



muddy sand
 scattered small shells & frags
 granule to small pebbles
 ~ 10%

probably burrowed

Olive gray
 5Y 3/2

discrete clay clasts

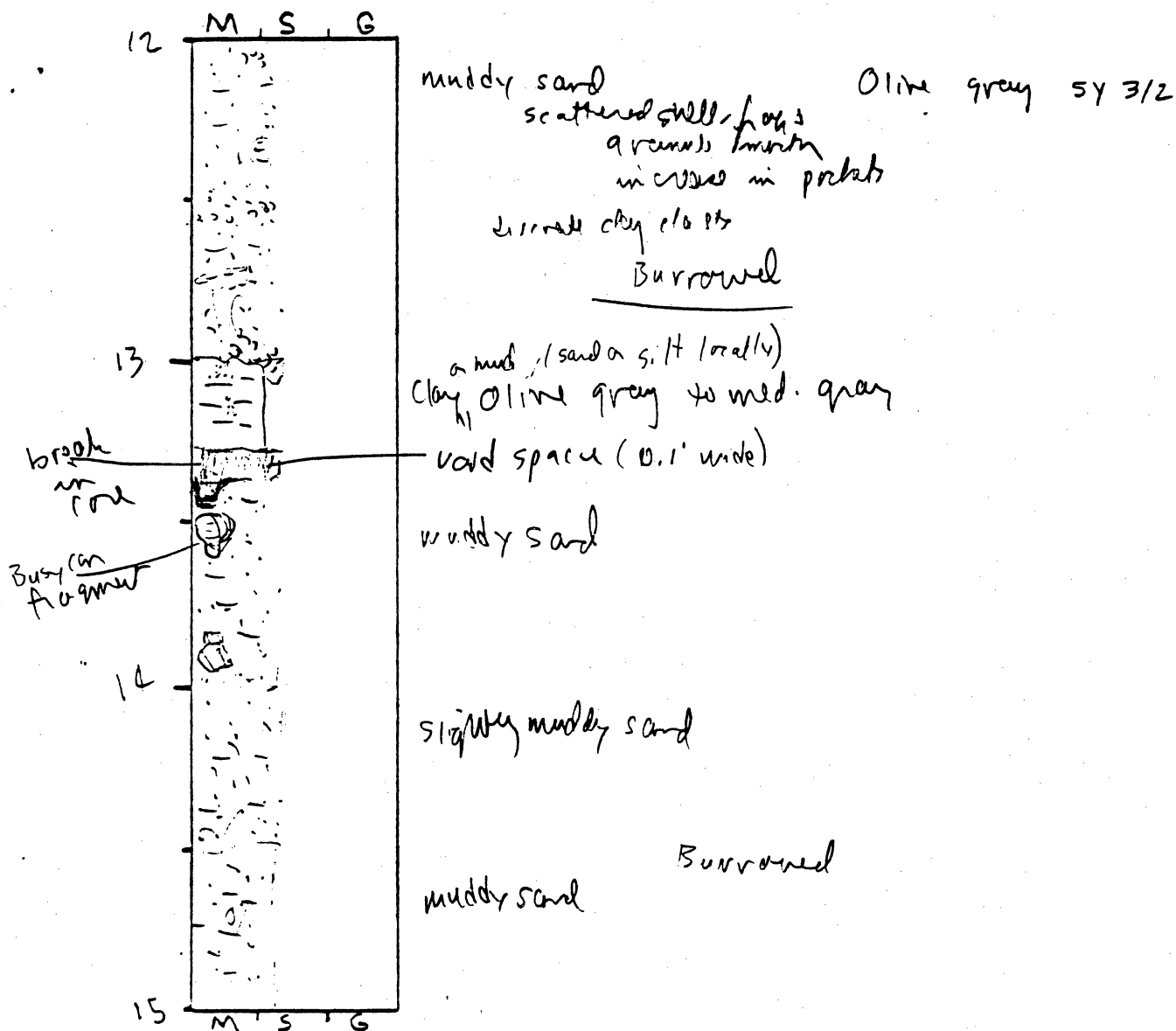
General Comments:

CORE LOG

CORE # SBV-23(E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

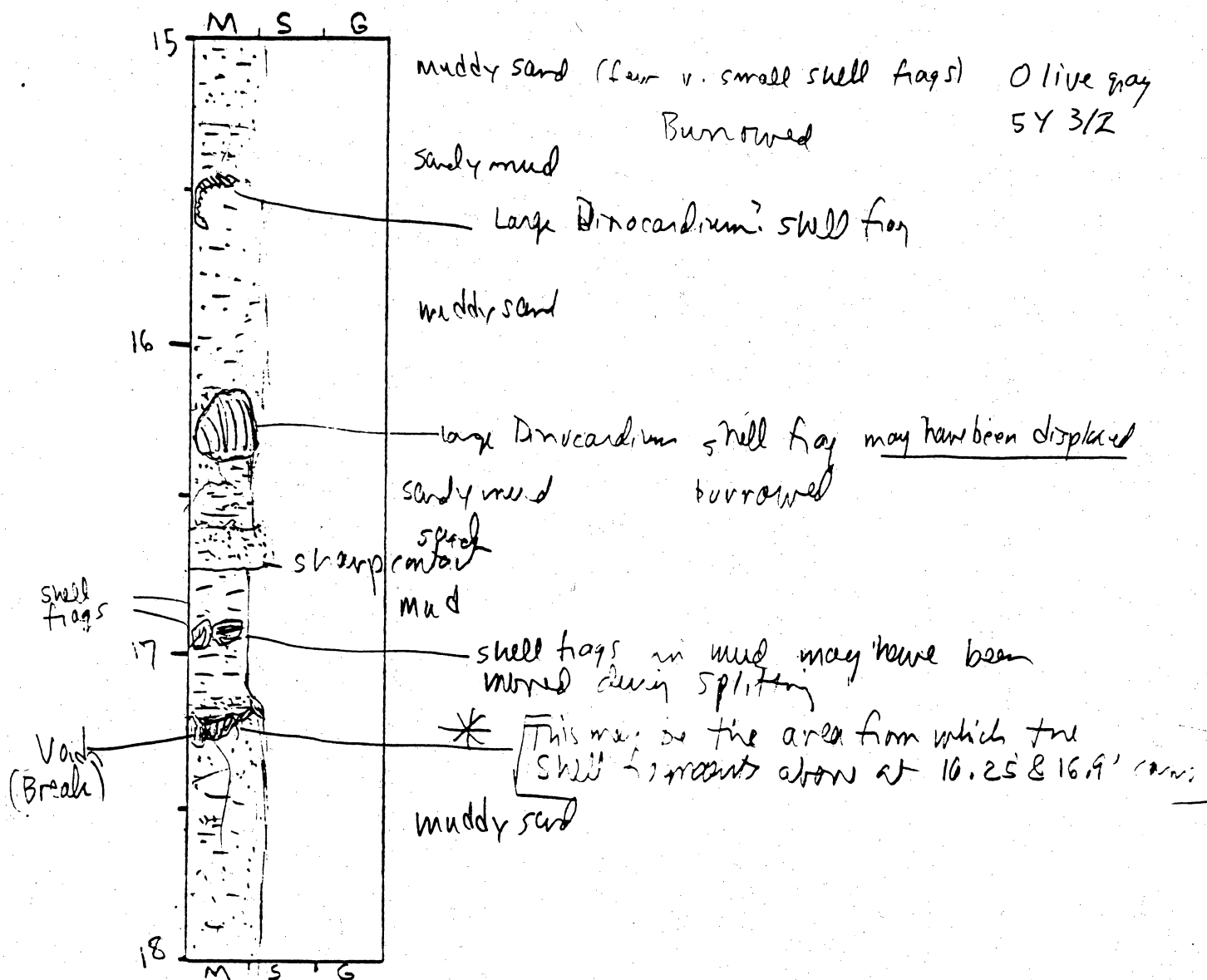


General Comments:

CORE LOG

CORE # SBV-23(F) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



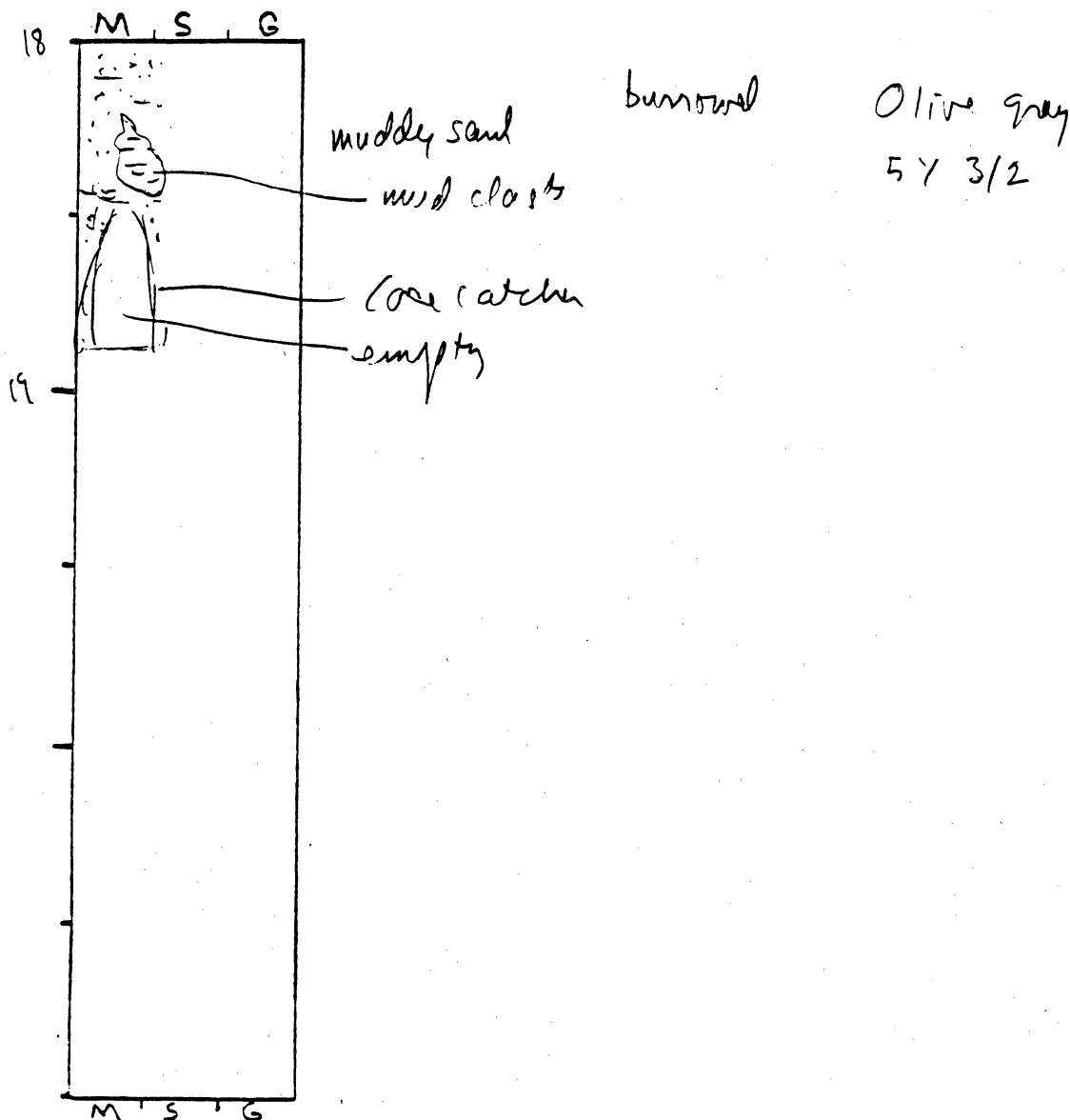
General Comments:

CORE LOG

CORE # SBV-73(G) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



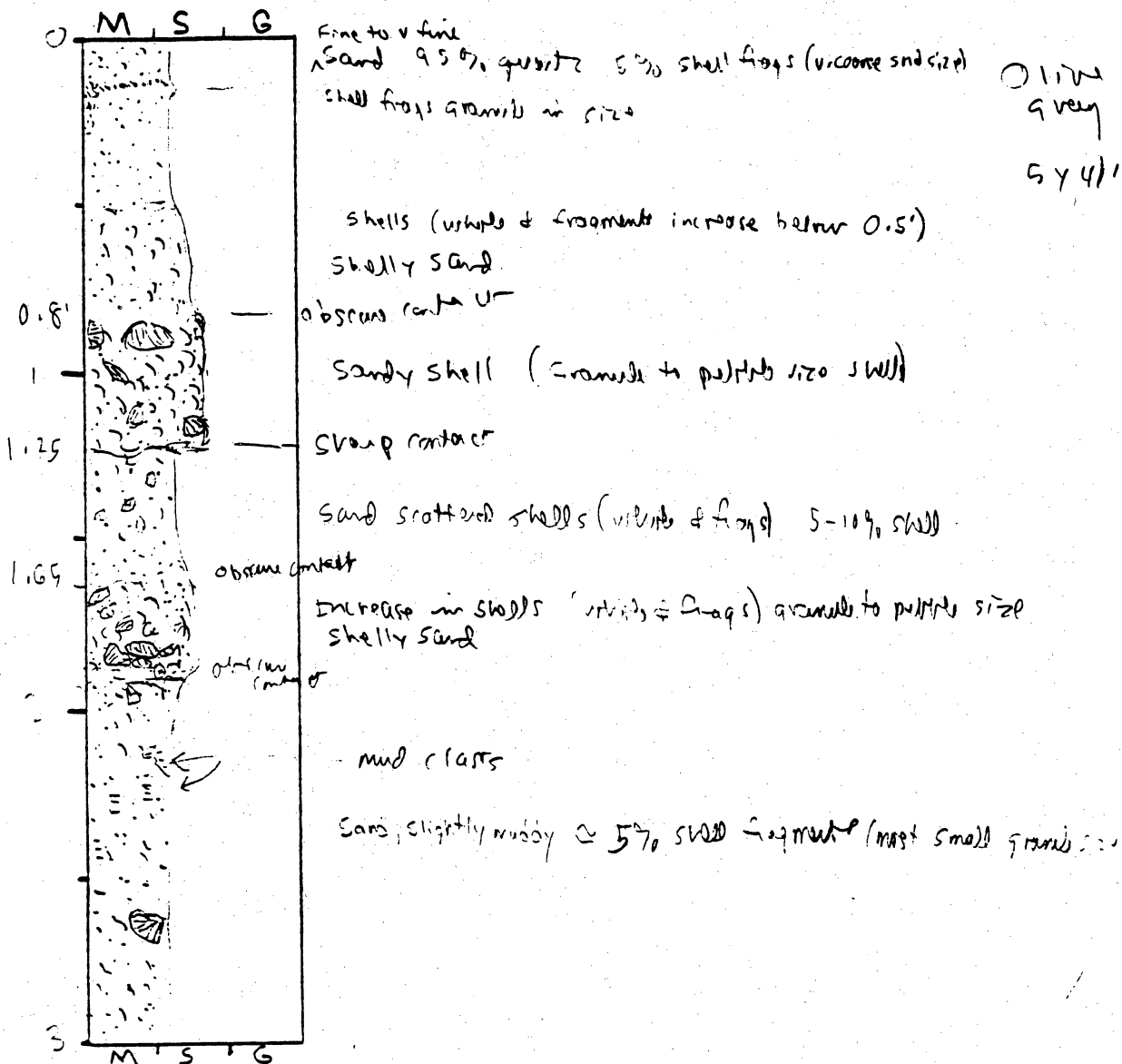
General Comments:

CORE LOG

CORE # SBY-24(A) TYPE Vibro Core LOCATION Sabino Bank
 LATITUDE 29° 23.378' LONGITUDE 93° 58.237' SURFACE ELEVATION -35'
 DEPTH PENETRATED ? LENGTH RECOVERED 20' % COMPACTION ?

OBTAINED BY Gibson - R/V K.L. Jones DATE 10-14-94
 DESCRIBED BY White DATE

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

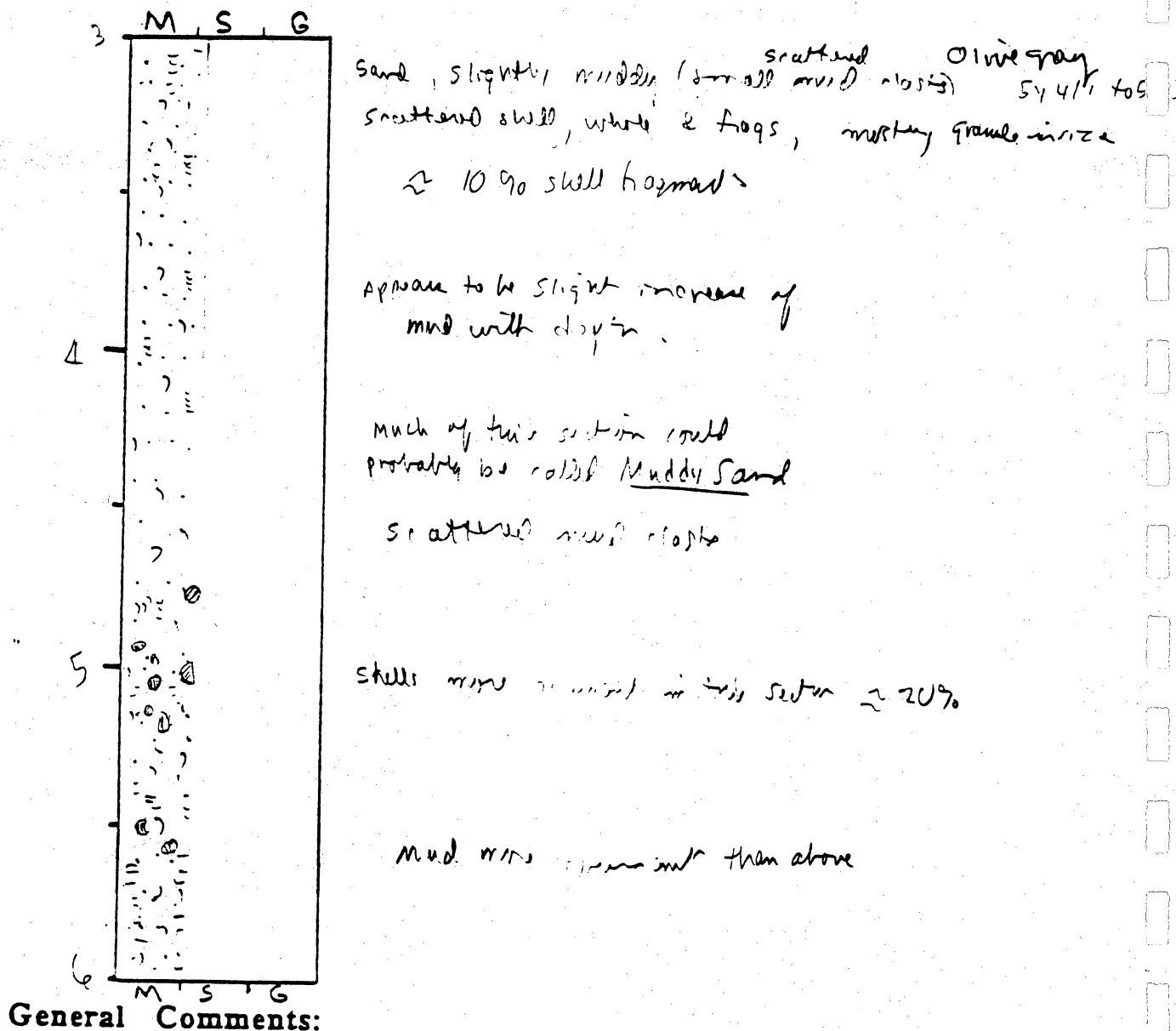


General Comments:

CORE LOG

CORE # S24-24(B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS

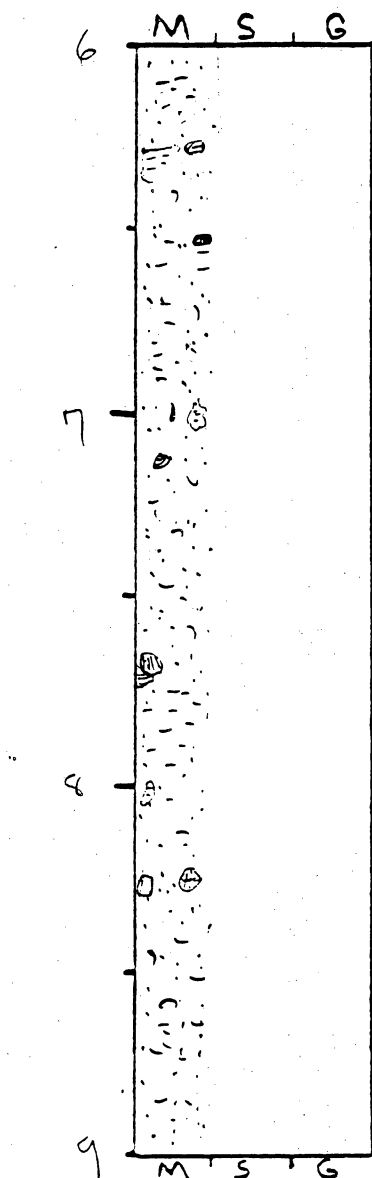


CORE LOG

CORE # SBY-240 TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



muddy sand (med clasts larger than in
 above section) 01 m grey
 SY 312
 scattered shell frags and whole shell, granules
 to small pebbles in size ~ 10-15%

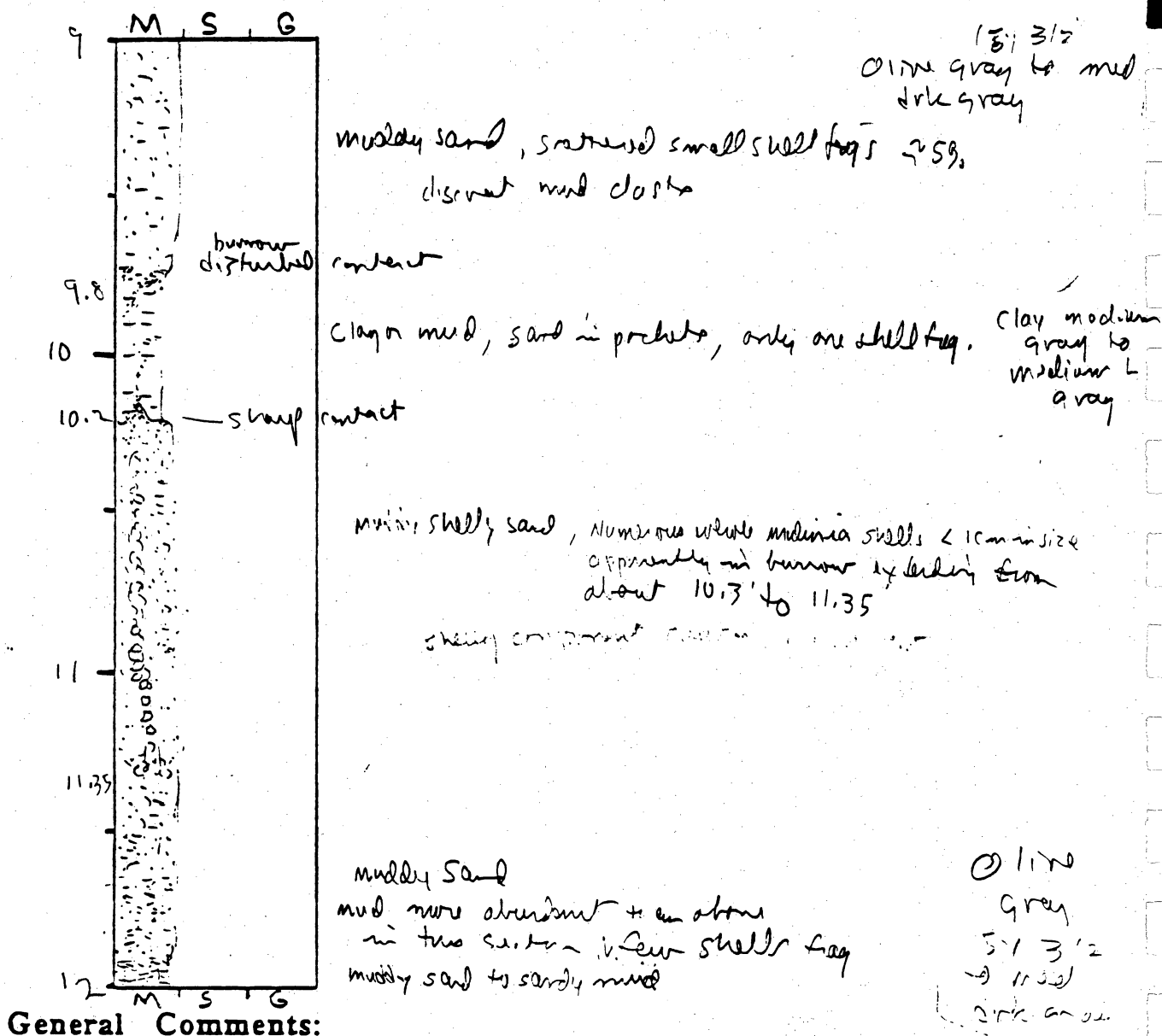
lignite med clasts

General Comments:

CORE LOG

CORE # SBV-24(d) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS

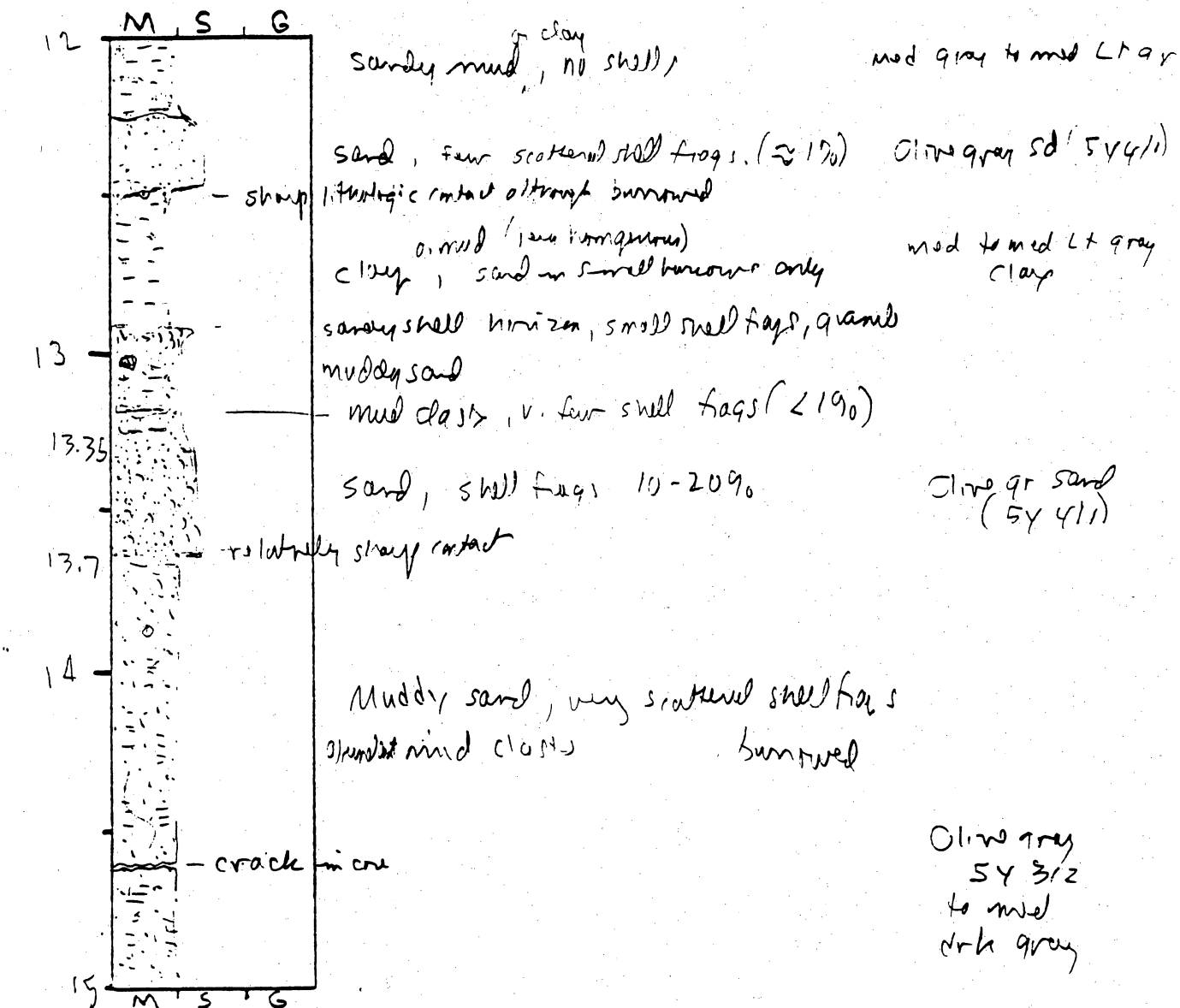


CORE LOG

CORE # SBV-24(E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



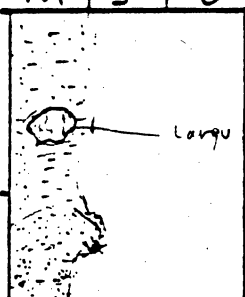
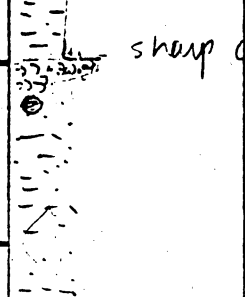
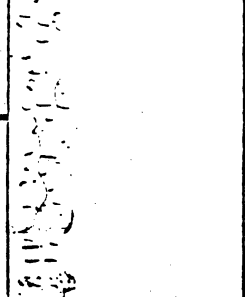
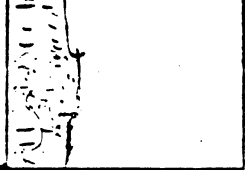
General Comments:

CORE LOG

CORE # SBV-24F TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

| | | | | |
|-------|---|--|-----------------------|------------------------------------|
| 15 | M, S, G | v muddy sand | | color muddy Olive gray 544/1 |
| |  | large shell frag (4cm across) sandy mud sand (distorted margin by coring) sandy mud (mud becomes more pure near base) | burrow | |
| 16 |  | sharp contact muddy, shelly sand or muddy sandy shell | | |
| 17 |  | but sandy mud in places primarily muddy sd, scattered shell frags mud very abundant in places | intensely burrowed | |
| 17.35 |  | sandy mud muddy sand sandy mud (no shell frags) muddy sand | | |
| 18 | M, S, G | sandy mud (no shell frags) to mud at base | | |

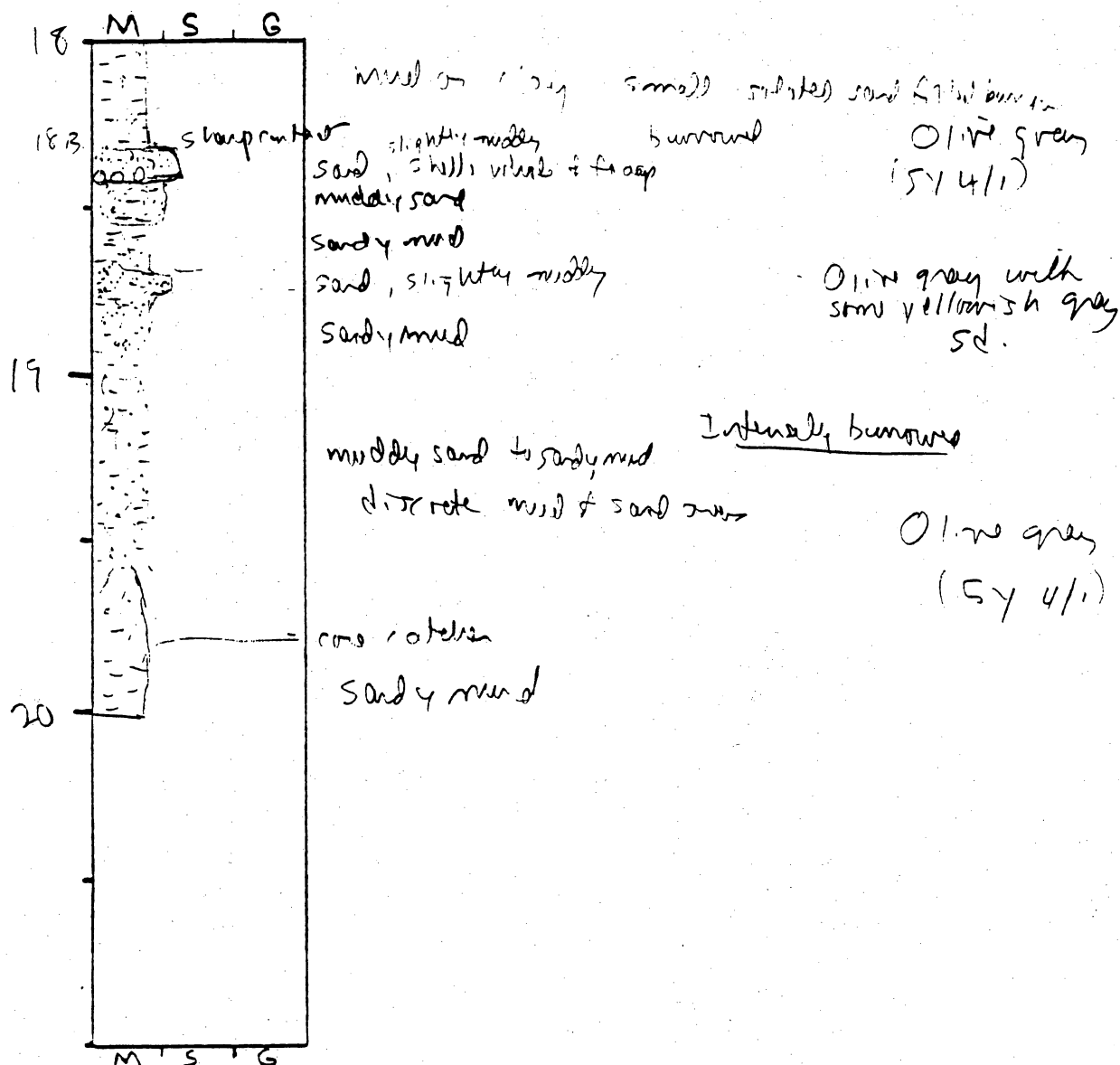
General Comments:

CORE LOG

CORE # SBV-241G TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



General Comments:

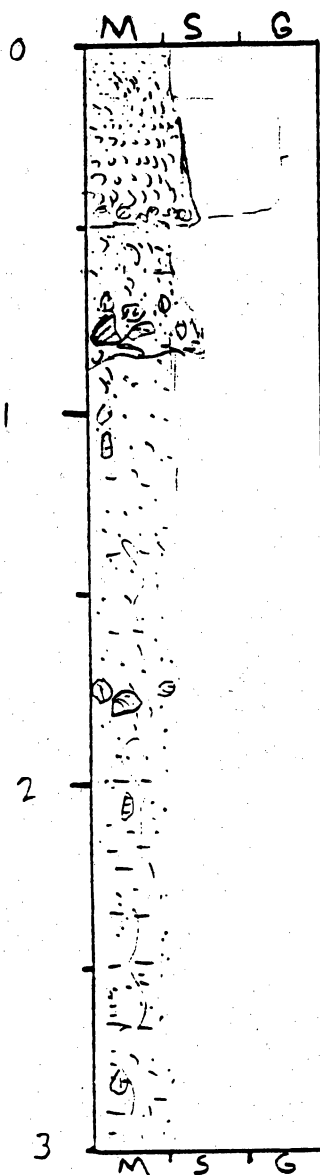
CORE LOG

CORE # SBV-25A TYPE Vibrocore LOCATION Sabine Bank
 LATITUDE 29° 20.215 LONGITUDE 94° 03.237 SURFACE ELEVATION -38.5'
 DEPTH PENETRATED ? LENGTH RECOVERED 18' 11 3/4" % COMPACTION ?

OBTAINED BY Gibeaut - R/V Kit Jones
 DESCRIBED BY V/nite

DATE 10-14-94
 DATE

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



Fine quartz sand grading down into coarse shell hash
 Olive gray sand (5Y 4/1)
 Dark gray, includes whole shells
 Shell hash; fining upward, granule to v. coarse sand size

shelly sand Lt olive gray (5Y 4/1)

sandy shell

Olive gray (5Y 4/1)

muddy sand, scattered small shell frags
 occasional whole shell
mud increasing with depth

Burrowed

discrete small mud clasts
 2-3 ft.

Olive gray
 (5Y 3/2)

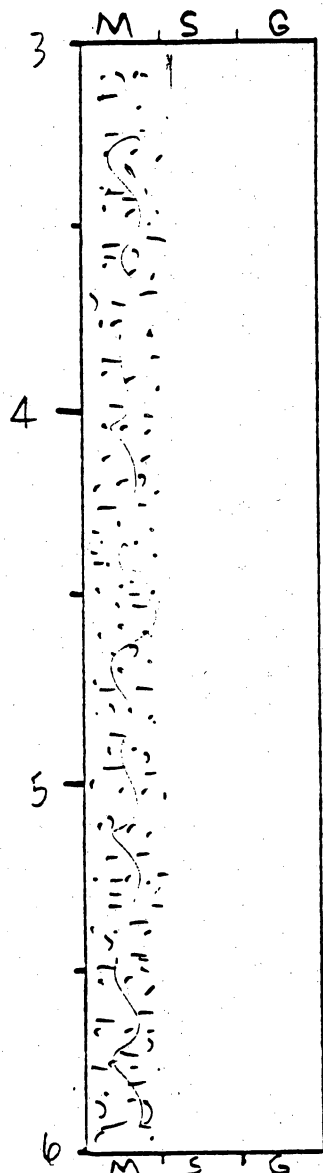
General Comments:

CORE LOG

CORE # SRV-25(B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



muddy sand intensely
 scattered shells burrowed
 granules in size (5-10%)
 muddier than previous section (above)

olive grey
 (54 3/2)

Discrete clay or mud

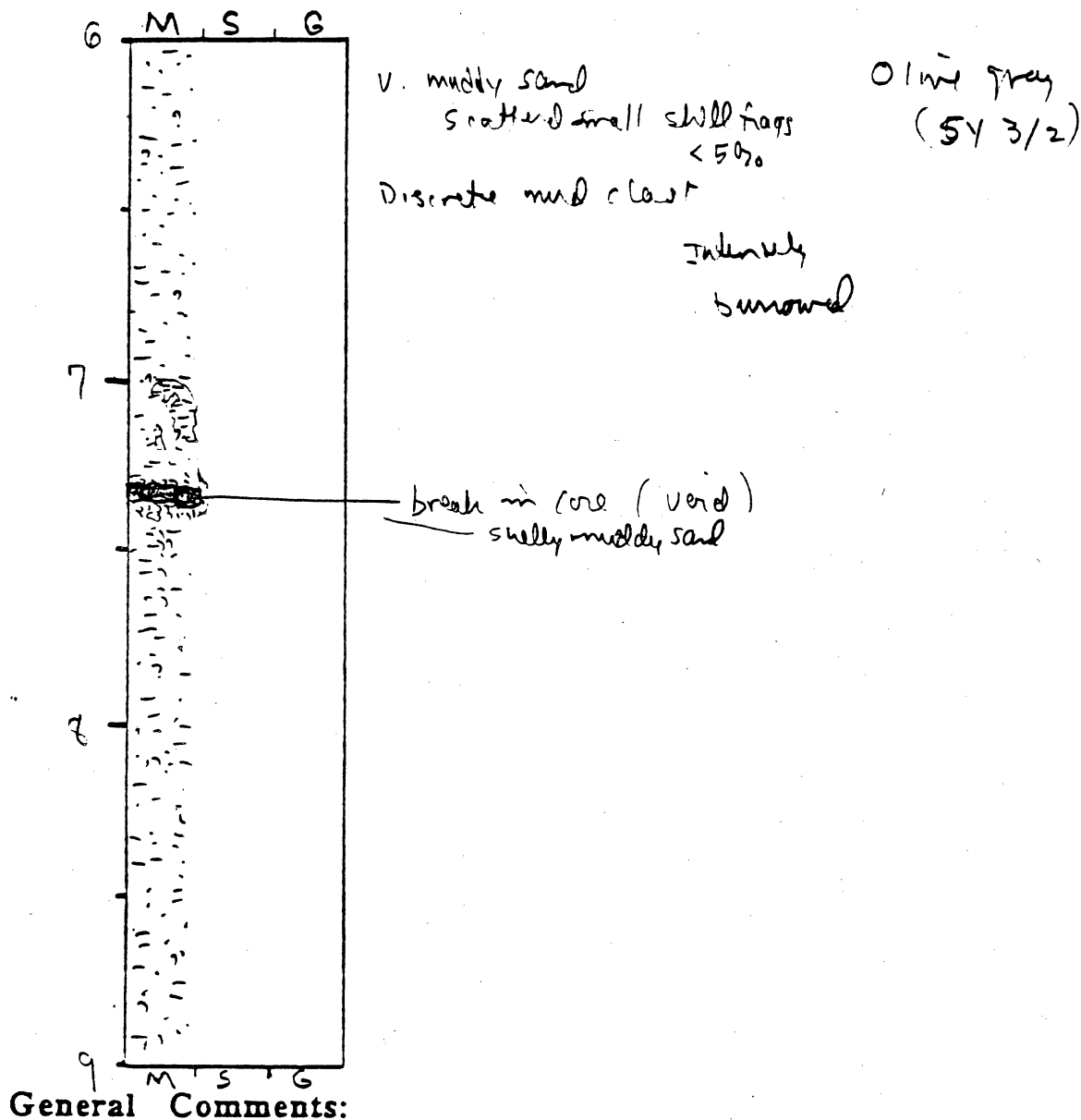
General Comments:

CORE LOG

CORE # SBV-25 (C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

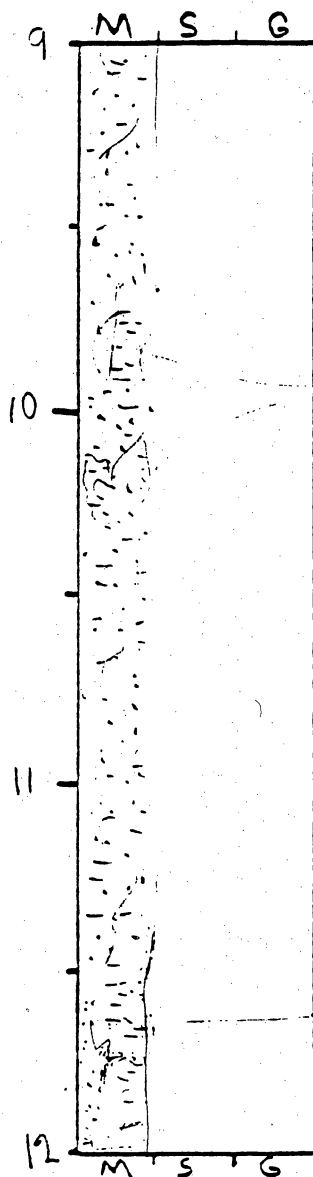


CORE LOG

CORE # SPY-25 (D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft. m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



V. muddy sand
 + locally
 sandy mud
 scattered small shell
 frags < 5%

intensely
 burrowed

Olive gray
 154 3/2

discrete mud clasts

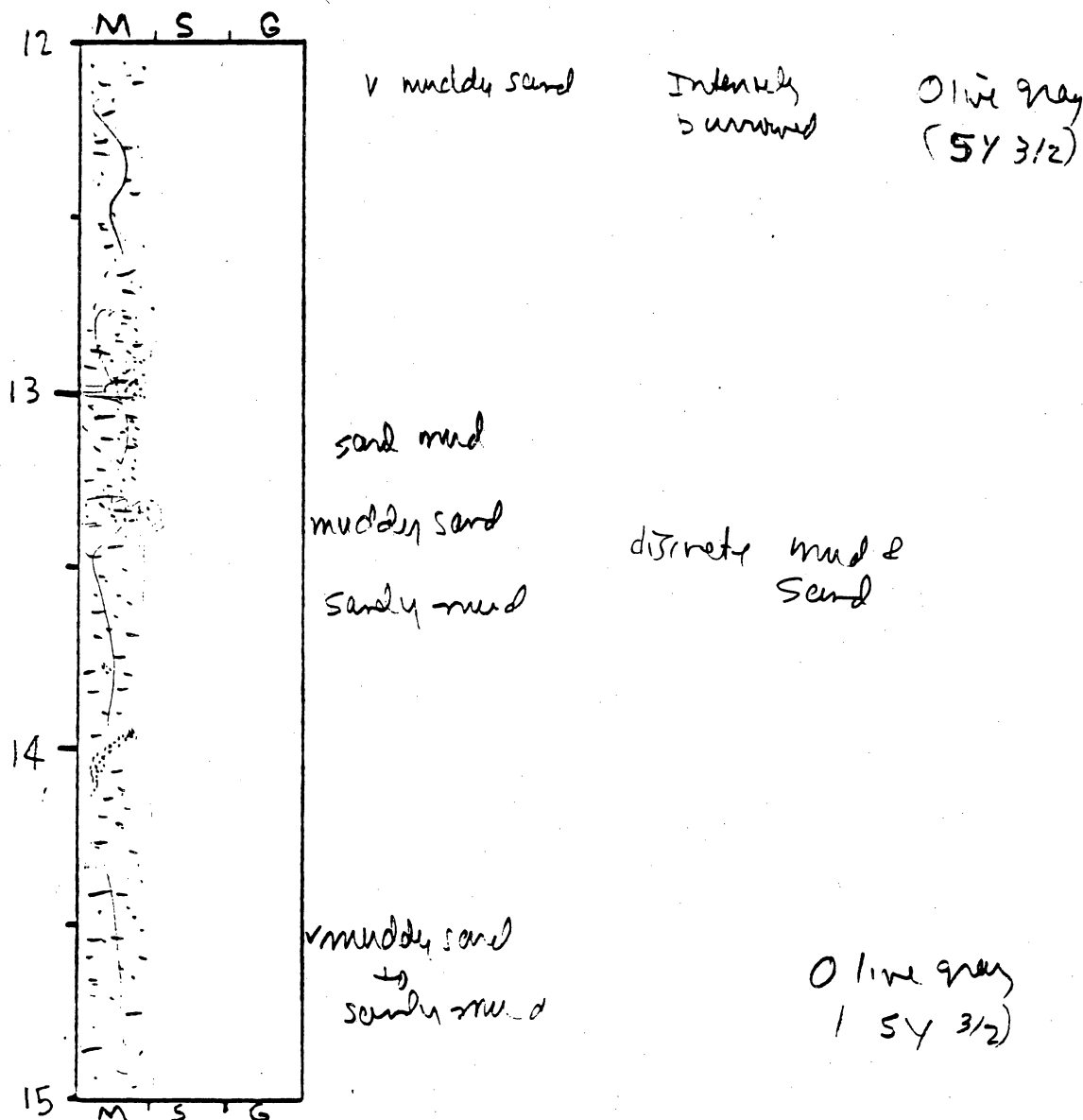
mud clast
 approaching sandy mud in composition

General Comments:

CORE LOG

CORE # SBV-25(E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



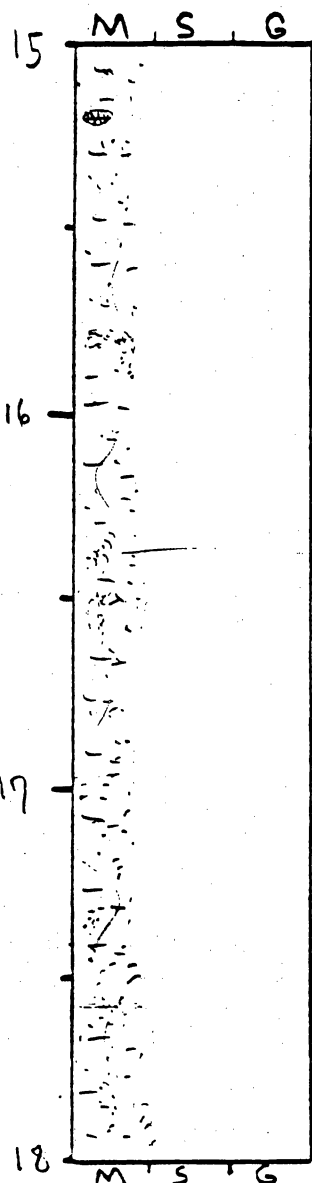
General Comments:

CORE LOG

CORE # SBV-25(E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



✓ muddy sand
 to sandy mud
 scattered shell frags < 1% except for local pockets
 intensely burrowed
 Olive Gray
 (5 y 3/2)

well pocket (small shell frags) 10 to 15% coarse to granule

intensely
 burrowed

sandy mud
 (mud appears dominant in this
 area)

muddy sand

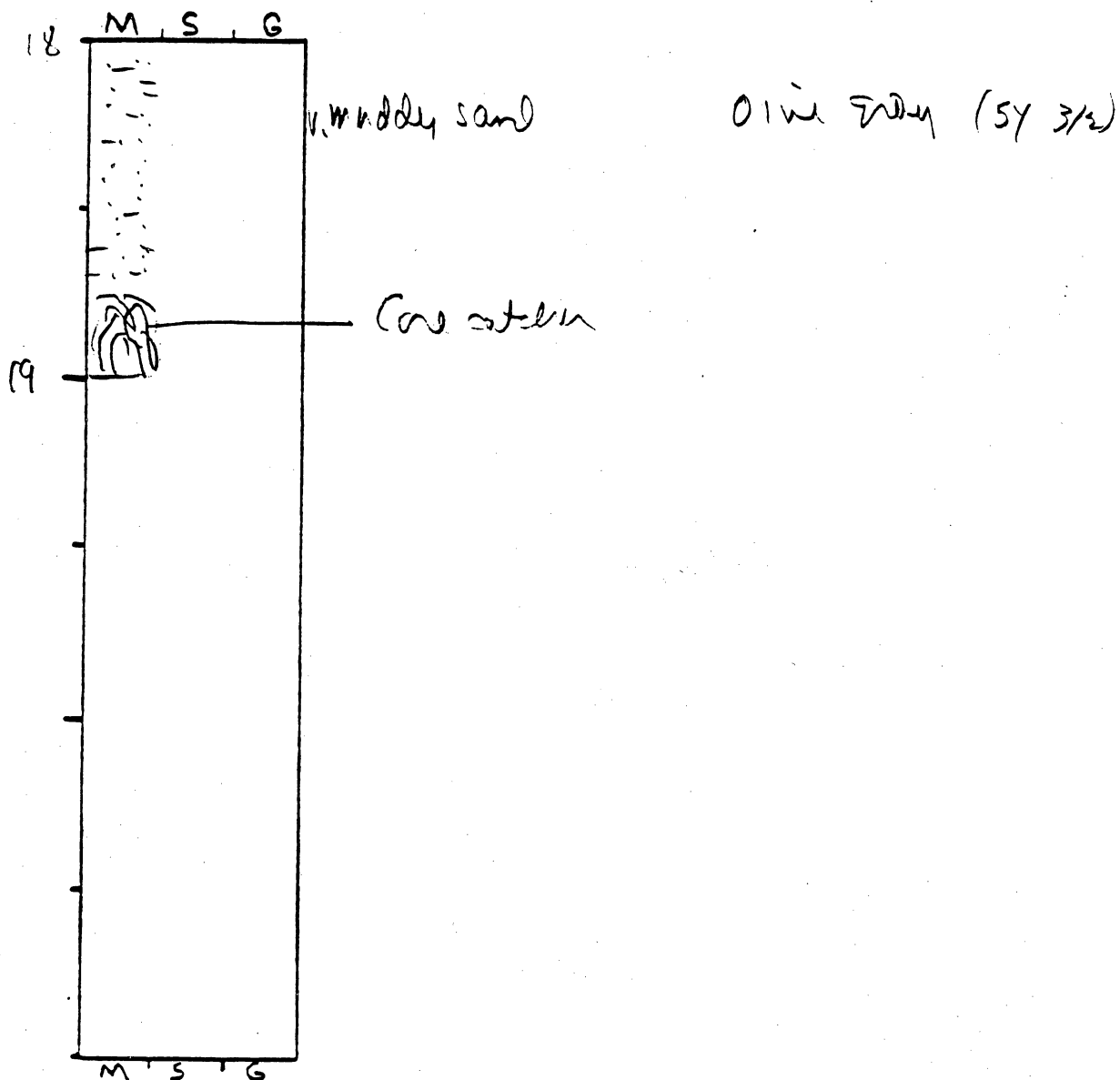
General Comments:

CORE LOG

CORE # SBV-25(G) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft. m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



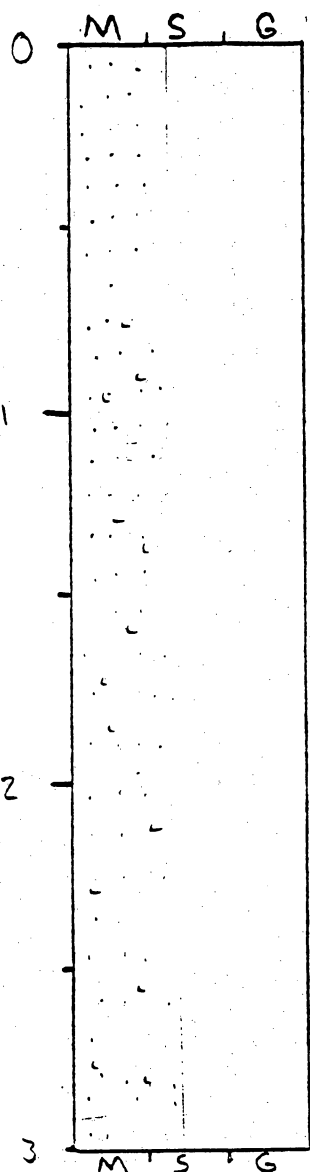
General Comments:

CORE LOG

CORE # HBV-1(A) TYPE Vibracore LOCATION Hoold Bank
 LATITUDE 20° 07.646' LONGITUDE 92° 11.265' SURFACE ELEVATION -28.5'
 DEPTH PENETRATED ? LENGTH RECOVERED 9' 2" % COMPACTION ?

OBTAINED BY Gibeault / R/V Kit Jones DATE 10-12-94
 DESCRIBED BY White DATE

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



Fine quartz sand (99%)
 Very well sorted
 Sub rounded to rounded

Light olive gray
 to yellowish gray

scattered & smaller
 granule size shell
 fragments (< 2%)
 more apparent below
 0.6'

1.1 - 1.4' gray in center of
 core

1.4 - 1.6 back to
 yellowish gray fine sand
 to light olive gray

1.6 - 2.8

Fine sand - medium dark gray
 with hint of light olive gray
 light olive gray along margins
 next to core

scattered granule size & smaller
 shell fragments

fine, well to very well sorted, sand

light olive gray fine sand

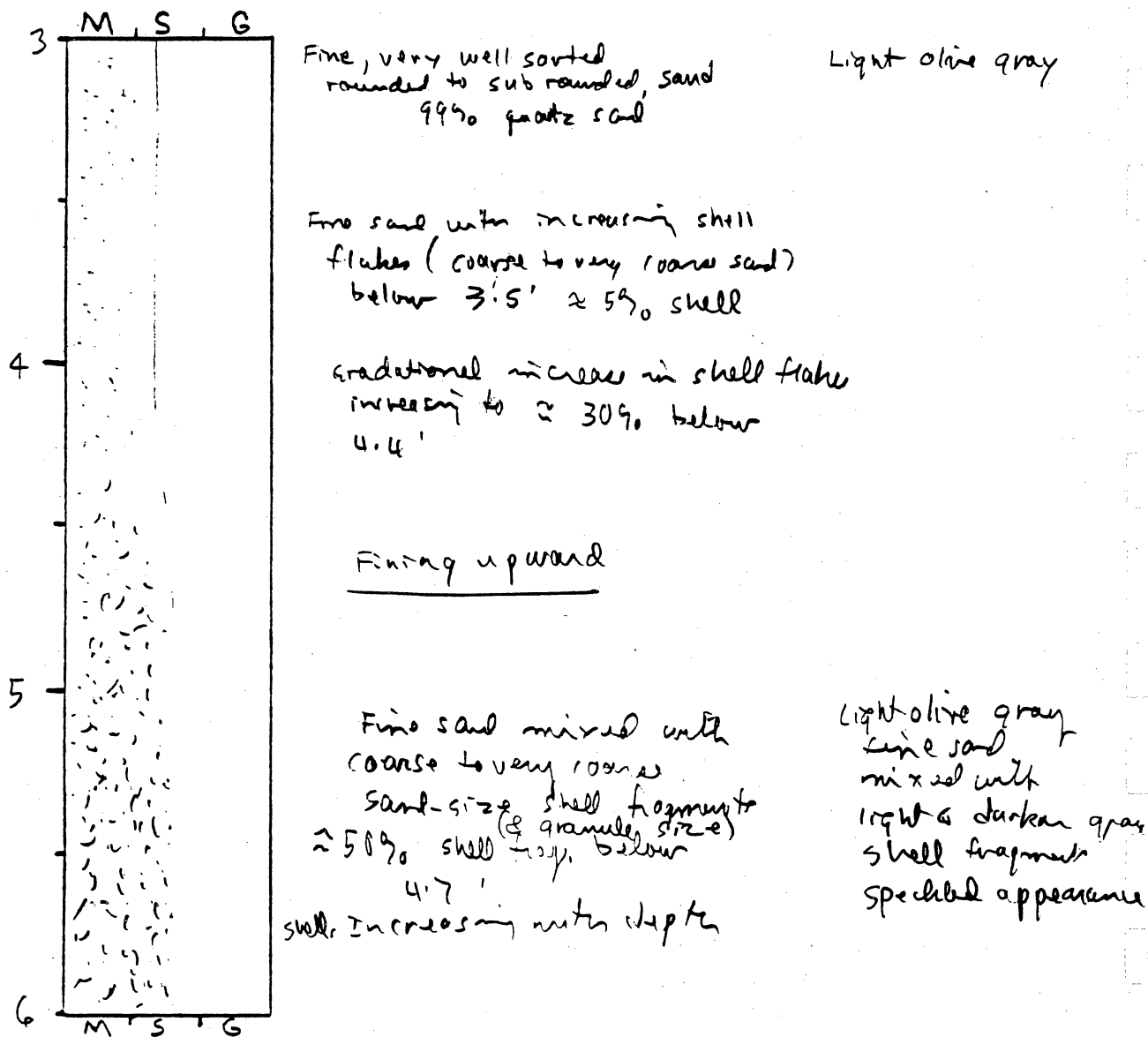
General Comments:

CORE LOG

CORE # H2V-1(B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



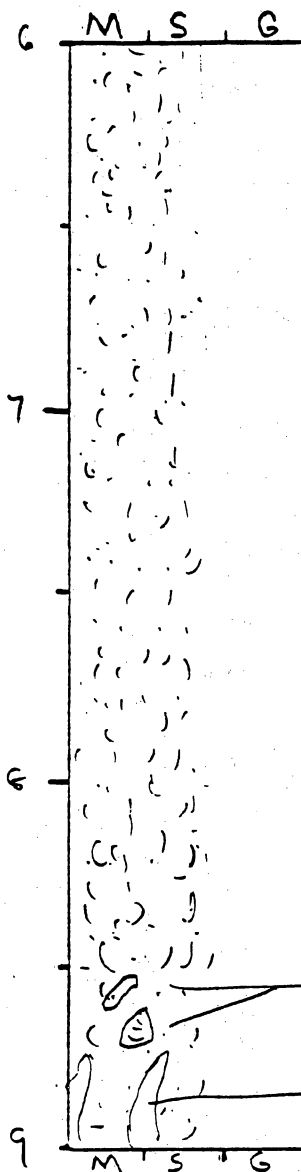
General Comments:

CORE LOG

CORE # HBV-1(C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



shelly sand or
 sandy shell
 ~ 50% shell fragments
 granule to pebble size
 mixed with fine sand

Light olive
 gray sand
 peppered with
 darker & lighter
 shell fragments

fining upward
 shells becoming more abundant
 than sand at depth

shell fragments
 becoming coarser

Sandy shell

shell fragments, 2-3 cm long.

core catcher

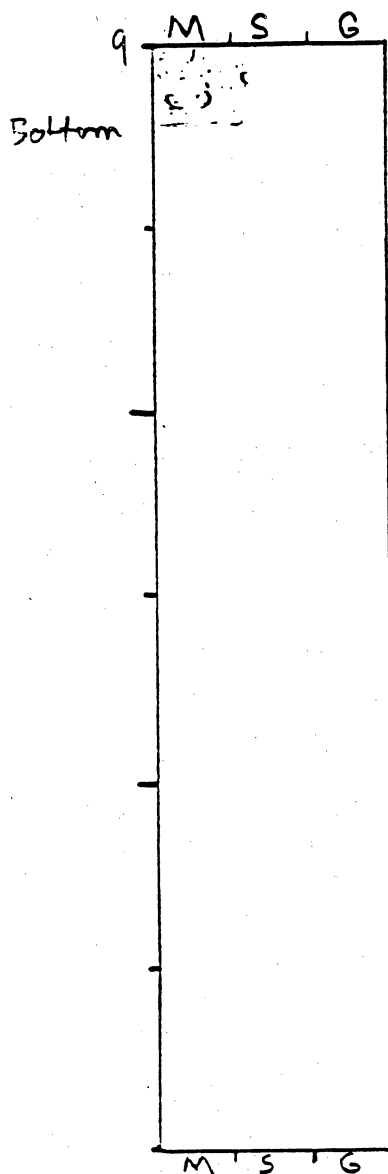
General Comments:

CORE LOG

CORE # HBV-1 (D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



Predominantly
fine quartz sand (95%)
scattered shells

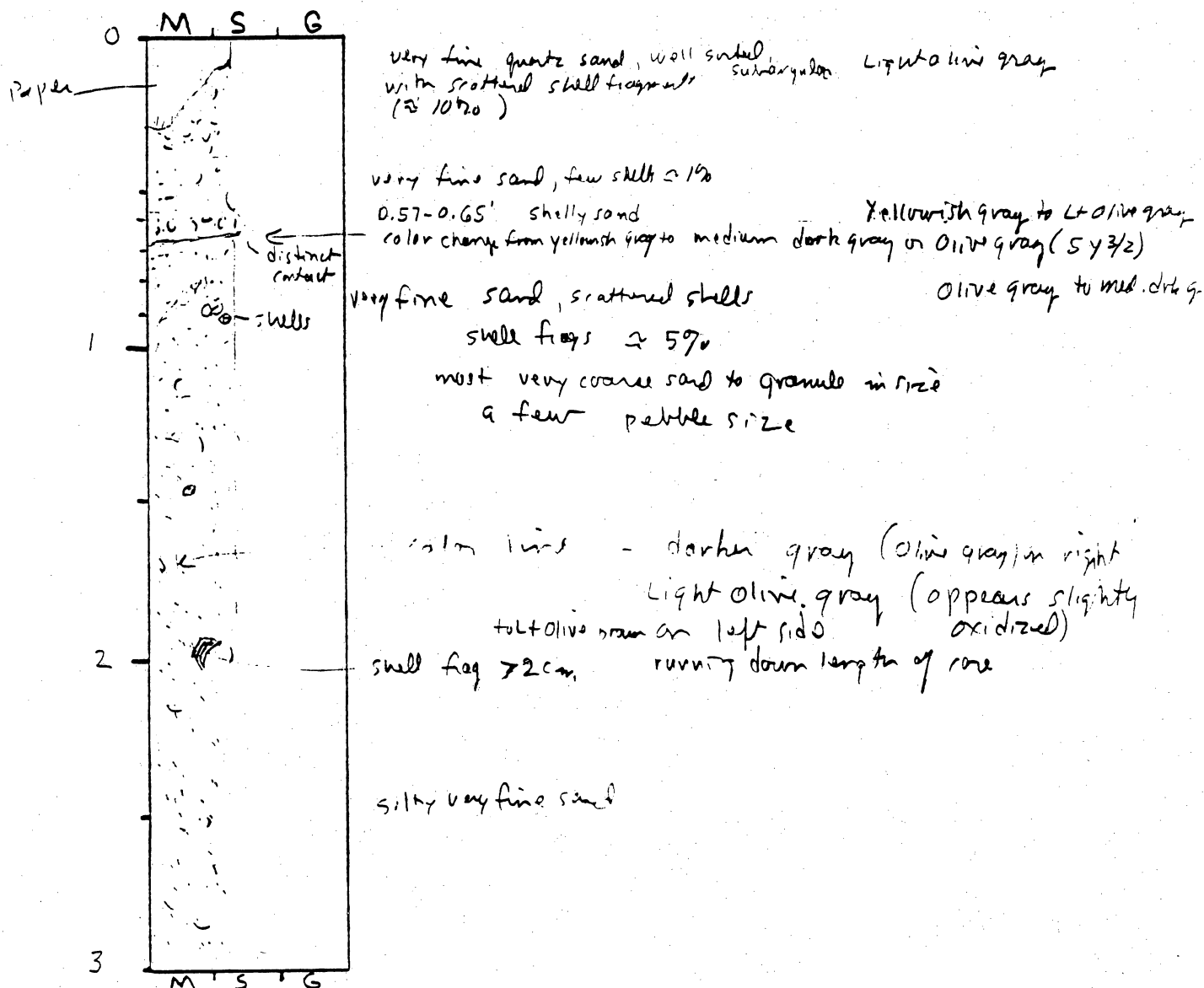
yellowish gray

General Comments:

CORE LOG

CORE # HBV-2A TYPE Vibacore LOCATION Heald Bank
 LATITUDE 29° 06.357' LONGITUDE 120° 10.097' SURFACE ELEVATION -52.5'
 DEPTH PENETRATED ? LENGTH RECOVERED 14' 7" % COMPACTION ?
 OBTAINED BY Gibson / R/V Kit Jones DATE 10-12-94
 DESCRIBED BY W. H. Fe DATE

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

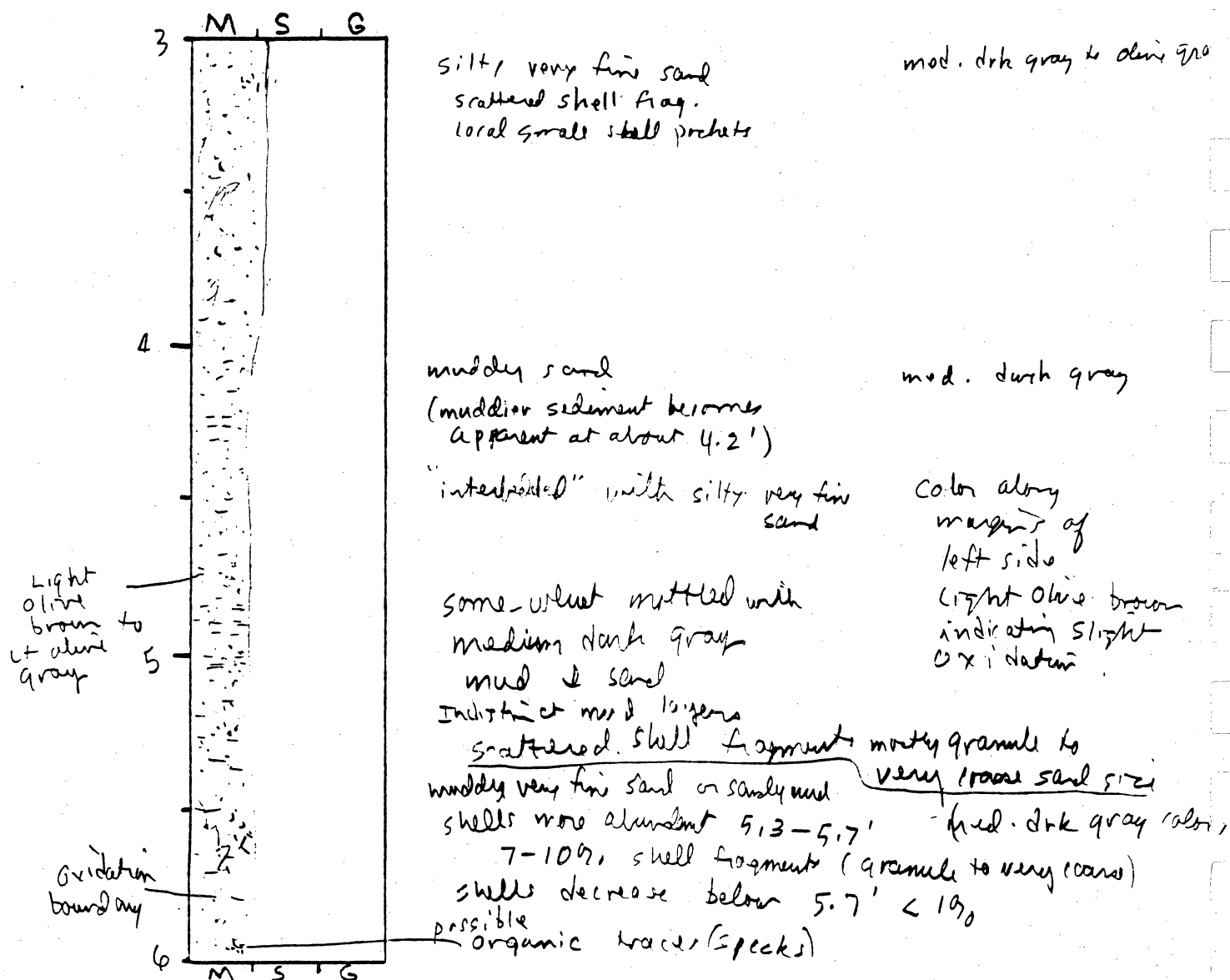


General Comments:

CORE LOG

CORE # 4BY-2(B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH
 (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



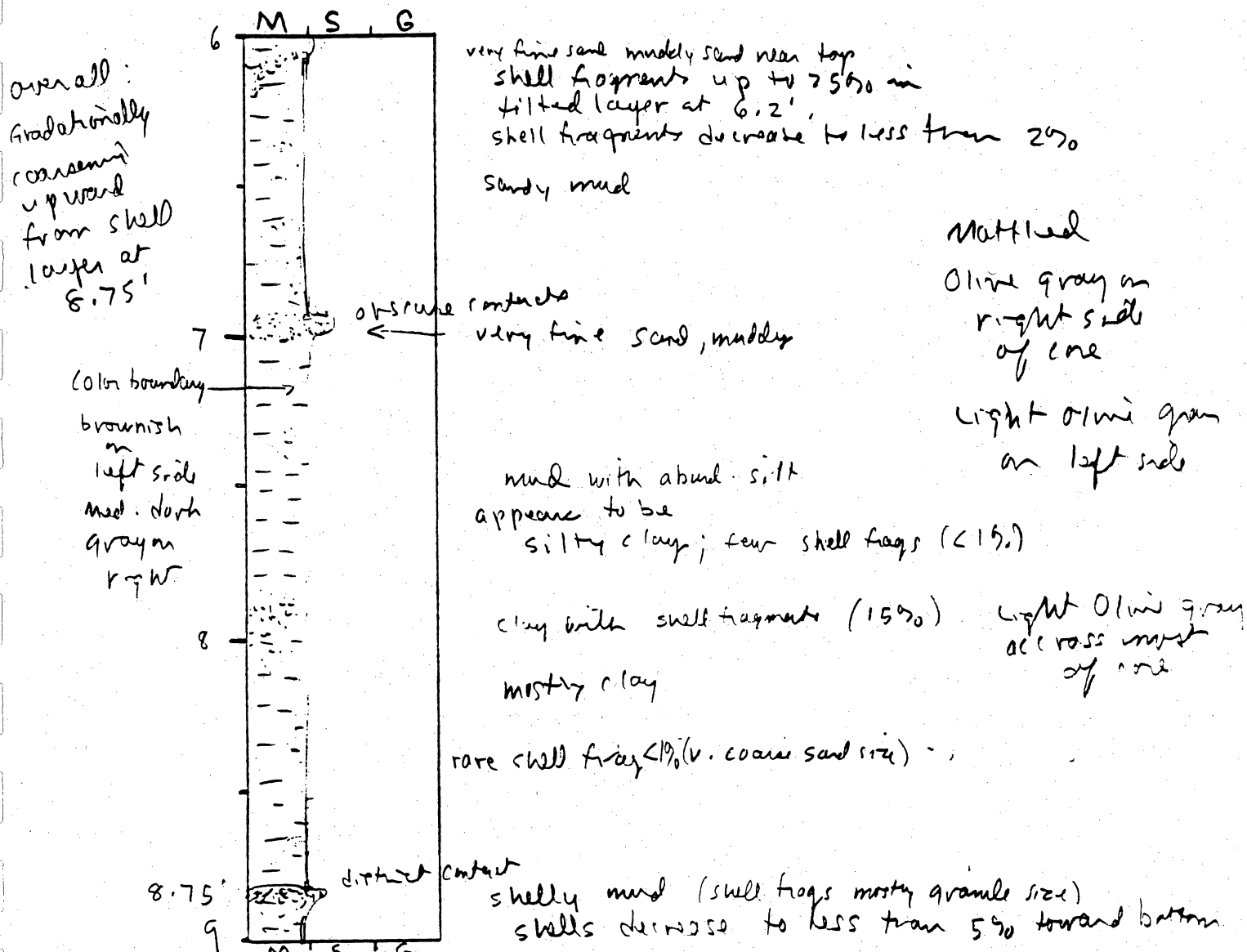
General Comments:

CORE LOG

CORE # HBV-2(C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



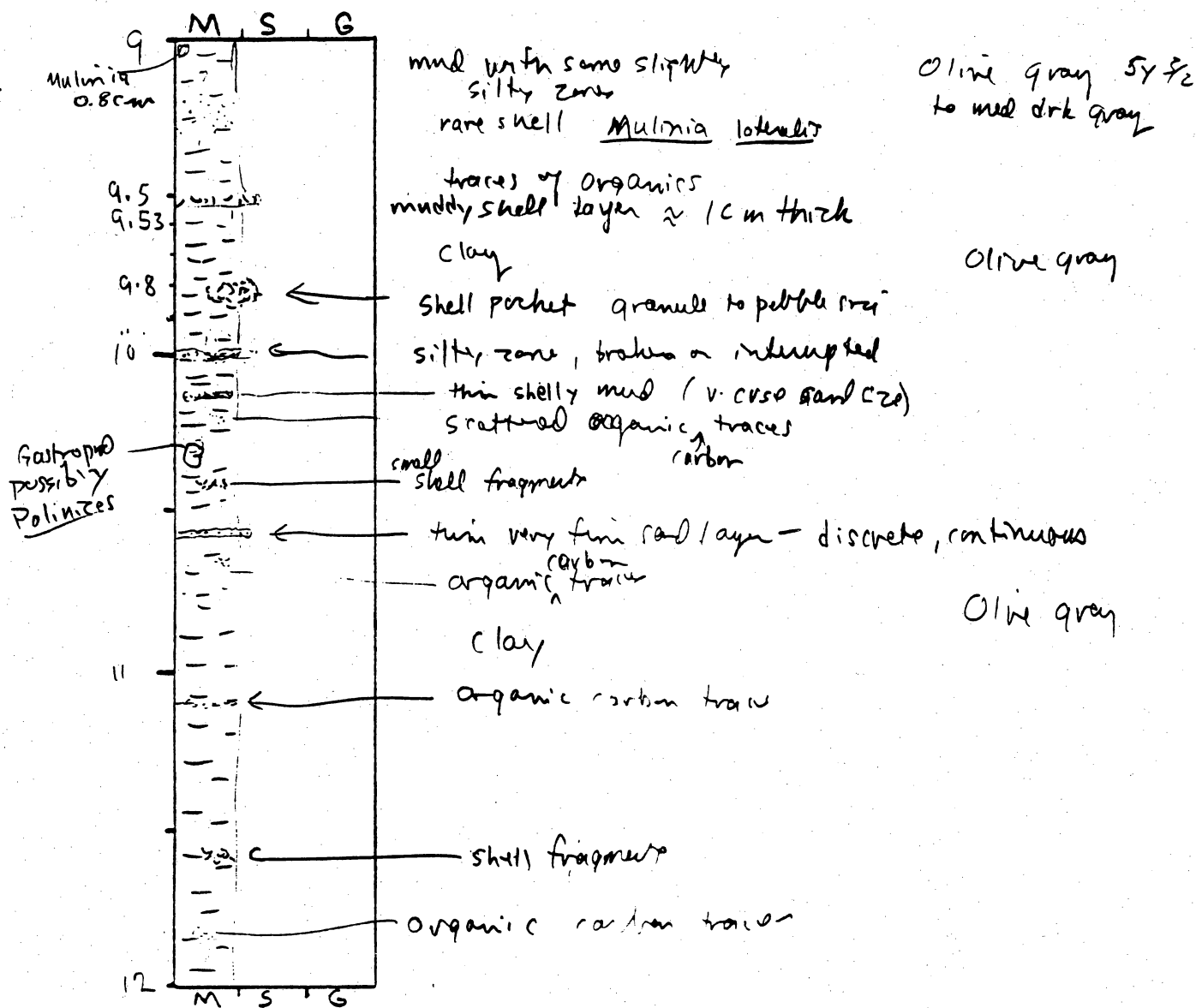
General Comments:

CORE LOG

CORE # HBV-2(D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



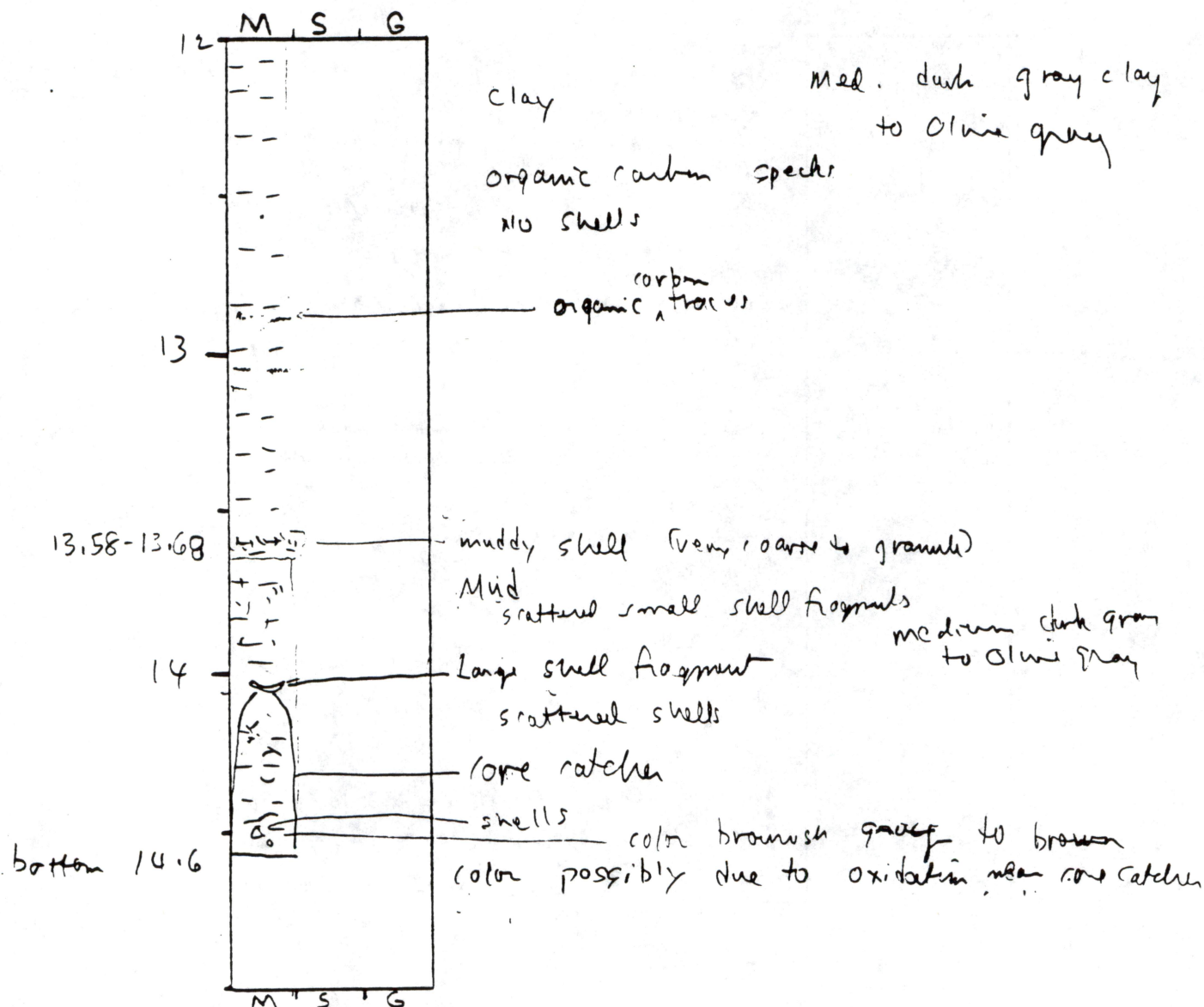
General Comments:

CORE LOG

CORE # HBV-2(E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



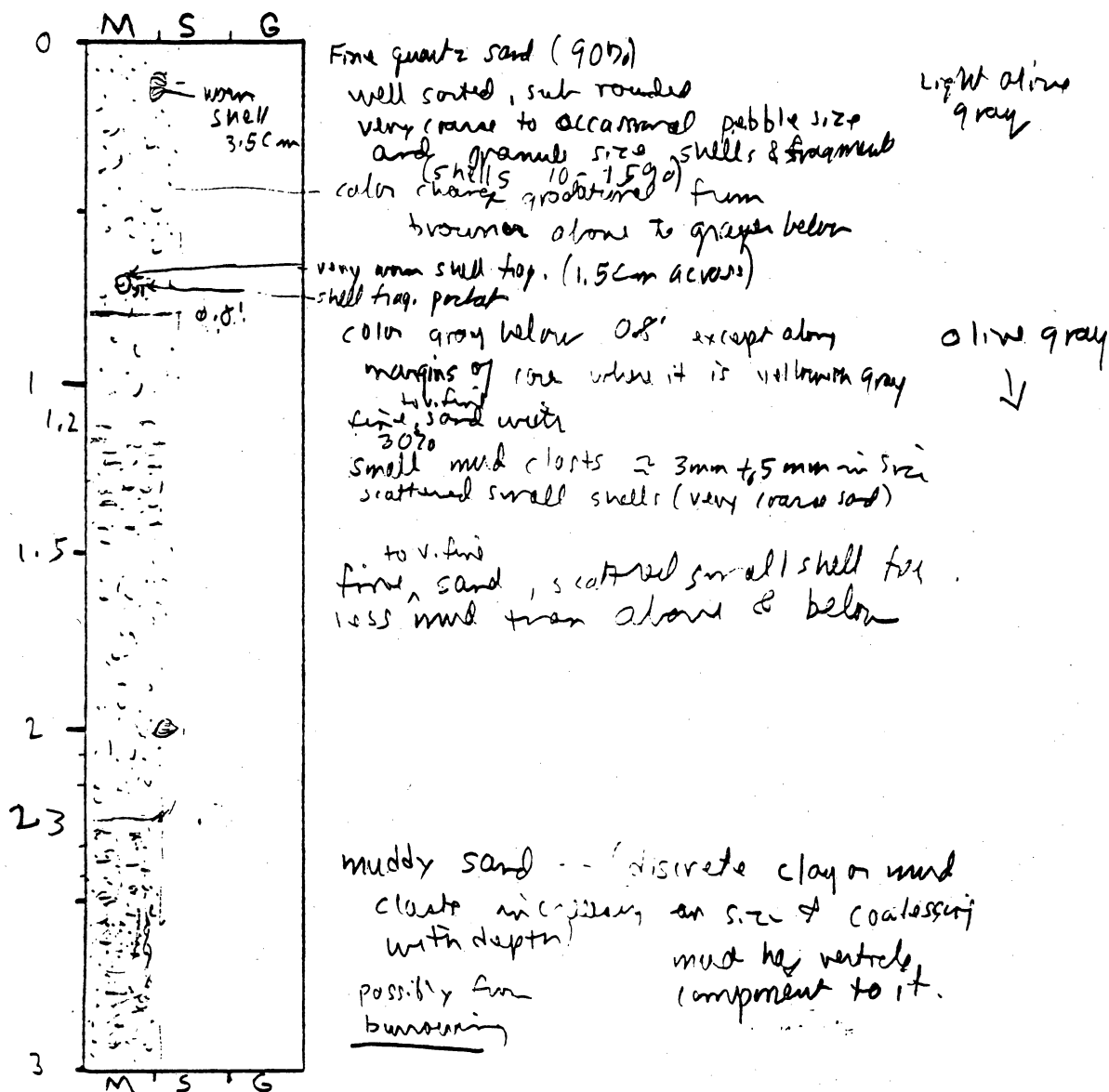
General Comments:

CORE LOG

CORE # HBY-3(A) TYPE Vibro core LOCATION Hould Bank
 LATITUDE 29° 07.373 LONGITUDE 24° 13.163 SURFACE ELEVATION -43.5'
 DEPTH PENETRATED ? LENGTH RECOVERED 20' % COMPACTION ?

OBTAINED BY G. Beant - R/V Kit Jones DATE 10-12-94
 DESCRIBED BY J. White DATE

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS

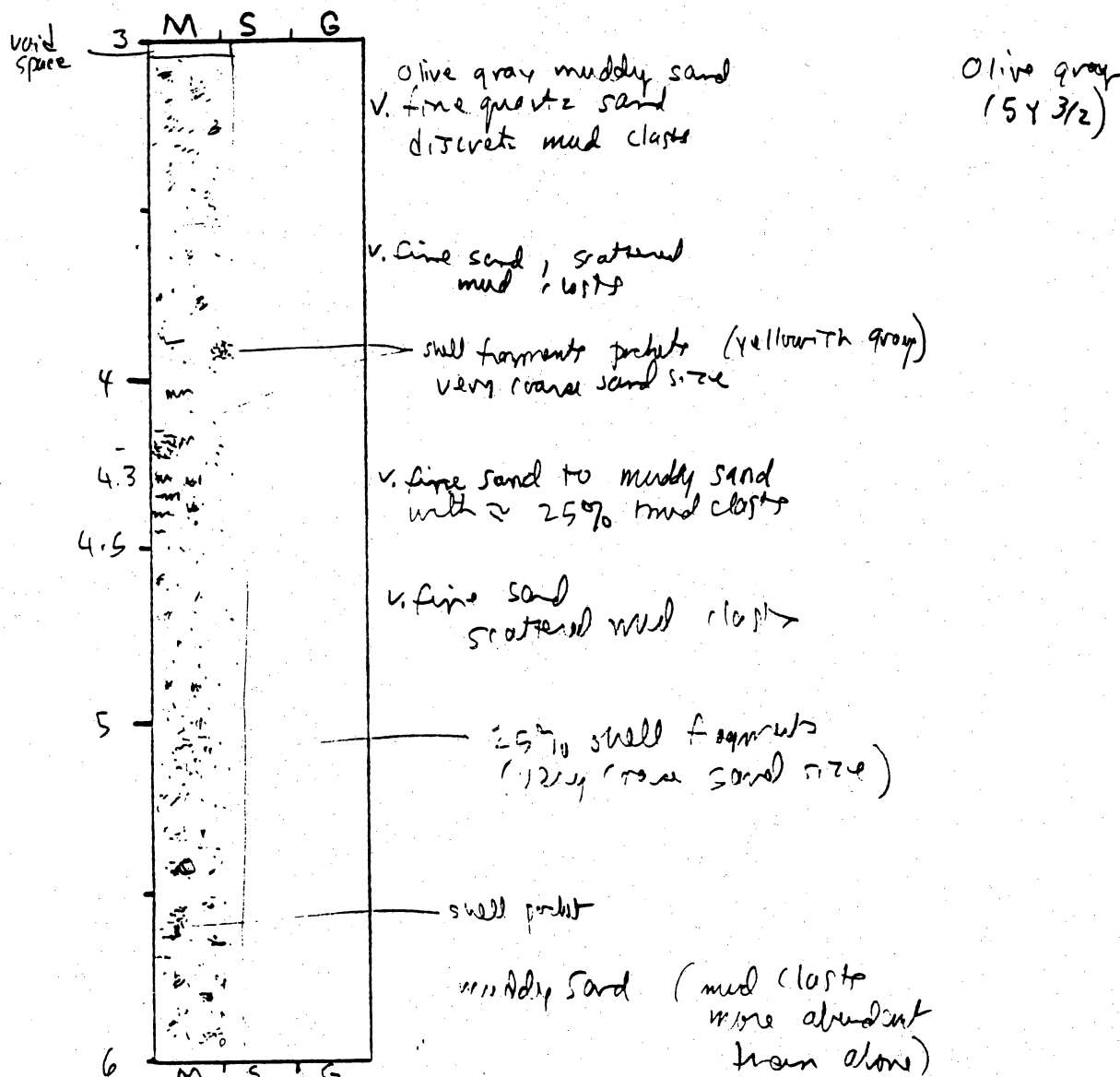


General Comments:

CORE LOG

CORE # H3V-3(3) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



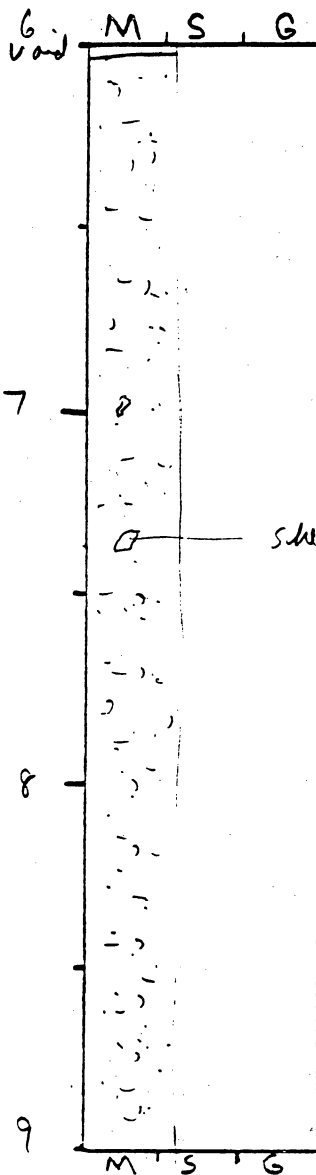
General Comments:

CORE LOG

CORE # H3V-3 (C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



fine sand slightly muddy
 scattered small (coarse to
 very coarse) shell fragments
 ~ 10% fragments
 rare large fragments

oliv gray

shell frag.

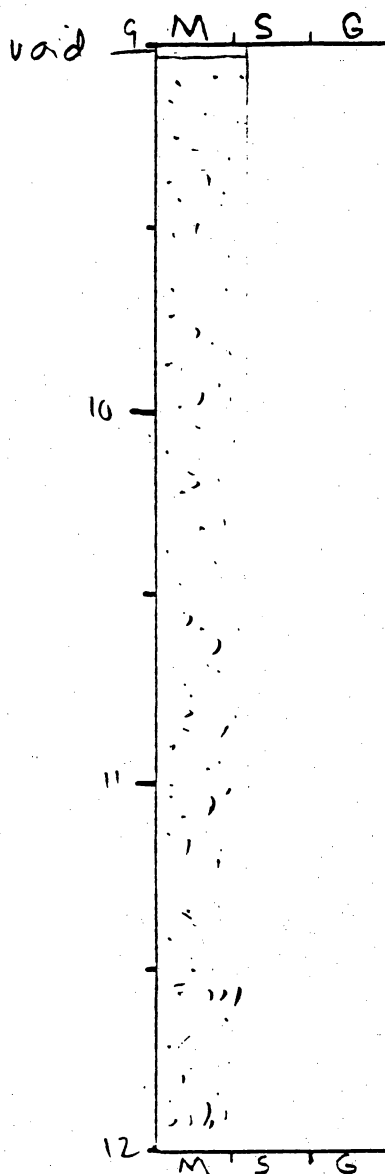
General Comments:

CORE LOG

CORE # HBV-3(D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



slightly muddy v. fine sand
 scattered small shell fragments
 (< 5%)

Olive gray
 with
 light olive gray to
 light olive brown
 mottling fair left
 side of core
 (and right side
 near bottom).

shell fragment increases in
 abundance and size below
 ~ 10.5' (approx.) ~ 10%
 Locally concentrated ~ 20%

General Comments:

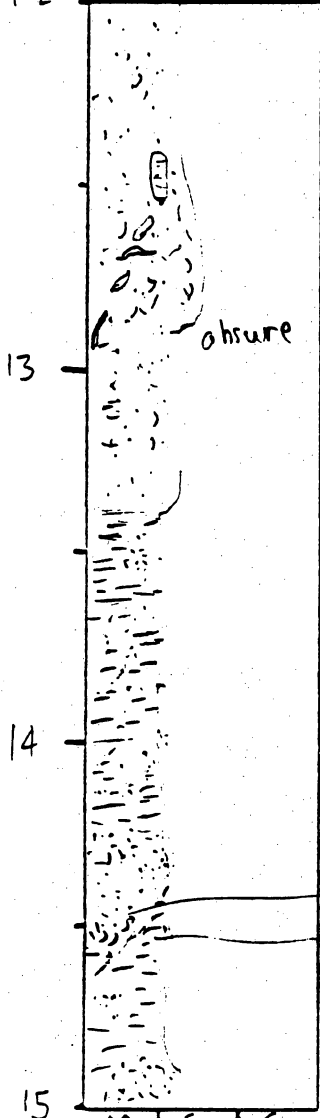
CORE LOG

CORE # 45V-3 (E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

12 M S G



v. fine sand
 slightly muddy
 scattered shells
 10%

olive
 gray
 (51 3/2)

increase in shells (some gravel size)
 > 25% shelly sand

13 obscure contact

v. fine sand
 increase in mud with depth
 scattered shells
 muddy sand to sandy mud (Mottling & irregular
 contact possibly due
 to burrowing)

14

13.7' - 14'
 mud becomes dominant
 (sandy mud)

muddy sand

shell pocket muddy shelly sand
 dipping contact

mud dominant (sandy mud)

15

sand dominant scattered shells

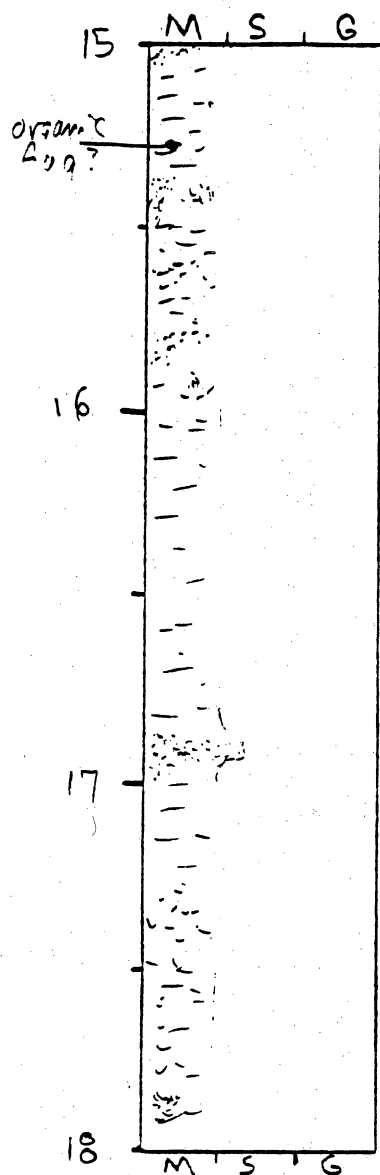
General Comments:

CORE LOG

CORE # HBV-3(F) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



mottled clay
 with pockets
 of shell frag.
 & sand

mottled
 thin layer
 of core
 thin light
 olive gray to
 olive gray

sand (very fine) fragments

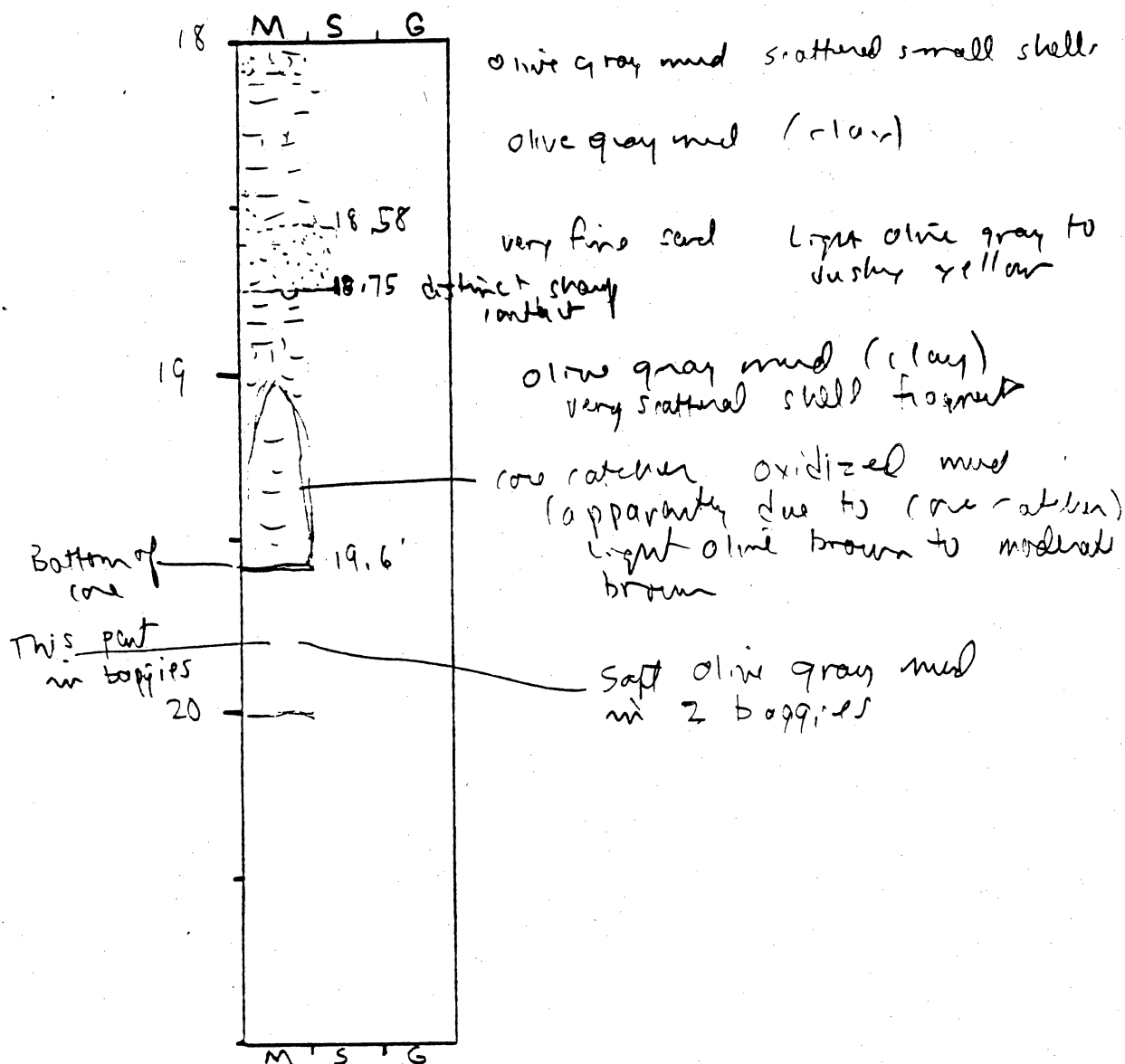
General Comments:

CORE LOG

CORE # H2V-3(S) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



General Comments:

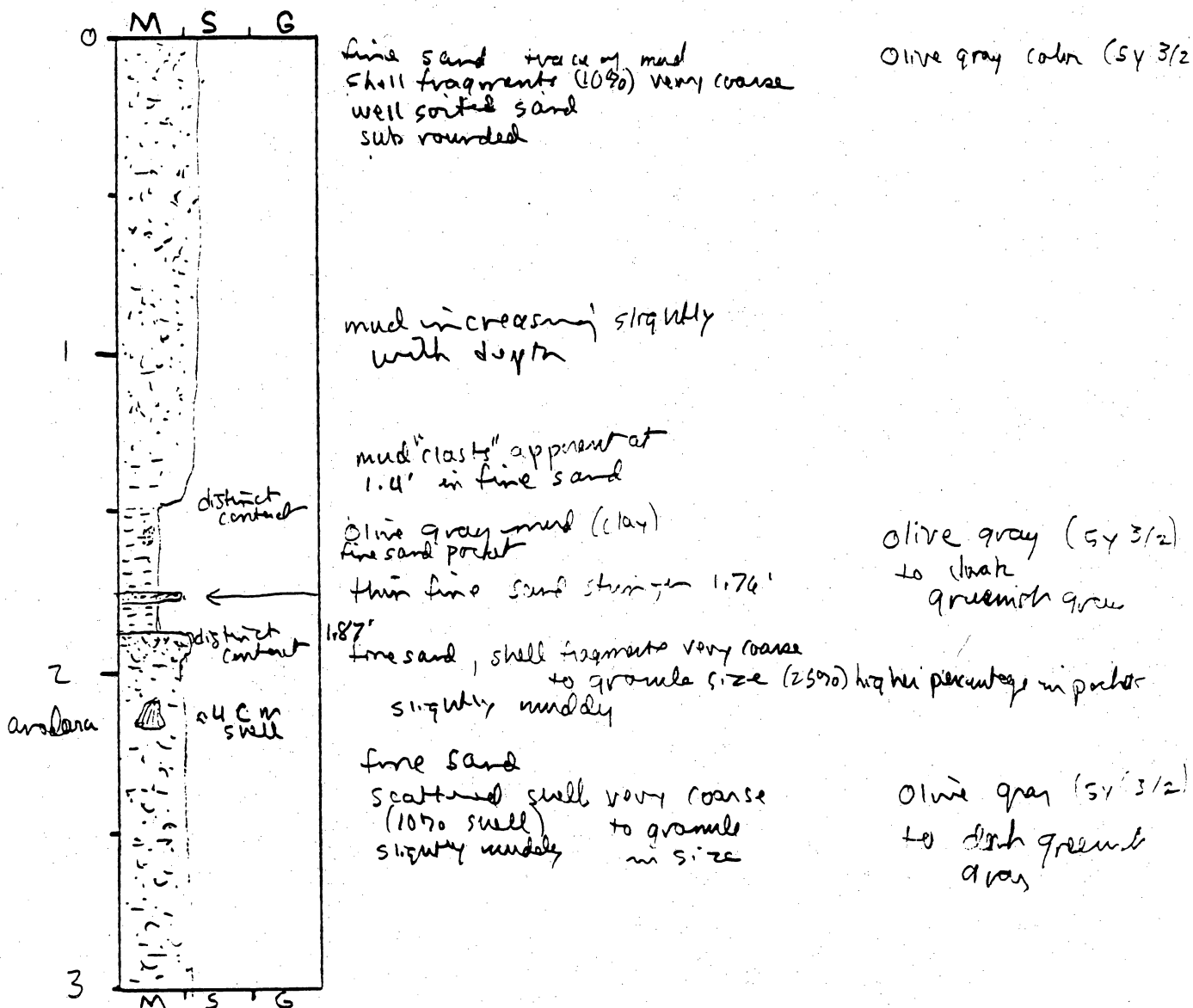
Photograph 1-25-95

CORE LOG

CORE # HBV-4(A) TYPE Vibrocore LOCATION Heald Bank
 LATITUDE 29° 08.443 LONGITUDE 94° 11.565 SURFACE ELEVATION -57.5'
 DEPTH PENETRATED ? LENGTH RECOVERED 15' 2 1/2" % COMPACTION ?

OBTAINED BY G. beault - R/V Kit Jones DATE 10-12-94
 DESCRIBED BY J. White DATE

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

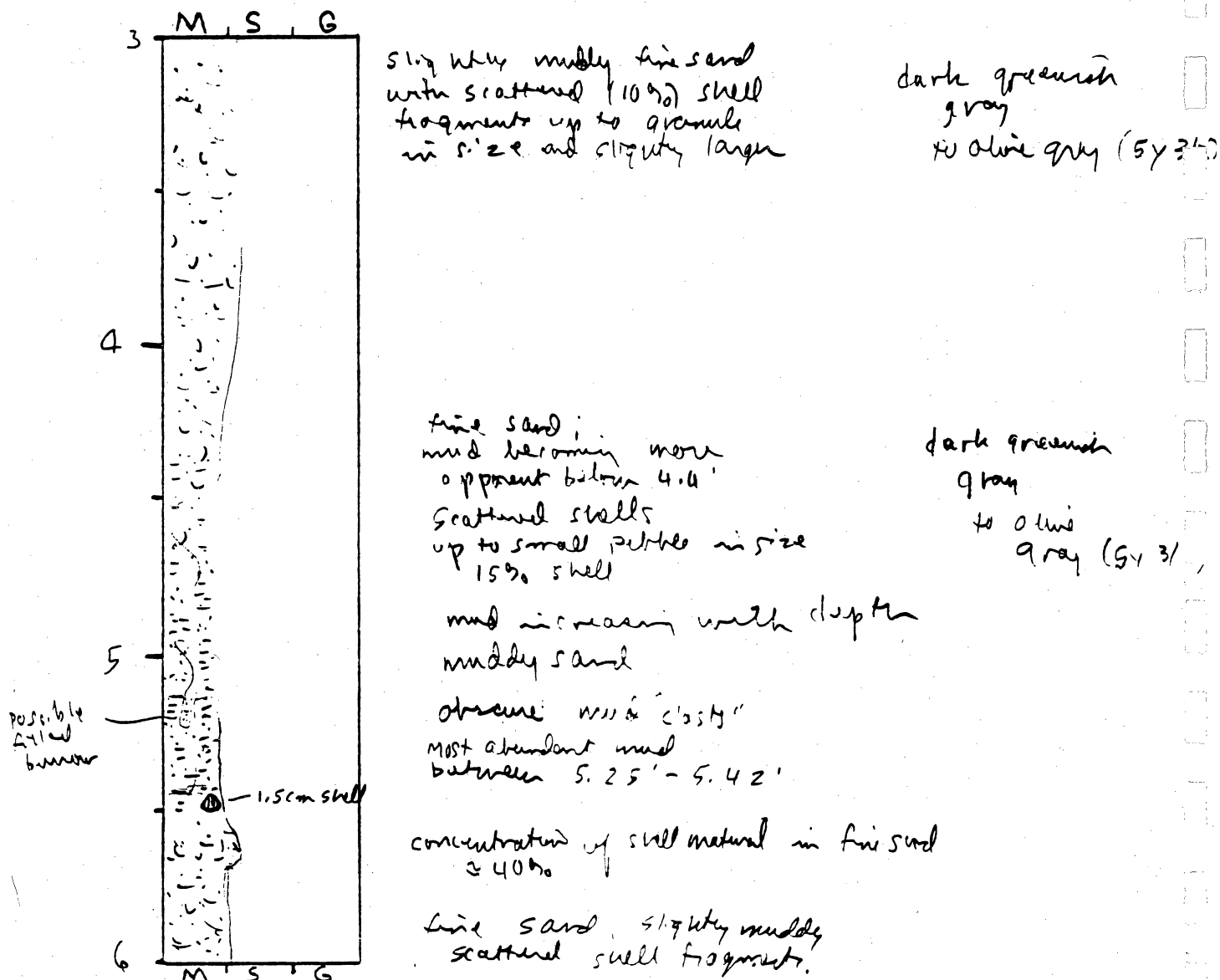


General Comments:

CORE LOG

CORE # HBV-4(8) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



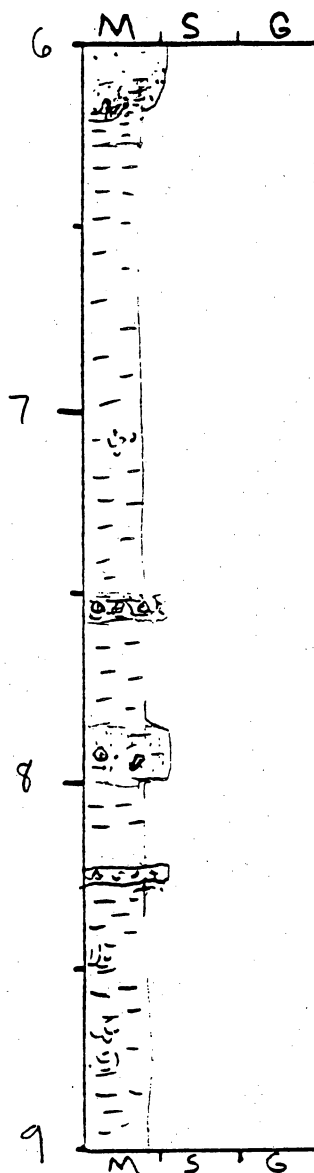
General Comments:

CORE LOG

CORE # HBV-4(c) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



fine sand, slightly muddy, scattered shells
 distinct contact at 6.25'
 but irregular surface possibly from rain
 or burrowing.

Clay
 few shell fragments

Local shell pocket

shelly muddy sand stringer

fine sand scattered shells (up to small
 pebbles in size)
 muddy

shell stringer at 8.25-8.30'
 gravel size

clay mud
 slightly sandy
 shell pockets, gravel
 in size.

olive gray (5Y 3/2)
 to
 dark greenish
 gray

(5Y 3/2)
 olive gray to
 dark greenish
 gray

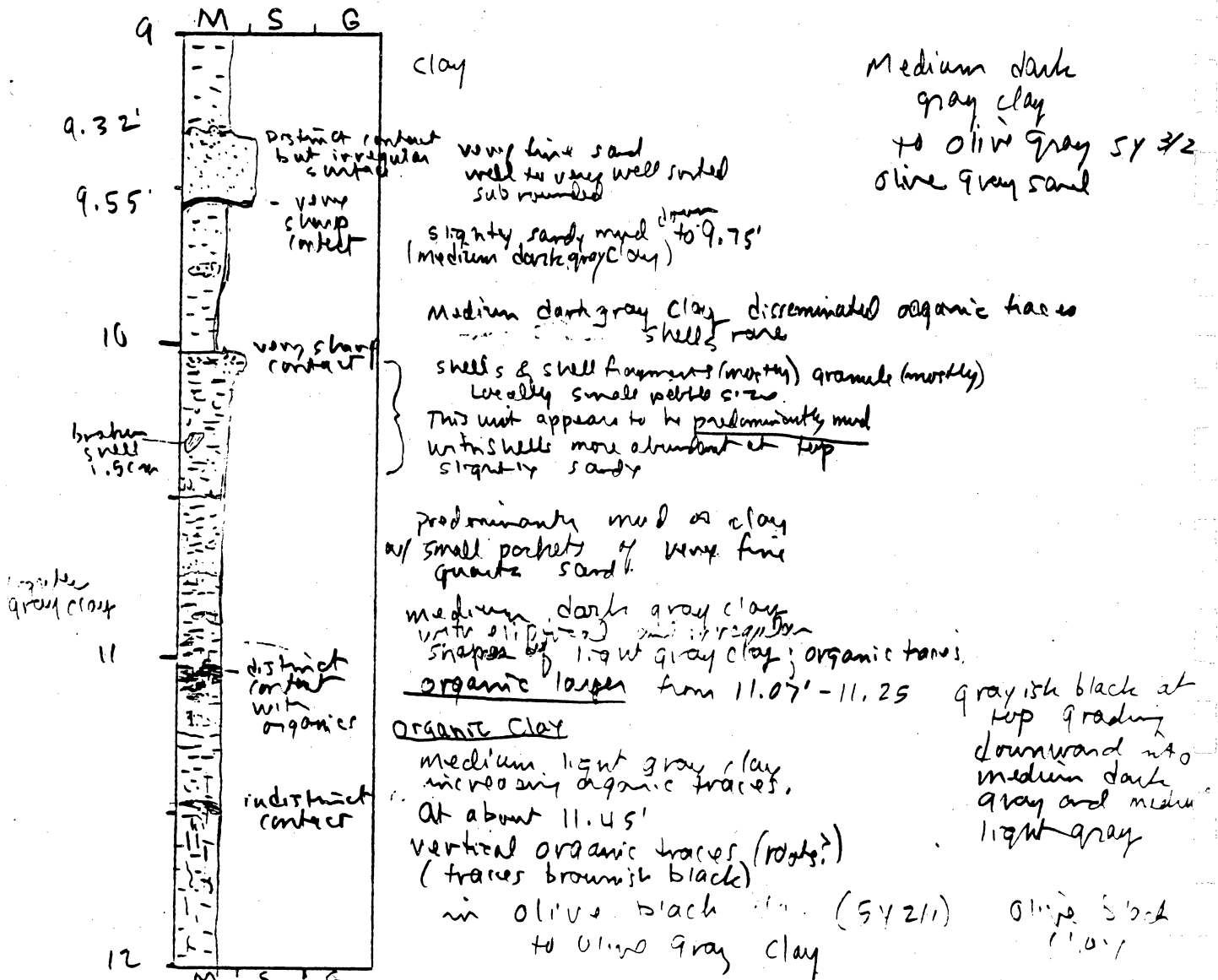
General Comments:

CORE LOG

CORE # HBV-4 (D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



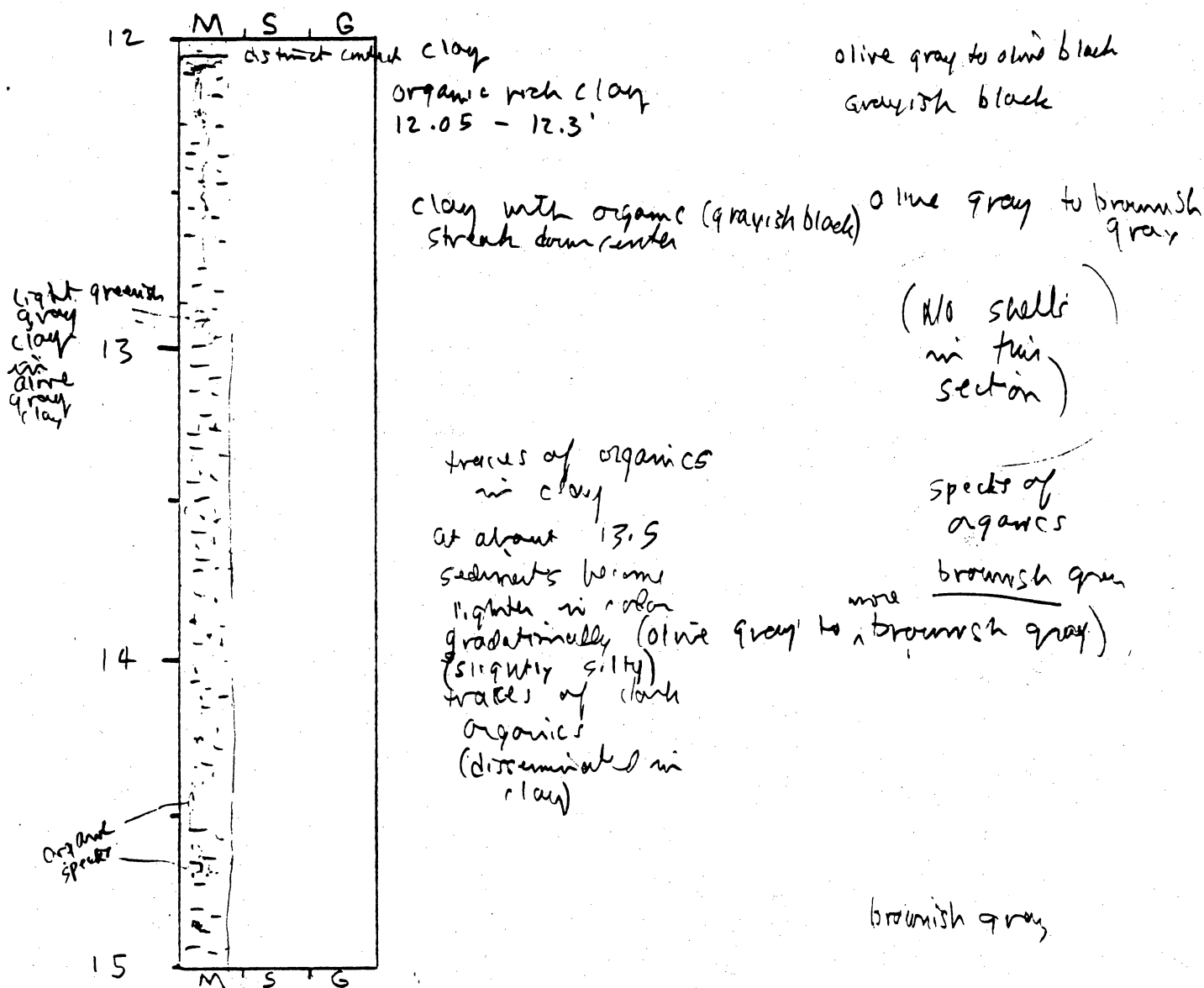
General Comments:

CORE LOG

CORE # HBV-4(E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS

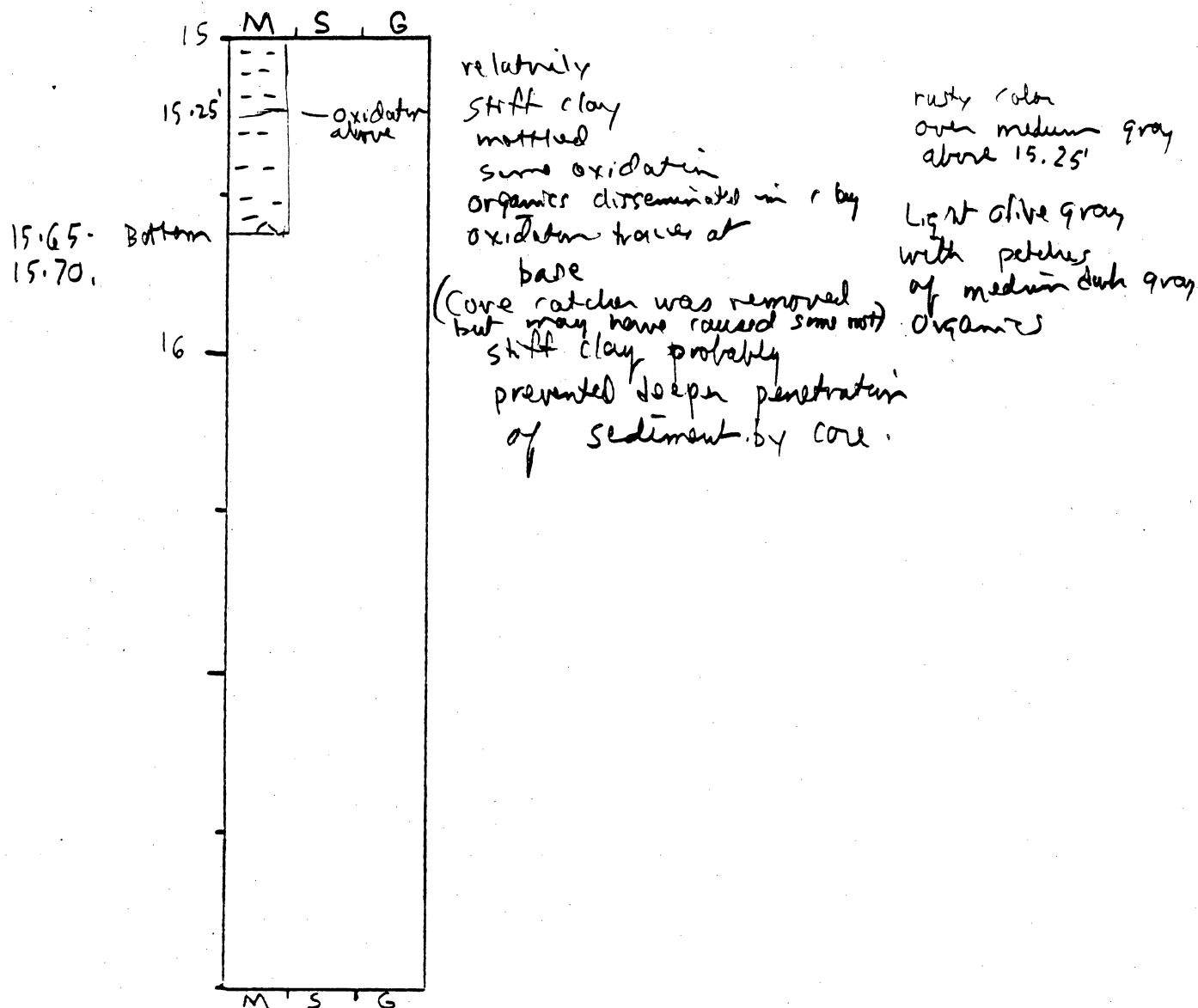


CORE LOG

CORE # HBV-4(F) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



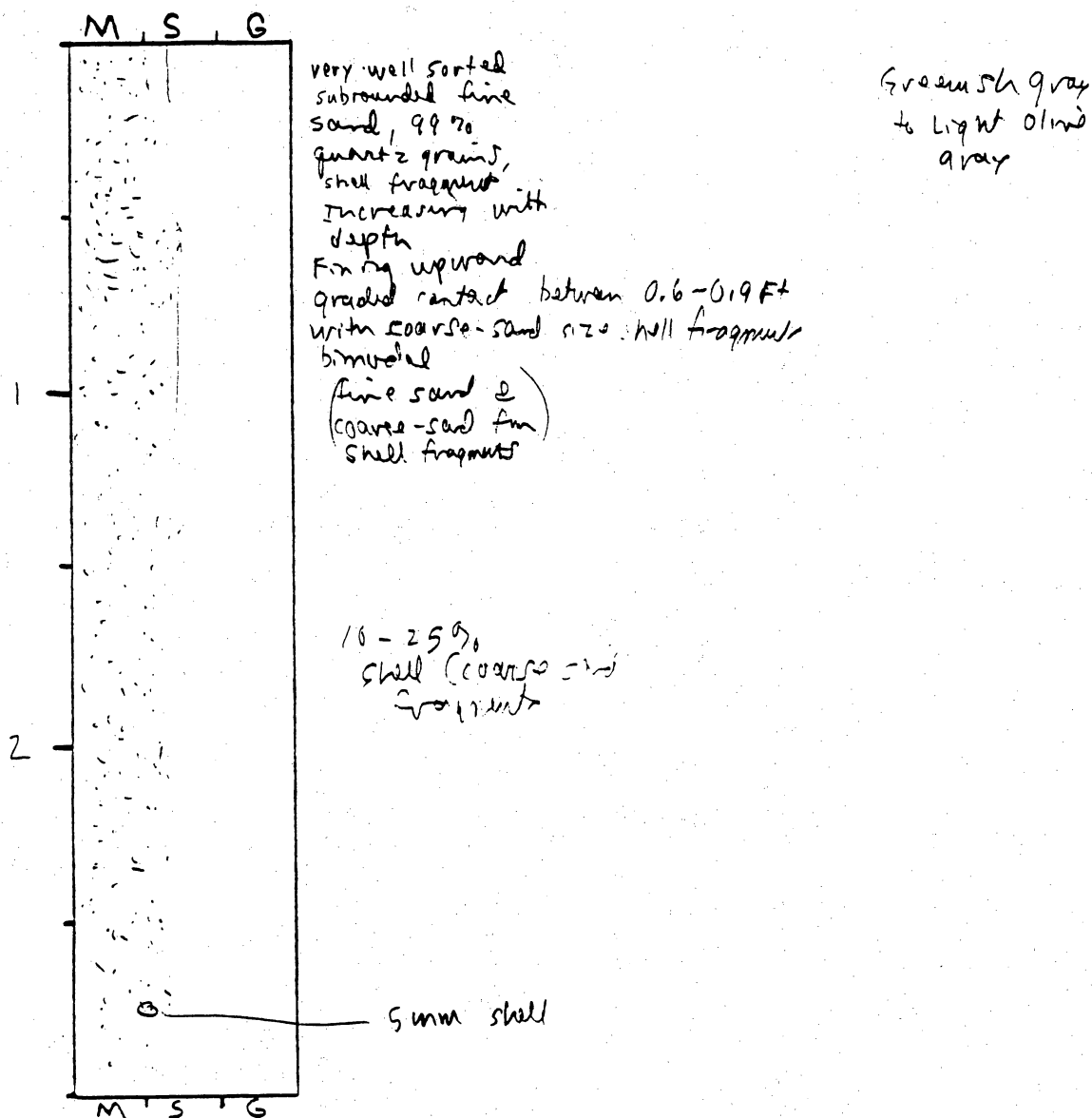
General Comments:

CORE LOG

CORE # HBV-5 (A) TYPE Vibro core LOCATION Heald Bank
 LATITUDE 29° 02.13' LONGITUDE 74° 11.025' SURFACE ELEVATION -35'
 DEPTH PENETRATED ? LENGTH RECOVERED 19' 10" % COMPACTION ?

OBTAINED BY G. Beauchamp - R/V Kit Jones DATE 10-12-94
 DESCRIBED BY White DATE

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



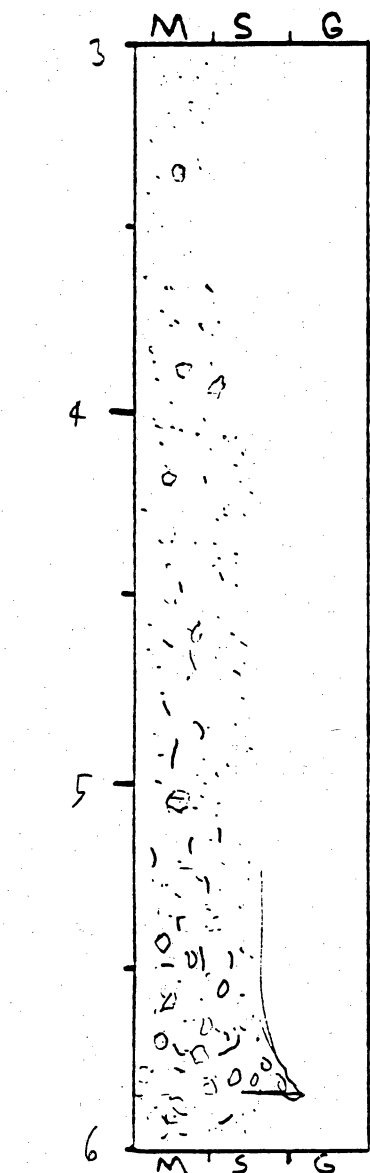
General Comments:

CORE LOG

CORE # H3V-S (8) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



Fine, predominantly
 quartz sand (sub rounded)
 with scattered ^{very} (well sorted)
 shells & shell
 fragments

Light
 olive gray

Increase in shell with
 depth
 Obscure contact at 2 3.8'
 (graded) fine well-sorted
 sand & increasing
 shell fragments
 very coarse

fine quartz sand
 with coarse sand
 sized shell fragments
 and scattered
 gravel sized shell
 increasing to depth of 5.75'

5.75' obscure contact
 with decrease in
 shell below
 fine sand with
 scattered shell

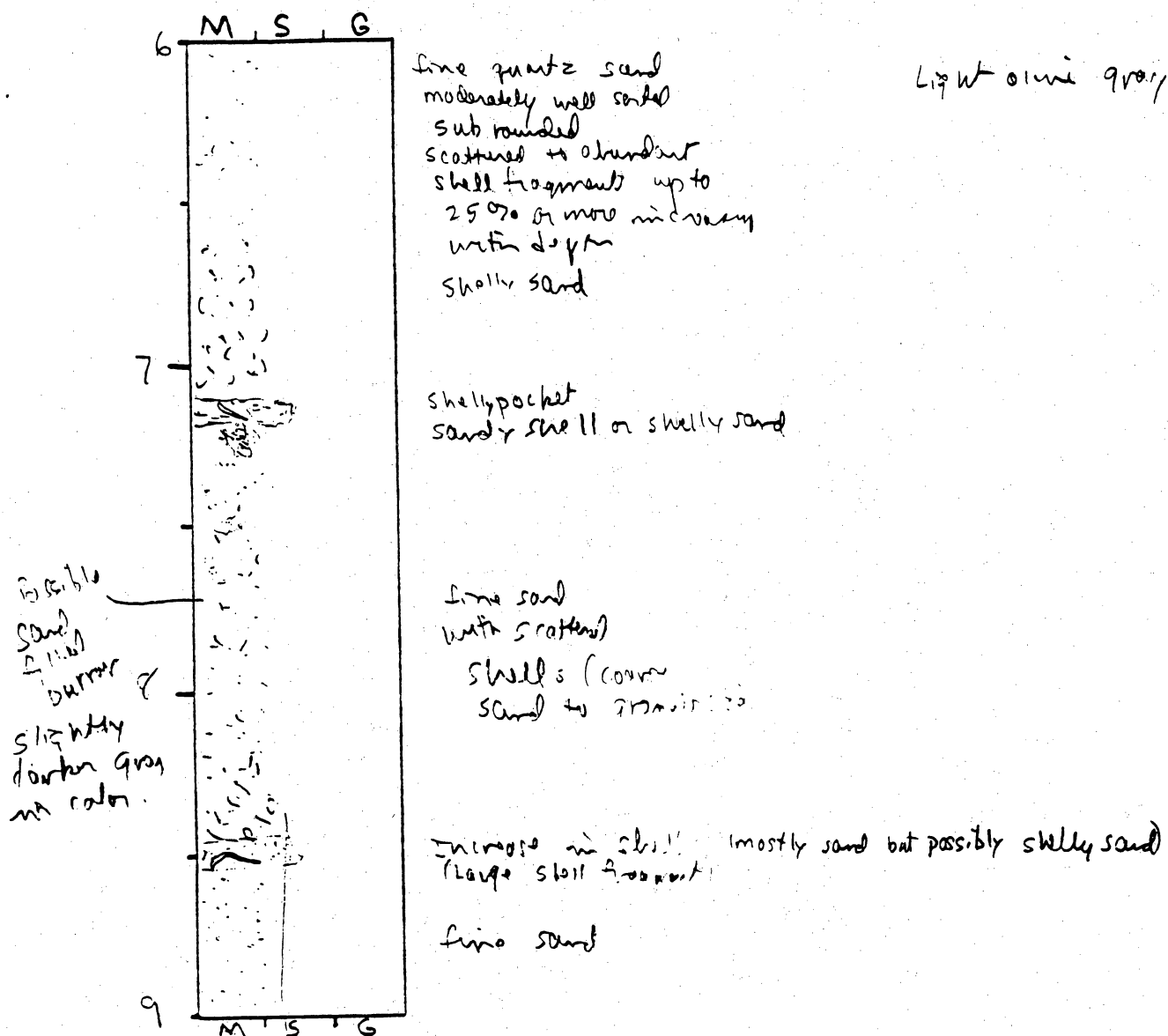
General Comments:

CORE LOG

CORE # HBV-5(C) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



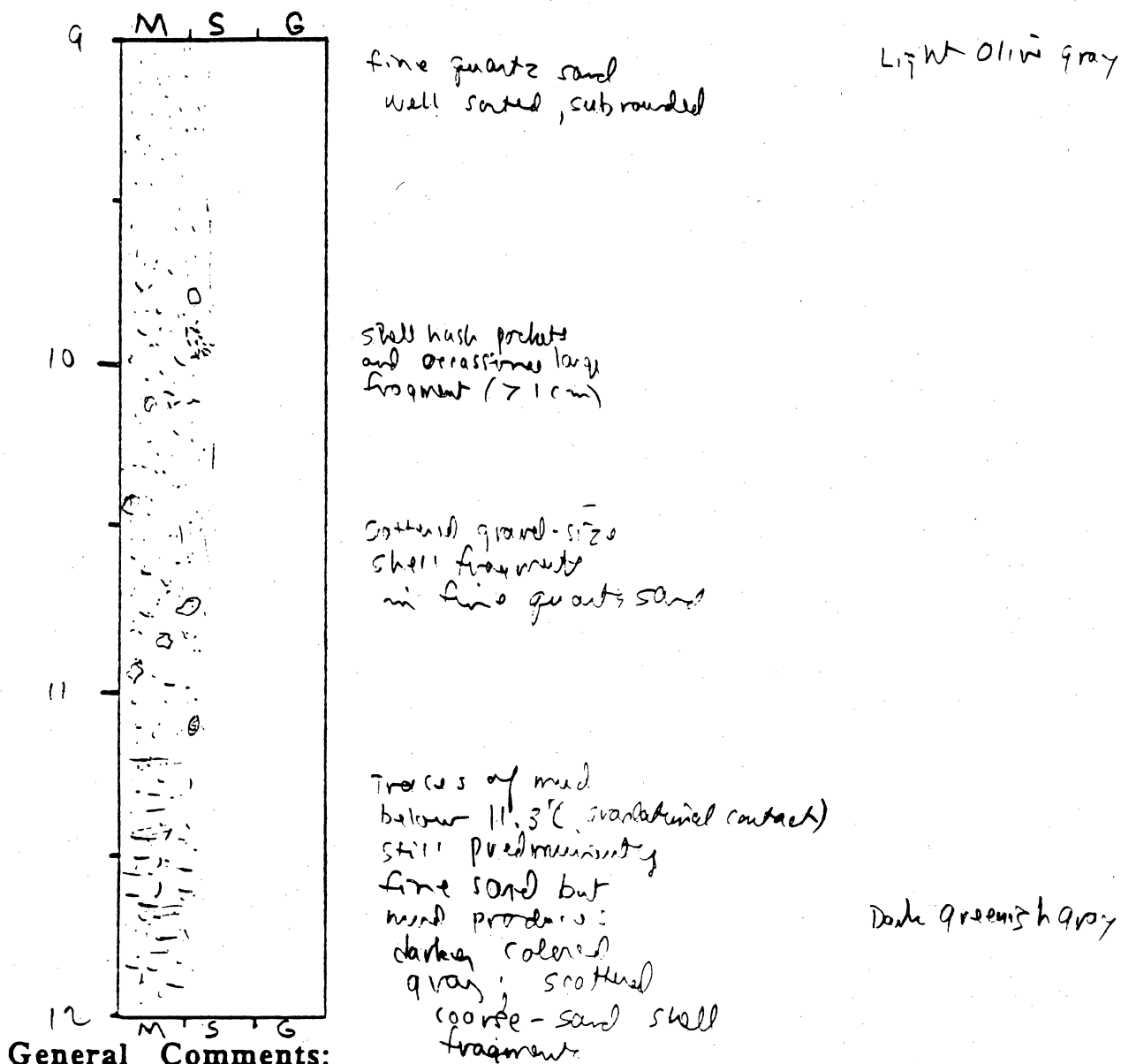
General Comments:

CORE LOG

CORE # 143V-5(D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS

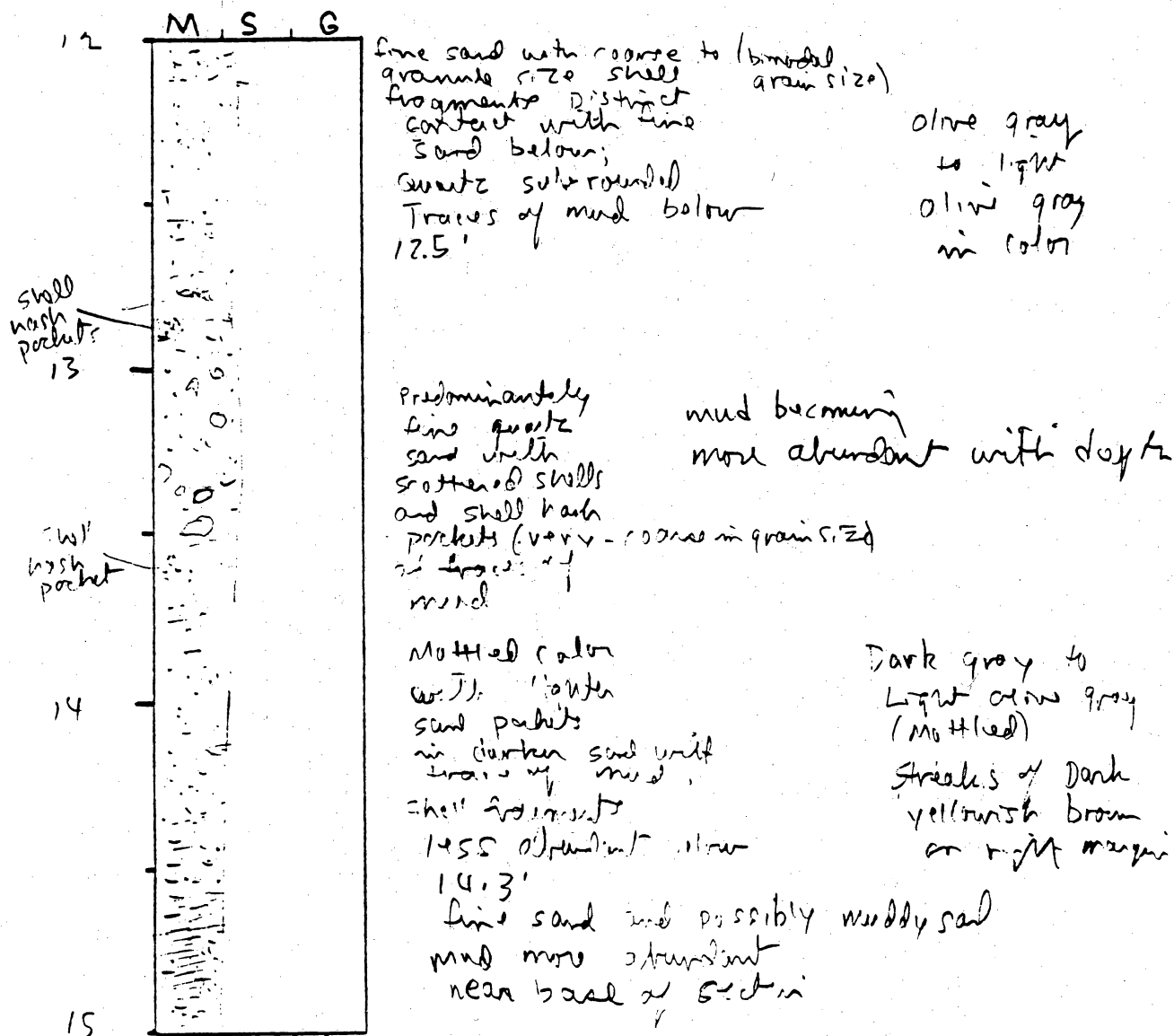


CORE LOG

CORE # HBV-5 (E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



General Comments:

CORE LOG

CORE # LBV-5 (F) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS

| | | | | |
|----|-------|---|--|--|
| 15 | M S G | fine quartz sand well sorted | | olive gray becoming dark greenish gray to dark gray below 15.4' |
| 16 | | fine quartz sand scattered shell fragments & occasional small (1-2 mm) shell hash pockets and more concentrated sand pockets slightly mottled | | Dark greenish gray to Dark gray |
| 17 | | | | |
| 18 | M S G | | | |

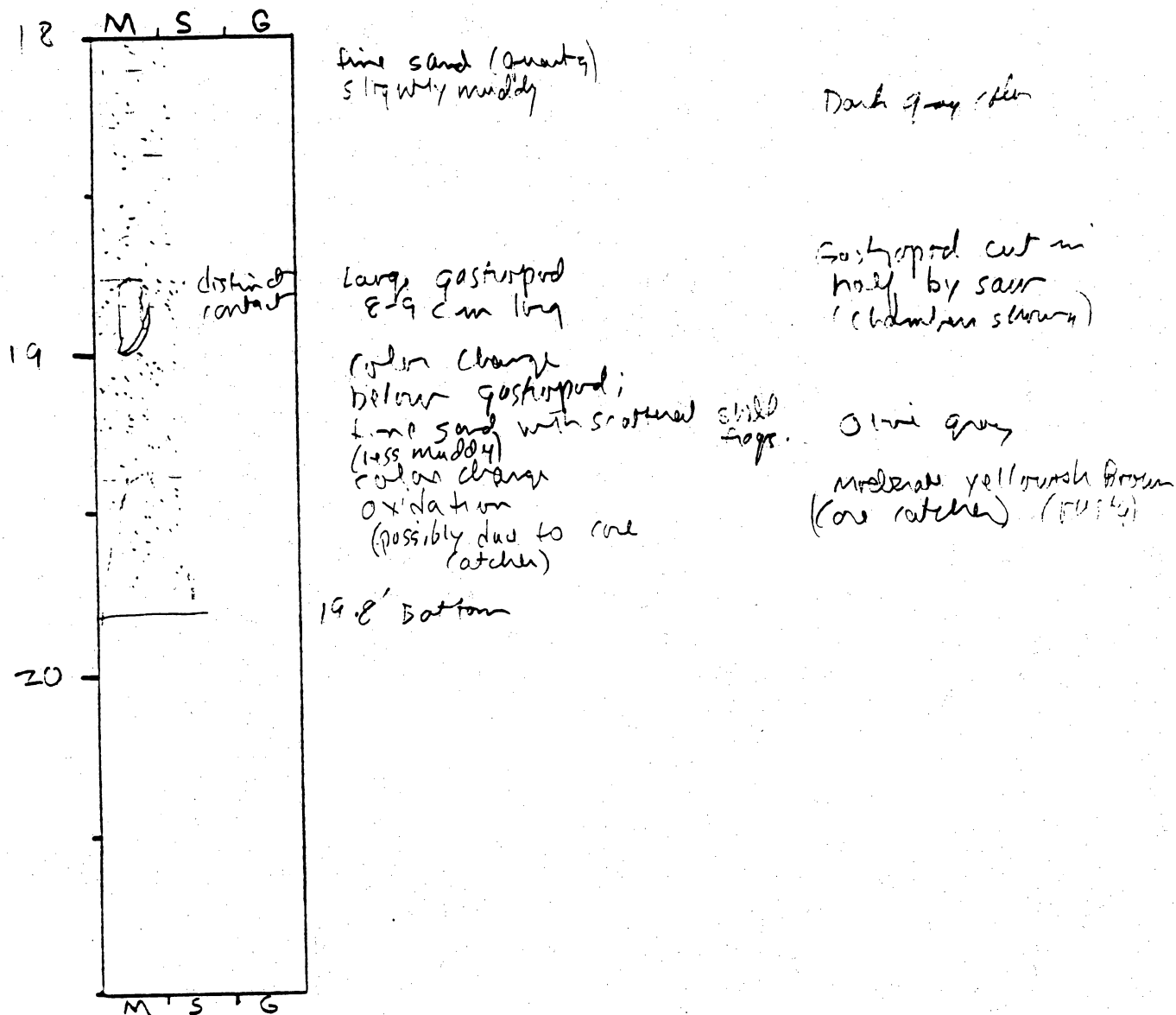
General Comments:

CORE LOG

CORE # HBV-5(G) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



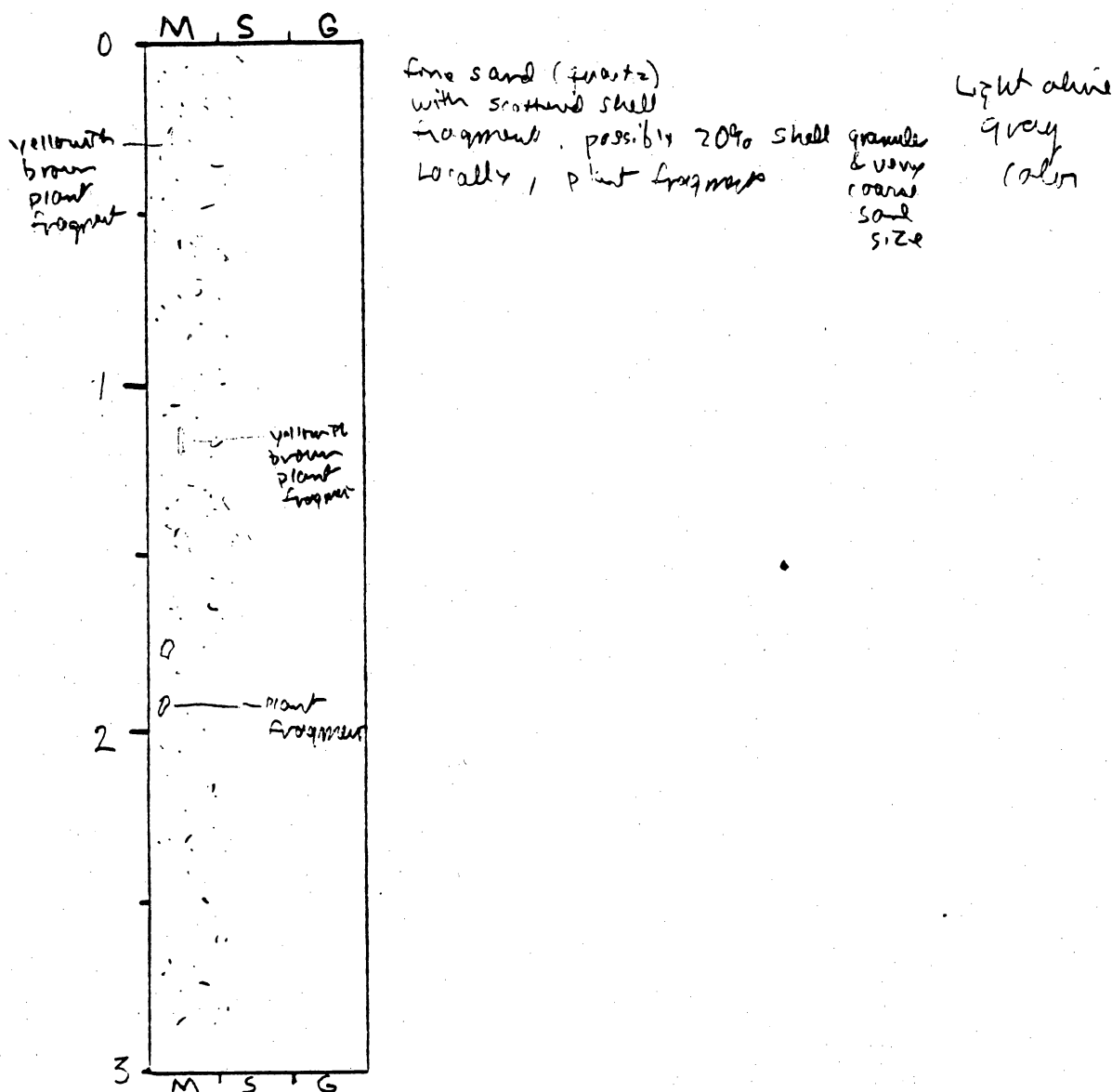
General Comments:

CORE LOG

CORE # HBY-6(A) TYPE Vibro core LOCATION Hog Id Bank
 LATITUDE 29° 08.630' LONGITUDE 120° 09.949' SURFACE ELEVATION -34'
 DEPTH PENETRATED ? LENGTH RECOVERED 10.6 % COMPACTION ?

OBTAINED BY Gibeaut - R/V Kit Jones DATE 10-12-94
 DESCRIBED BY White DATE

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

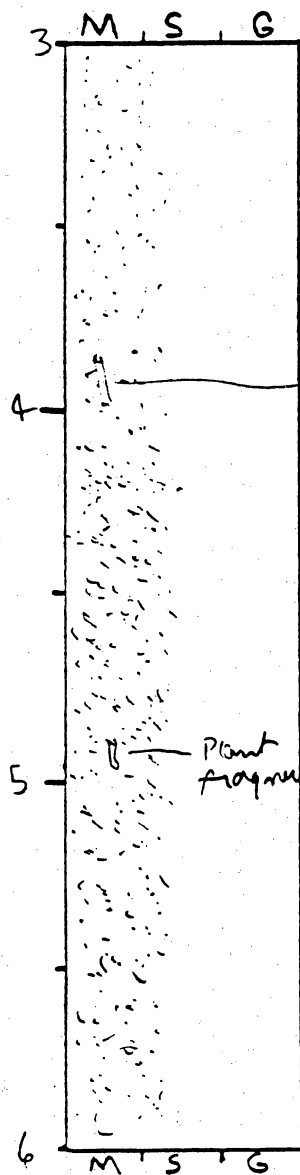


General Comments:

CORE LOG

CORE # HBV-G (B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____
 OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



fine sand (quartz)
 scattered shell fragments
 granule to coarse grained.
 quartz well sorted
 sub-rounded

Light olive
 gray
 in color
 with dark specks (shells)
 and some heavier frags

Foraminifera plant fragment

fine sand
 coarsening becomes more
 apparent below 4.3' but
 is
 Gradational.
 Coarsening downward
 as shell material
 becomes more abundant
 ~ 25%

General Comments:

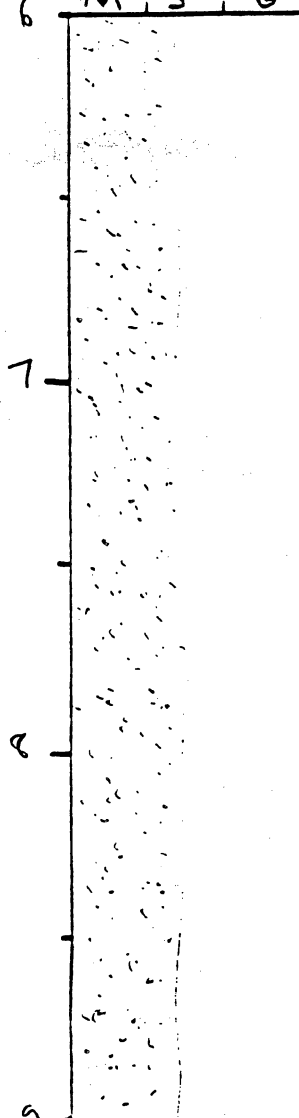
CORE LOG

CORE # 17BV-61C TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|

6 M S G



fine quartz sand
 with ^{sand} shell fragments
 coarse to granule in
 size.
 Quartz well sorted, sub rounded
 Appears to be slight
 coarsening with
 depth as

shell fragments
 compose ~ 25%
 of sediment

Quarried shell
 fragment up to
 6 mm in length

Light olive gray
 with black
 speckles
 from shell
 fragments &
 heavy mineral

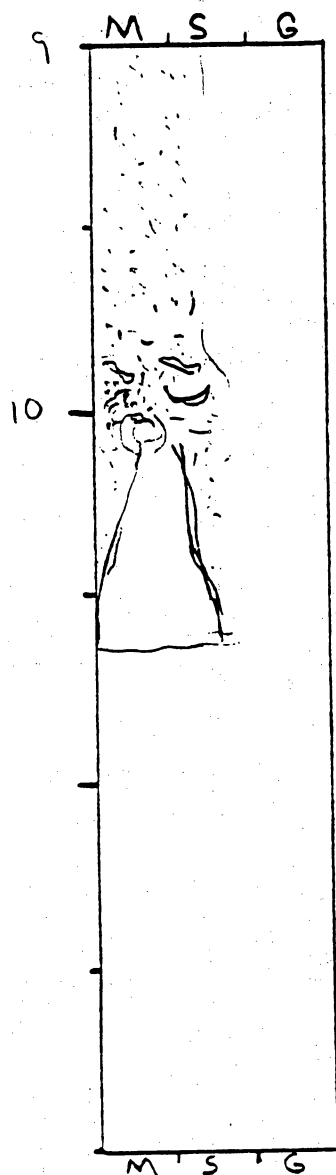
General Comments:

CORE LOG

CORE # HBV-6 (D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



fine sand (quartz)
 coarse to granule
 shell fragments ~ 25%
 qtz sand sub-rounded
 well sorted

Light olive gray
 with darker speckles
 of shell fragments

Shelly sand
 to sandy shell
 most granule
 size or finer
 but some gravel size
 shells.

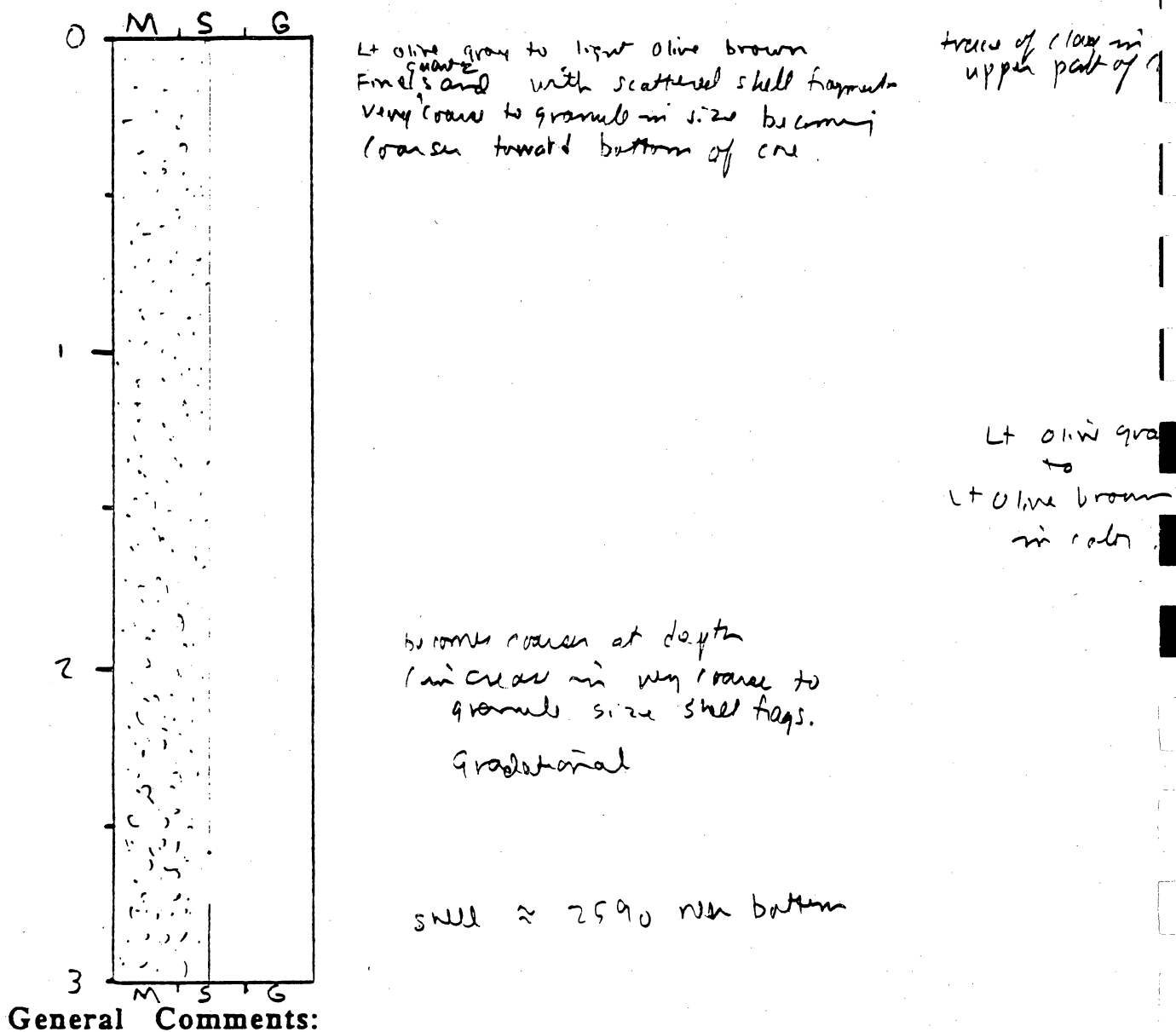
General Comments:

CORE LOG

CORE # H BV-7 (A) TYPE Vibracore LOCATION Head Bank
 LATITUDE 29° 08.72 LONGITUDE 94° 02.13 SURFACE ELEVATION -50'
 DEPTH PENETRATED ? LENGTH RECOVERED 15' % COMPACTION ?

OBTAINED BY Gibeaut - RN Kit Jones DATE 10-12-94
 DESCRIBED BY White DATE

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS

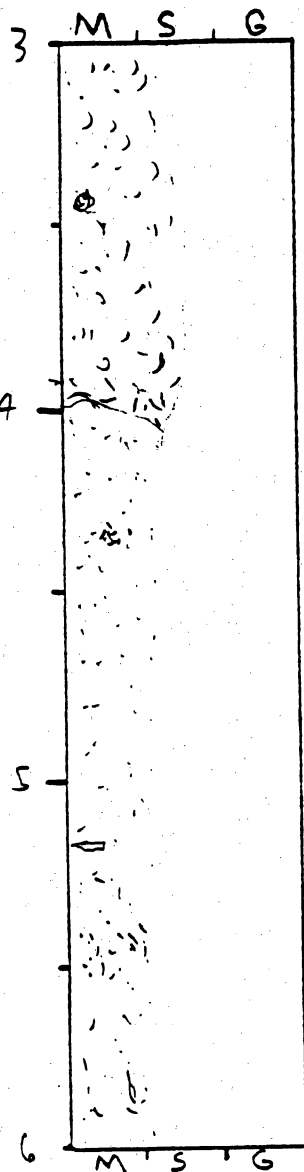


CORE LOG

CORE # 13V-7 (B) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



Lt Olive gray shelly fine sand to medium & coarse (fine shell fragments)

Shell fragments & whole shells (7mm long)

sediment becomes greener
 < 10% shell fragments except for local patches
 v. fine sand with scattered shells

Lt Olive gray
 to
 Olive gray

increase in shell: locally 10-15%

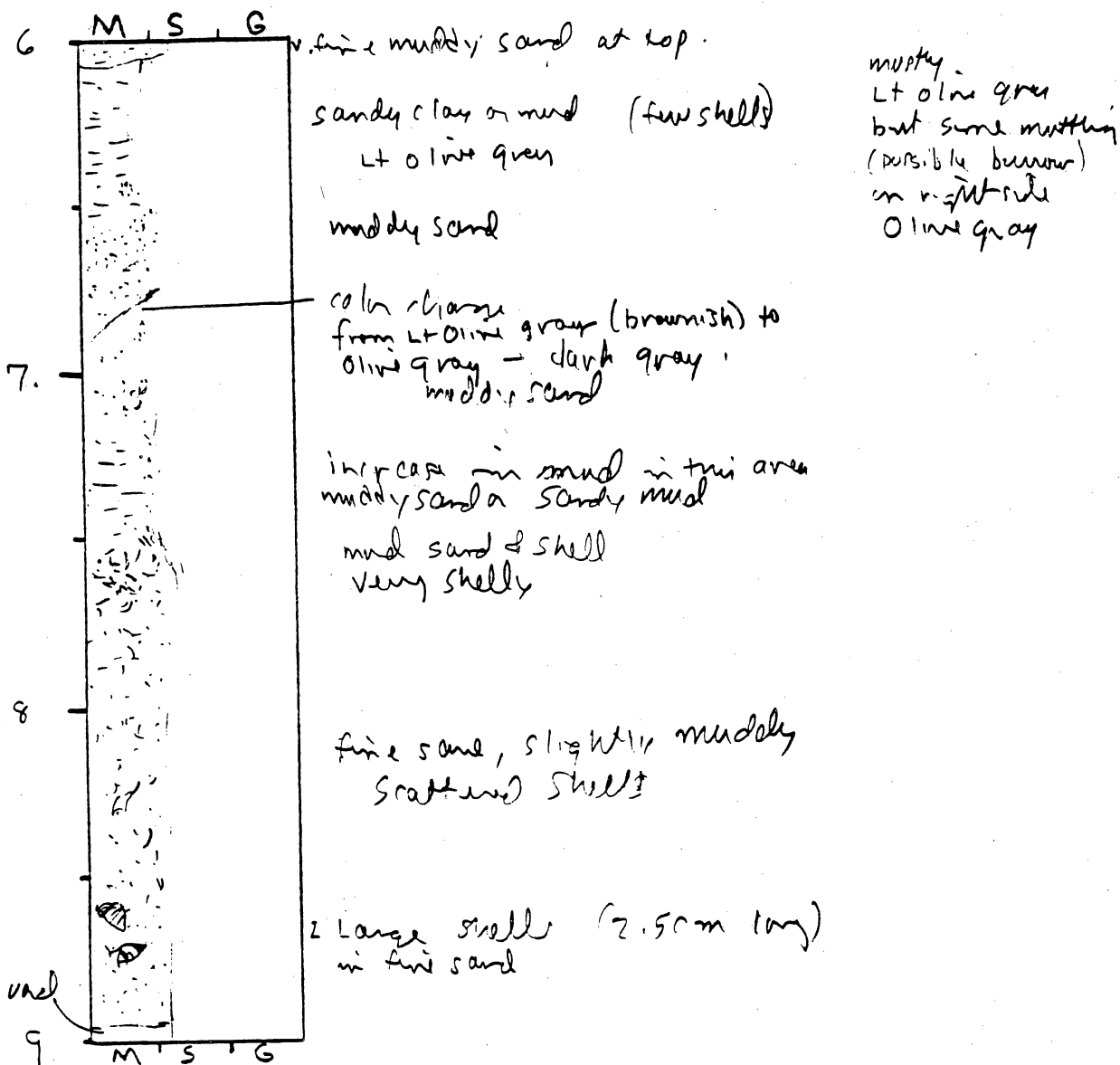
General Comments:

CORE LOG

CORE # 143V-7(c) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



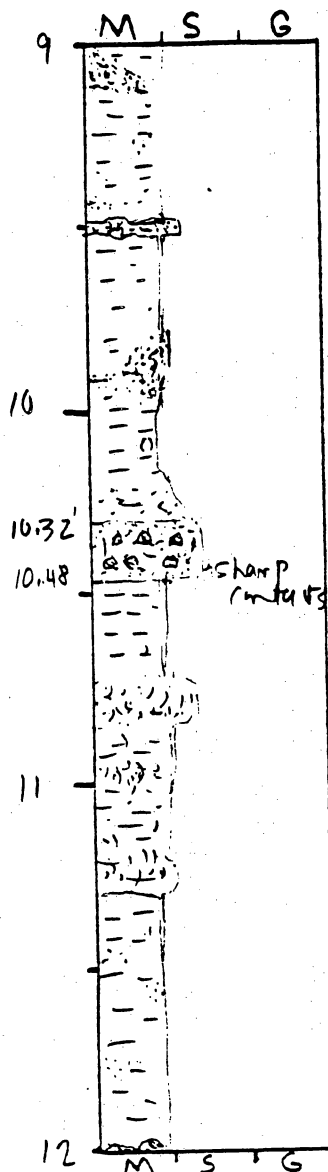
General Comments:

CORE LOG

CORE # 14B1-7 (D) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

| DEPTH (ft, m) | SKETCH | LITHOLOGY | STRUCTURE | REMARKS |
|------------------|--------|-----------|-----------|---------|
|------------------|--------|-----------|-----------|---------|



Olive gray mud with pockets of very fine sand (olive gray)
 Some burrowing
 thin sand layer

Sand pocket in mud

Some light olive
 gray mottling
 (brownish)

muddy sand zone above shell zone

shelly sand or sandy shell, shell fragments & whole shells up to 1 cm in
 mud (rare shells)

Sandy shelly mud or muddy shell (fragments & whole shells
 1 cm wide)

mixture of mud, sand
 & scattered shells

shelly mud or muddy shell, some sand

Musty olive gray mud, some sand pockets
 few shells

small
 pockets of brown sand in bottom, small whole shells

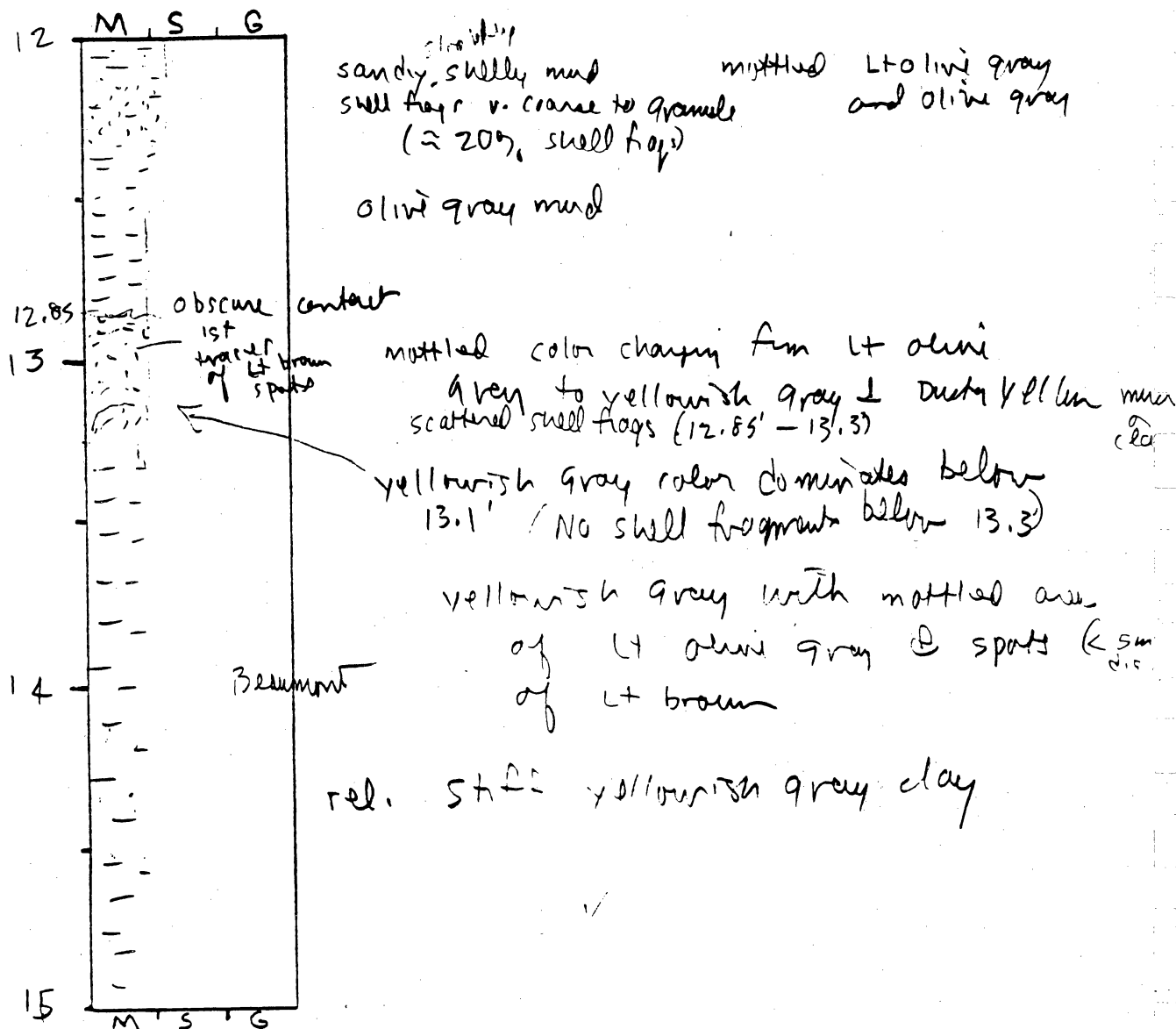
General Comments:

CORE LOG

CORE # HBV-7(E) TYPE _____ LOCATION _____
 LATITUDE _____ LONGITUDE _____ SURFACE ELEVATION _____
 DEPTH PENETRATED _____ LENGTH RECOVERED _____ % COMPACTION _____

OBTAINED BY _____ DATE _____
 DESCRIBED BY _____ DATE _____

DEPTH (ft, m) SKETCH LITHOLOGY STRUCTURE REMARKS



General Comments:

Addendum 12. Particle Size Analyses, Heald Bank and Sabine Bank Samples

Particle Size Analyses
Heald Bank and Sabine Bank samples

| Lab # | Sample ID | Sand % | Silt % | Clay % |
|-------|-------------|--------|--------|--------|
| 1 | HBV-1-1.5 | sieve | | |
| 2 | HBV-1-5.5 | sieve | | |
| 3 | HBV-1-8.0 | sieve | | |
| 4 | HBV-2-1.5 | 81 | 8 | 11 |
| 5 | HBV-2-4.5 | 34 | 40 | 26 |
| 6 | HBV-2-7.5 | 12 | 60 | 27 |
| 7 | HBV-2-10.2 | 6 | 28 | 66 |
| 8 | HBV-3-1.8 | sieve | | |
| 9 | HBV-3-2.6 | 72 | 7 | 21 |
| 10 | HBV-3-4.5 | 74 | 6 | 20 |
| 11 | HBV-3-6.5 | 77 | 6 | 17 |
| 12 | HBV-3-12.75 | 74 | 9 | 17 |
| 13 | HBV-4-1.0 | sieve | | |
| 14 | HBV-4-5.0 | sieve | | |
| 15 | HBV-4-6.5 | 18 | 32 | 50 |
| 16 | HBV-5-2.0 | sieve | | |
| 17 | HBV-5-5.75 | sieve | | |
| 18 | HBV-5-14.75 | sieve | | |
| 19 | HBV-5-19.1 | sieve | | |
| 20 | HBV-6-1.0 | sieve | | |
| 21 | HBV-6-4.5 | sieve | | |
| 22 | HBV-6-9.8 | sieve | | |
| 23 | HBV-7-2.5 | sieve | | |
| 24 | HBV-7-6.25 | 24 | 36 | 40 |
| 25 | HBV-7-9.3 | 15 | 44 | 42 |
| 26 | SBV-12-1.0 | sieve | | |
| 27 | SBV-12-4.5 | sieve | | |
| 28 | SBV-12-7.0 | sieve | | |
| 29 | SBV-12-11.0 | 76 | 12 | 12 |
| 30 | SBV-11-0.25 | 67 | 16 | 16 |
| 31 | SBV-11-4.5 | 44 | 29 | 27 |
| 32 | SBV-10-0.7 | 68 | 16 | 16 |
| 33 | SBV-10-3.2 | 54 | 26 | 20 |
| 34 | SBV-10-7.0 | 25 | 42 | 34 |
| 35 | SBV-10-11.2 | 6 | 28 | 66 |
| 36 | SBV-13-0.4 | sieve | | |

| | | | | |
|----|--------------|-------|----|----|
| 37 | SBV-13-0.75 | 66 | 17 | 17 |
| 38 | SBV-13-5.5 | 60 | 21 | 19 |
| 39 | SBV-13-14 | 68 | 16 | 16 |
| 40 | SBV-14-1.5 | sieve | | |
| 41 | SBV-14-4.2 | sieve | | |
| 42 | SBV-14-8.6 | 44 | 36 | 20 |
| 43 | SBV-15-0.5 | 68 | 16 | 17 |
| 44 | SBV-15-0.95 | 68 | 16 | 17 |
| 45 | SBV-16-0.2 | sieve | | |
| 46 | SBV-16-2.5 | sieve | | |
| 47 | SBV-16-4.5 | 78 | 9 | 12 |
| 48 | SBV-17-1.0 | sieve | | |
| 49 | SBV-17-5.8 | sieve | | |
| 50 | SBV-17-9.2 | sieve | | |
| 51 | SBV-17-14.0 | sieve | | |
| 52 | SBV-18-0.5 | sieve | | |
| 53 | SBV-18-5.7 | sieve | | |
| 54 | SBV-18-8.25 | sieve | | |
| 55 | SBV-19-0.8 | 20 | 42 | 38 |
| 56 | SBV-19-2.8 | sieve | | |
| 57 | SBV-19-5.5 | 68 | 20 | 13 |
| 58 | SBV-19-8.5 | 53 | 29 | 19 |
| 59 | SBV-20-0.5 | sieve | | |
| 60 | SBV-20-2.7 | sieve | | |
| 61 | SBV-20-4.1 | sieve | | |
| 62 | SBV-21-1.0 | sieve | | |
| 63 | SBV-22-2.0 | sieve | | |
| 64 | SBV-22-5.75 | sieve | | |
| 65 | SBV-22-10.95 | sieve | | |
| 66 | SBV-22-13.5 | sieve | | |
| 67 | SBV-23-0.5 | sieve | | |
| 68 | SBV-23-5.5 | sieve | | |
| 69 | SBV-23-12.4 | sieve | | |
| 70 | SBV-23-17.8 | 49 | 34 | 17 |
| 71 | SBV-24-2.2 | sieve | | |
| 72 | SBV-24-5.6 | sieve | | |
| 73 | SBV-24-7.0 | sieve | | |
| 74 | SBV-24-16.5 | 41 | 40 | 19 |
| 75 | SBV-25-0.4 | sieve | | |
| 76 | SBV-25-1.5 | sieve | | |
| 77 | SBV-25-11.2 | sieve | | |

Particle Size Analyses - Sieve
Heald Bank and Sabine Bank samples

| Lab # | Sample ID | cumulative %'s | | | | | | | | | | | | | | | | pan % |
|-------|-------------|----------------|-------|-------|-------|------|------|------|------|------|------|------|------|------|-------|---|--|-------|
| | | -2.0ø | -1.5ø | -1.0ø | -0.5ø | 0ø | 0.5ø | 1.0ø | 1.5ø | 2.0ø | 2.5ø | 3ø | 3.5ø | 4.0ø | | | | |
| | | % | % | % | % | % | % | % | % | % | % | % | % | % | % | % | | |
| 1 | HBV-1-1.5 | 0.0 | 0.0 | 0.1 | 0.4 | 0.6 | 1.0 | 1.7 | 2.9 | 7.7 | 43.9 | 93.0 | 99.7 | 99.9 | 100.0 | | | |
| 2 | HBV-1-5.5 | 0.0 | 0.8 | 4.0 | 10.5 | 20.3 | 31.3 | 38.9 | 43.4 | 48.7 | 69.4 | 94.9 | 99.5 | 99.8 | 100.0 | | | |
| 3 | HBV-1-8.0 | 5.2 | 10.7 | 18.5 | 28.7 | 38.6 | 46.4 | 51.2 | 54.3 | 58.3 | 73.8 | 95.1 | 99.5 | 99.7 | 100.0 | | | |
| 4 | HBV-2-1.5 | 0.3 | 0.4 | 0.7 | 0.9 | 1.2 | 1.6 | 2.0 | 2.3 | 2.9 | 7.0 | 41.9 | 87.0 | 97.4 | 100.0 | | | |
| 5 | HBV-2-4.5 | hydrometer | | | | | | | | | | | | | | | | |
| 6 | HBV-2-7.5 | hydrometer | | | | | | | | | | | | | | | | |
| 7 | HBV-2-10.2 | hydrometer | | | | | | | | | | | | | | | | |
| 8 | HBV-3-1.8 | 0.0 | 0.2 | 1.1 | 3.2 | 6.1 | 8.6 | 11.0 | 13.7 | 27.7 | 77.5 | 95.8 | 97.2 | 97.6 | 100.0 | | | |
| 9 | HBV-3-2.6 | 0.0 | 0.0 | 0.0 | 0.1 | 0.5 | 1.0 | 1.8 | 2.6 | 3.8 | 14.1 | 68.8 | 96.8 | 99.2 | 100.0 | | | |
| 10 | HBV-3-4.5 | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 | 0.8 | 1.4 | 1.9 | 3.2 | 13.5 | 71.3 | 96.1 | 99.1 | 100.0 | | | |
| 11 | HBV-3-6.5 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.6 | 1.2 | 1.7 | 2.8 | 12.3 | 68.7 | 95.1 | 98.6 | 100.0 | | | |
| 12 | HBV-3-12.75 | 0.0 | 0.0 | 0.0 | 0.9 | 2.4 | 3.9 | 5.0 | 5.7 | 6.3 | 10.1 | 66.6 | 86.7 | 97.1 | 100.0 | | | |
| 13 | HBV-4-1.0 | 0.0 | 0.1 | 0.5 | 0.7 | 1.1 | 1.8 | 4.0 | 8.3 | 16.6 | 48.4 | 81.8 | 93.0 | 95.2 | 100.0 | | | |
| 14 | HBV-4-5.0 | 2.0 | 3.2 | 4.9 | 6.7 | 9.2 | 12.8 | 16.4 | 20.4 | 25.6 | 37.4 | 60.2 | 80.5 | 88.8 | 100.0 | | | |
| 15 | HBV-4-6.5 | hydrometer | | | | | | | | | | | | | | | | |
| 16 | HBV-5-2.0 | 0.0 | 0.1 | 0.2 | 1.0 | 2.6 | 5.8 | 9.8 | 13.8 | 22.6 | 55.0 | 93.1 | 99.5 | 99.8 | 100.0 | | | |
| 17 | HBV-5-5.75 | 2.3 | 2.8 | 4.0 | 6.2 | 9.7 | 14.8 | 19.5 | 23.4 | 30.1 | 58.7 | 93.2 | 99.3 | 99.7 | 100.0 | | | |
| 18 | HBV-5-14.75 | 0.3 | 0.5 | 1.0 | 2.4 | 5.0 | 8.5 | 11.8 | 15.2 | 19.3 | 38.4 | 79.5 | 93.3 | 94.9 | 100.0 | | | |
| 19 | HBV-5-19.1 | 0.0 | 0.0 | 0.2 | 1.2 | 3.4 | 6.5 | 9.4 | 12.5 | 16.4 | 28.5 | 69.9 | 91.0 | 94.4 | 100.0 | | | |
| 20 | HBV-6-1.0 | 0.0 | 0.1 | 0.4 | 1.2 | 3.2 | 6.9 | 11.0 | 15.2 | 24.9 | 64.2 | 95.3 | 99.3 | 99.6 | 100.0 | | | |
| 21 | HBV-6-4.5 | 0.0 | 0.1 | 0.6 | 2.3 | 6.1 | 12.3 | 18.4 | 23.7 | 33.8 | 70.3 | 96.0 | 99.4 | 99.7 | 100.0 | | | |
| 22 | HBV-6-9.8 | 8.6 | 9.6 | 11.2 | 14.3 | 19.4 | 25.9 | 31.9 | 36.5 | 45.3 | 76.4 | 97.2 | 99.5 | 99.7 | 100.0 | | | |
| 23 | HBV-7-2.5 | 1.3 | 2.4 | 4.8 | 10.6 | 20.5 | 34.1 | 47.8 | 54.7 | 68.2 | 84.8 | 97.2 | 99.7 | 99.8 | 100.0 | | | |

[illegible]

