REPORT NUMBER USC GEOLOGY 69-3

ORIGIN AND RECENT HISTORY OF NEWPORT SUBMARINE CANYON, CALIFORNIA CONTINENTAL BORDERLAND

TECHNICAL REPORT FOR OFFICE OF NAVAL RESEARCH
CONTRACT NO. NONR 228 (17)
NR 083-144

By

David Felix

Department of Geological Sciences
University of Southern California
Los Angeles, California 90007

Submitted to

Geophysics Branch
Office of Naval Research
Washington, D.C.

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CONTENTS

TABLES

ILLUSTRATIONS

ABSTRACT

Newport Canyon is the largest of several channels which cut the continental margin off Newport Beach, California. All of the channels were initiated subaerially by the Santa Ana River during the Pleistocene and Holocene. Submarine erosion may have continued until early in the last century. Prior to 1825, the river provided sediment directly to the ocean in the vicinity of the canyon head. Subsequent construction of a barrier beach by the river caused its diversion into Newport Bay, and a change in coastal alignment which altered longshore current patterns.

The upper portions of the canyon are now being filled with organic-rich silt and clay at the rate of approximately 1.4 cm/year. The primary sources of this material are the Orange County sewer outfall and the Santa Ana River. Suspension of fine-grained sediment on the shelf and deposition within the canyon is the normal mode of transport for all modern canyon sediment. Collection of sand and debris in the nearshore head is precluded by the divergence of longshore currents from the head under most wave conditions. The canyon is presently inactive and cannot be the source of modern turbidites in the San Diego Trough.

INTRODUCTION

General Statement and Purpose

Newport Submarine Canyon is one of the small canyons which incise the mainland shelf off southern California. It has been assumed to be the southern terminus of a "littoral cell," a term coined by Emery (1960) to describe segments of the California coast bounded by submarine canyons heading close to shore. In Emery's model, Newport Canyon is responsible for trapping long-shore drift material and channeling it to the San Diego Trough. Hand and Emery (1964) cite the canyon as the major active pathway for turbidite-like sediments in the Trough.

A preliminary study of sediment stability in the canyon head (Felix, 1967) revealed that sand was not collecting in the head, and that mud present in the canyon was in a stable condition. A high sand content, and active movement of this sand down the canyon, would be prerequisites for the formation of "turbidites" found at and beyond the mouth of the canyon (Hand and Emery, 1964).

In the hope of resolving conflicting observations, a detailed geological study was initiated in the upper portion of the canyon system. Early in the field work it was apparent that a descriptive study of canyon sediments would be of little value in determining sediment sources and pathways. Thus, the area was subsequently enlarged to include the shelf adjacent to the canyon and the beach. This made possible the historical development of the modern sedimentation system.

Geographic Setting

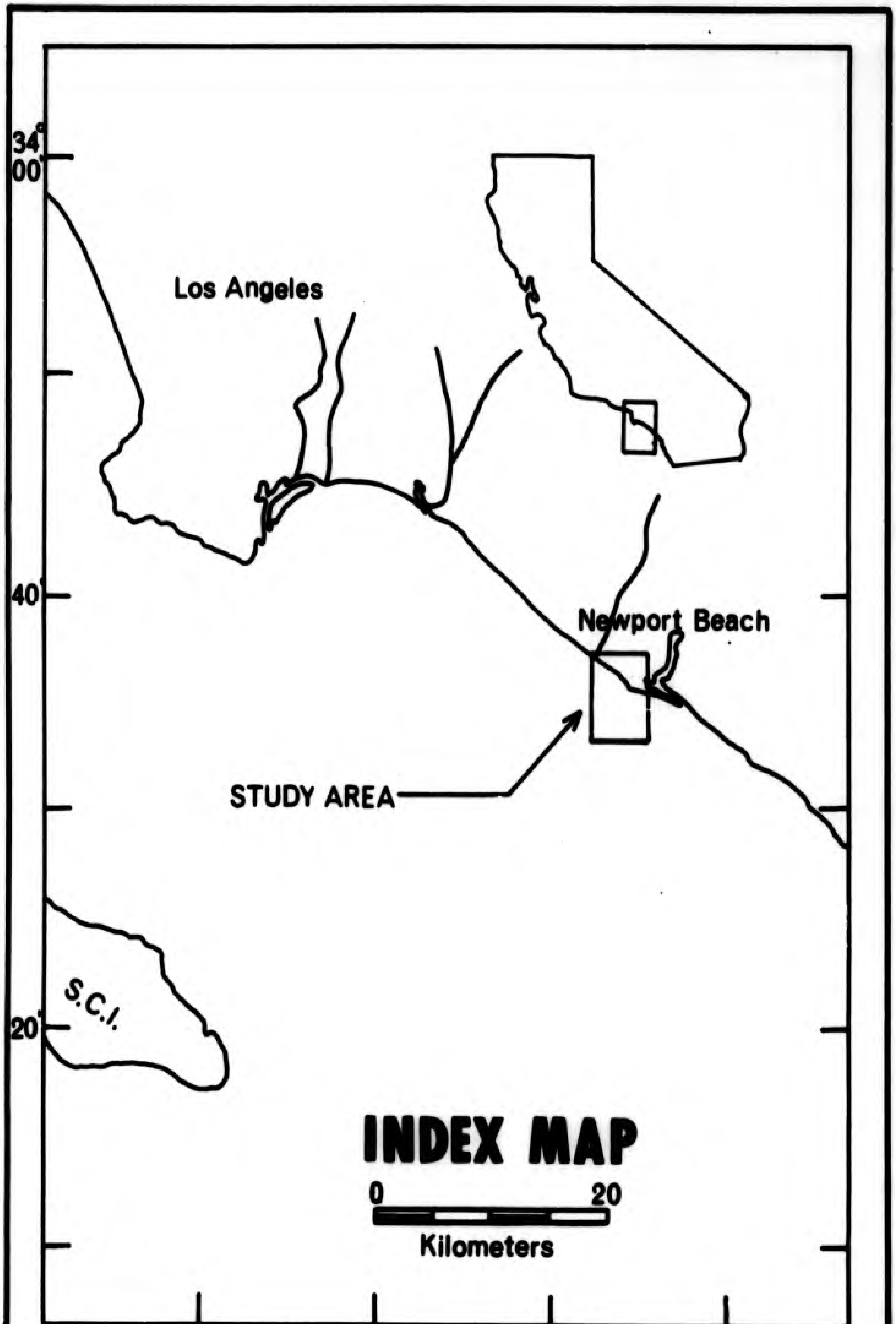
The study area encompasses 20 sq km of sea floor off the city of Newport Beach in Orange County, California (Fig. 1) and extends from 1 km east of the municipal pier to the Santa Ana River mouth and from the beach approximately 5 km offshore (Fig. 2).

The Santa Ana River is the main drainage for the Orange County hinterland. Although presently confined to a cement channel, it previously traversed over a wide flood plain, changing its course and the position of its mouth frequently. The river has long been the major source of new sediment to the nearshore zone at Newport Beach, but sediment contribution is now limited to very fine sand and mud.

The Orange County sewer outfall plays a significant role in the modern sedimentation system. Its dispersal field is centered approximately 2 km southwest of the river mouth in 18 meters of water. Originally constructed in 1929, it was enlarged in 1954. Discharge at present is about 450×10^6 liters of chlorinated, filtered effluent per day.

Previous Investigations

For all of its potential significance, Newport Canyon has received only the most cursory study by geologists. Indeed, it is not mentioned in the latest reference work on submarine canyons by Shepard and Dill (1967). Papers by Weismeyer (1967) and the United States Army Corps of Engineers (1966) present two


34°
00'
Los Angeles
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Newport Beach
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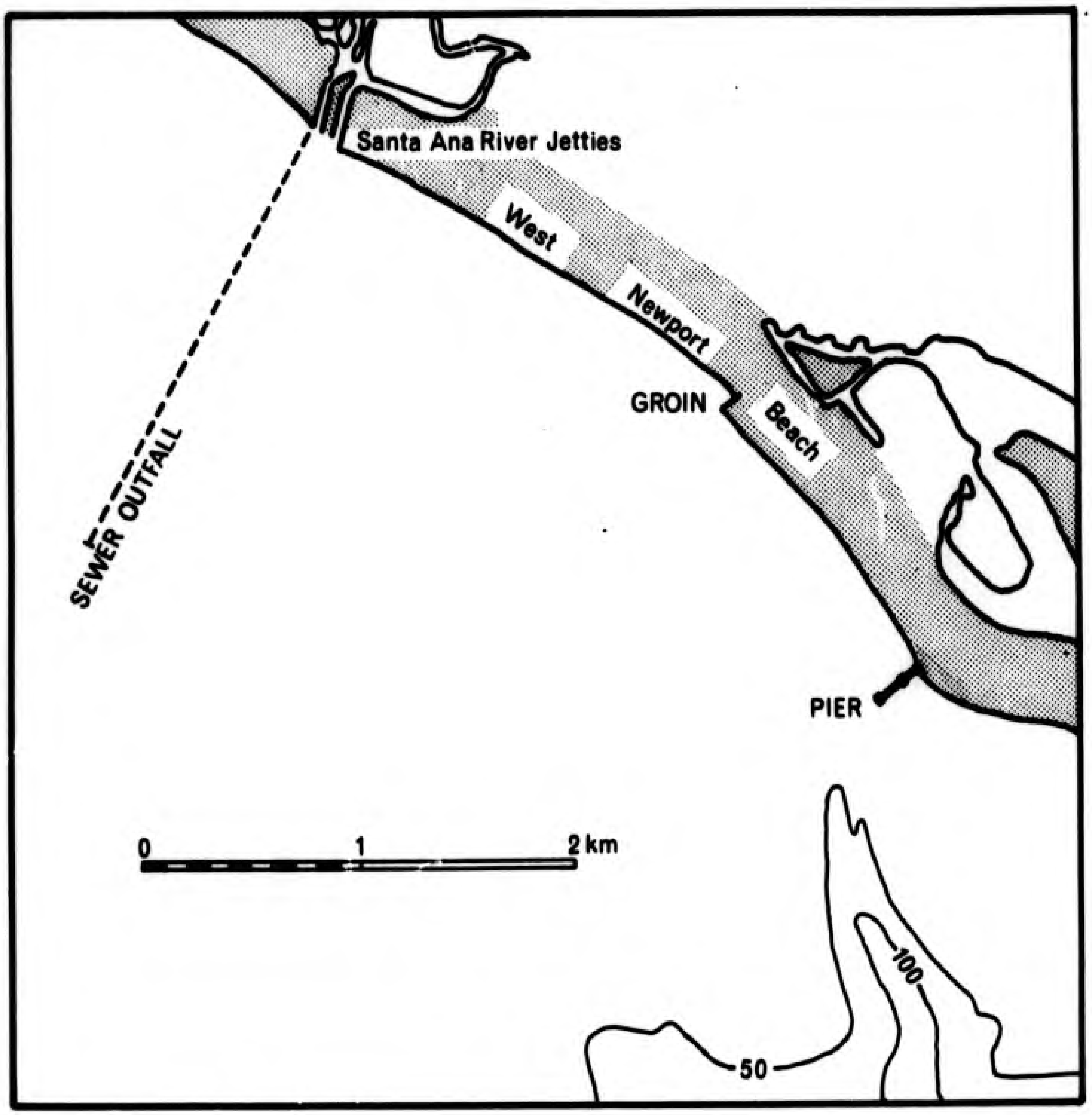

COASTAL FEATURES OF STUDY AREA

interpretations of the shallow bathymetry. Bradford (1965) made several PDR profiles over deeper portions of the canyon and secured three short gravity cores from the main channel. Other sediment studies of limited extent were undertaken by Hand (1962), Hand and Emery (1964), United States Army Corps of Engineers (1966) and Loop (1967). MacDougall (1967) made a study of suspended matter in the canyon head close to the Newport Beach pier. A possible origin of the canyon and its genetic relationship to the Santa Ana River was presented by Stevenson (1954) as part of a study of the Newport Bay marshes.

Stevenson (1958) described the offshore current system as traced by extensive drift card surveys. Studies performed for the United States Army Corps of Engineers (1966) were concerned with longshore currents and littoral transport paths over a 1 year period in 1964-1965.

Several investigations were directed toward foraminifera, bacteriology, and sediment and water chemistry of the sewage field just prior to and after construction of the sewer (Rittenburg, et al., 1958; Watkins, 1961; Bandy, et al., 1965; Stevenson and Grady, 1956), but none are applicable to the present study.

Methods

Bathymetric Methods

Existing nautical charts of the Orange County coast (U.S.C. & G.S. 5108 and 5142) do not depict Newport Canyon in sufficient detail to permit their use as base maps for a small-scale study.

The upper portion of the canyon (within 6 km of the pier) was resurveyed using modern, continuous depth recorders and positioning equipment. Most of the sounding traverses were made with a Gifft model GDR-IC-19-T Sonar Transceiver connected to a hull-mounted Edo Transducer on the R. V. Velero IV. Over the shallow portions of the canyon where the Velero could not be maneuvered, soundings were recorded aboard the Ahoyoha III using a Raytheon model DE-725A Recording Fathometer. Because of the relatively shallow water (less than 300 m), corrections for sound velocity were not made, but depth of keel was taken into account.

Positioning on the Velero was accomplished with a Sperry Mark III radar, all readings being obtained from the end of the Newport pier. On the Ahoyoha, traverses were made at constant engine speed, and positions determined at the beginning and end of each line by horizontal sextant sights on three fixed objects. Strong tidal currents caused considerable ship drift and "crabbing" during the longer traverses. Allowance was made to account for this in plotting the contour data.

Oceanographic Methods

Current patterns in the nearshore and offshore areas of Newport Beach are erratic, reflecting their control by wave refraction, tide, wind, and eddies from the California current. Because of the time required for a significant current study, data were taken from existing reports rather than repeating the work. These reports have been mentioned under Previous Investigations. It should be noted that the study of longshore currents was done by

Interstate Electronics Corporation of Anaheim, California for the United States Army Corps of Engineers, and was based on lifeguards' observations of dye patches introduced into the surf zone.

Temperature structure exerts control on the distribution of suspended matter through its effect on density. Bathythermograph readings were obtained at each of 10 stations on March 29, 1968, Velero cruise number 943. Although salinity does affect density, the range of values is so small within the study area it was not considered.

Suspended Sediment Methods

To trace pathways of suspended matter, a series of large volume water samples was taken on March 29, 1968. The sea surface was calm, so minimal recovery of particulate matter was expected.

After determination of depth to the thermocline through the use of a bathythermograph, 4 liter van Dorn Bottles (van Dorn, 1956) were arranged on the hydrographic cable so as to obtain samples from just above and below the main thermocline and from near the bottom. If there was considerable distance between the thermocline and bottom, an additional bottle was placed in the interval. Depth control was by means of a meter wheel on the ship. The deepest bottle at each station was equipped with a tripping arm so that it would close 1 m above the bottom (Rittenburg, et al., 1955). A bucket sample was taken at the surface. Samples were stored in polyethylene jugs.

Measured volumes of 1.5ℓ to 2.5ℓ were filtered through type

AA Millipore filters of known weight in the manner described by Banse, et al. (1963). These filters have a mean pore size of 0.8 μ ± 0.05 μ (Millipore Filter Corporation, 1966). Filter and sediment were dried in a silica gel dessicator until weight loss ceased, and the in situ concentration of total suspended matter calculated.

Filters were then placed in petri dishes. Dish and filter were weighed, and 10 percent H_2O_2 added and allowed to digest any organic matter for 10 days. After subsequent drying and weighing, the concentration of organic and inorganic portions were determined.

Throughout the analysis, five control filters were subjected to all procedures except that no water was filtered through them. These were later used to correct for changes in filter weight.

Size of the suspended sediment grains was measured under a petrographic microscope equipped with a calibrated eyepiece. Three samples were scraped from the filters onto glass slides, mixed into a slurry, and subjected to X-ray analysis to determine clay mineralogy following the procedure of Warshaw and Roy (1961).

Bottom Sediment Methods

Offshore sampling was undertaken during the first 6 months of 1968. Forty-nine grab samples were taken from the Ahoyoha III of the Allan Hancock Foundation. A Hayward "orange peel" dredge was used for most of the samples; others were obtained with a Dietz-LaFond snapper. Eleven beach samples and three in shallow water were recovered by hand scooping. Five short gravity cores from the axis and flanks of the canyon were obtained during two cruises on the R. V. Velero IV, and portions of four vibracores were donated by the United States Army Corps of Engineers. In addition, 2 dredge hauls were recovered from the walls of the canyon using a biological (chain bag) dredge.

Several SCUBA dives into the canyon head and on the shelf served to confirm the continuity of sediment patterns and to delineate minor physical features which could influence sediment distribution.

Laboratory procedure consisted of size and partial mineralogical analysis to determine energy environments and to trace sediment pathways; nitrogen determination to evaluate the contribution of sewage; organic carbon measurements of a few samples to distinguish various sources of organic matter; and X-ray analysis of selected clay fractions to correlate, if possible, sources of supply with suspended sediment and bottom clays.

Size analysis of the sand was carried out utilizing an automatic settling tube (Felix, 1968). Silt and clay fractions were determined by standard pipette methods. As organic matter and organically flocculated clays make up a significant portion of the bottom sediment, it was felt that these should be analyzed in their natural state. Sample preparation, therefore, was limited to several washings with distilled water and wet sieving to separate sand from the silt-clay fraction. The use of a settling tube rather than the conventional sieve technique is mandatory in the environment of the study area where a large portion of the sand grains are platy minerals (mica and chlorite). Such grains physically behave as small particles when settling through the water column. A mechanical analysis, based on mean grain diameter and intermediate grain cross-section, would be of scant value in interpretation of sediment distribution and energy environments. It would indicate considerable quantities of sand-size material in the canyon, whereas such material is transported as suspended load by weak currents and not in traction as sand would be.

Analysis of ammonoid nitrogen was carried out by a modified Kjeldahl method (Bradstreet, 1965). Total carbon analyses were performed on selected samples to obtain carbon-nitrogen ratios. The method employs a LECO (Laboratory Equipment Corporation) carbon analyzer, combined with a digestion process for the determination of carbonate-carbon. The procedure recently was described by Kolpack and Bell (1968).

X-ray analysis of clay-size material followed the procedure of Warshaw and Roy (1961) using copper radiation on a Phillips diffractometer.

Gravity and vibracores were treated in the same manner as surface grab samples. In addition, the gravity cores were photographed and radiographed to delineate structural features. The vibracores had been cut into segments in the field, so structure was limited to that noted at the time of recovery.

Acknowledgments

Sampling time on the Ahoyoha III was financed by the Allan Hancock Foundation, University of Southern California. Richard Bergeron, skipper of the Ahoyoha, was generous with suggestions and help during the field work. Robert Given, resident biologist at the University of Southern California Santa Catalina Island Marine Science Center, kindly provided the Hayward grab sampler and accompanying winch used to obtain most of the offshore samples.

Dr. Donn Gorsline of the Department of Geological Sciences arranged for ship time on the R. V. Velero IV under National Science Foundation Grant GB-6913. Keith Barger, marine technician, assisted during the coring and water sampling operations from the Velero. Norman Hyne provided samples and mineralogic data from coastal streams in the Newport Beach area. Numerous other graduate and undergraduate students in the University of Southern California Department of Geological Sciences donated their time and labor as field assistants and diving partners.

Help was solicited from, and volunteered by, several organizations outside of the university community. The United States Army Corps of Engineers Shore Protection Branch in Los Angeles generously provided access to their large collection of aerial photographs. Several profitable discussions were held with Clifford Ford, Civil Engineer with the Shore Protection Branch. Robert Townsend, geologist with the Army Engineers, donated samples from several vibracores recovered off Newport Beach. John Sickler of the Orange County Sanitation Department cooperated in supplying data on the Newport Beach outfall and samples of the effluent for chemical analysis.

Drs. D. S. Gorsline, R. O. Stone, and F. H. Merriam critically read the manuscript and made numerous suggestions regarding form and content.

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The assistance of the aforementioned individuals and groups is gratefully acknowledged.

BATHYMETRY OF NEWPORT CANYON

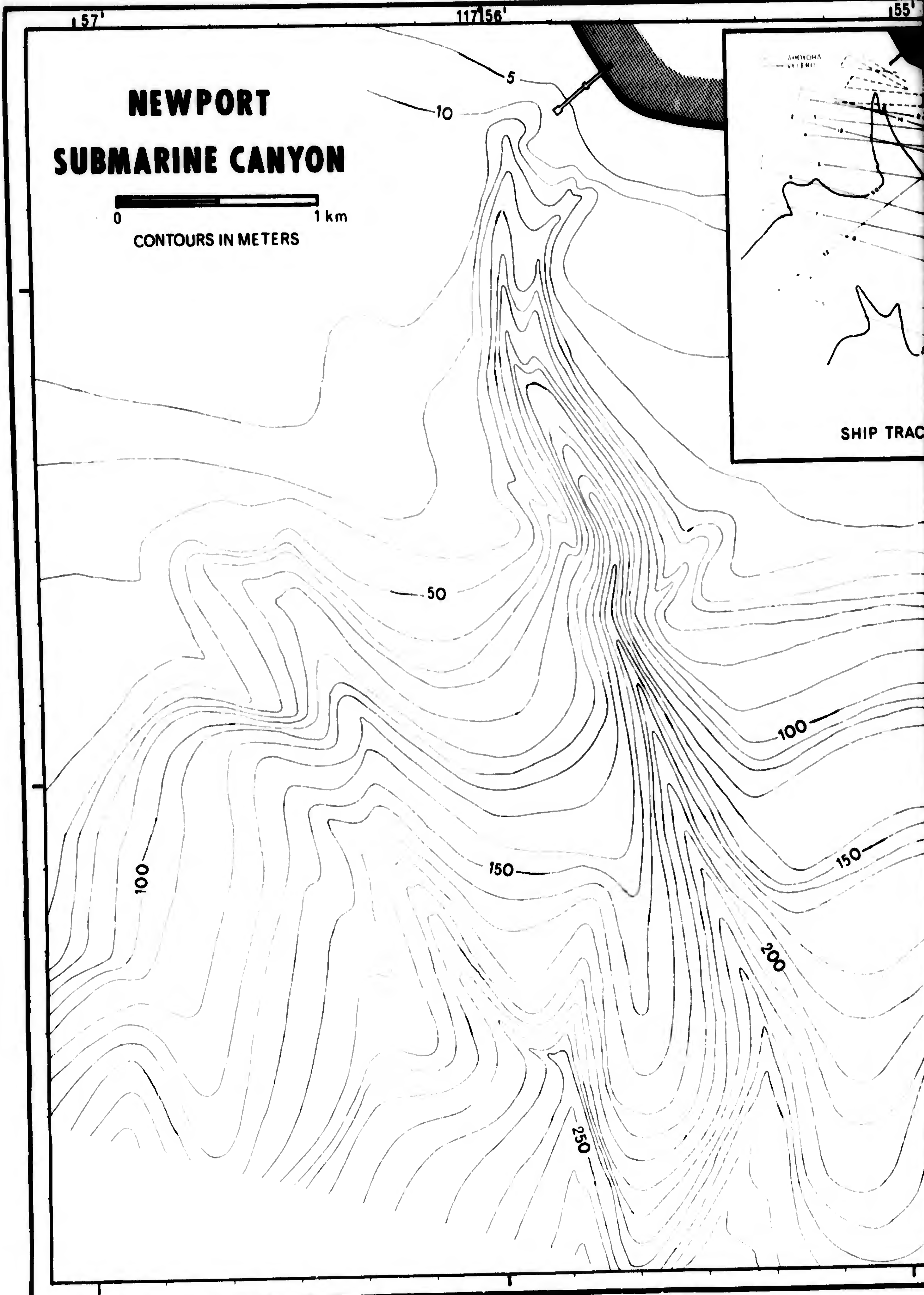
Canyon Morphology

General Statement

The Newport Canyon system is a complex of dendritic tributaries and independent channels which incise the continental margin (Fig. 3). In this study the term Newport Canyon is restricted to the longest channel which heads close to shore and its immediate tributaries (Fig. 4).

As the canyon is genetically related to the Santa Ana River, a brief summary of the Pleistocene to modern history of the river, taken from Stevenson (1954), is presented below.

> Erosion of the large filled channel which now forms the northern end of Newport Bay commenced in the mid-Pleistocene. At that time relief was considerable, with sea level being 60 m below that at present (Fig. 5). The Santa Ana River wandered over the alluviated Los Angeles Basin, changing its course frequently. During one of these swings it left the vicinity of the Bay and moved west where it cut the "arroyo" now known as Newport Submarine Canyon. Uplift ceased at the end of the Pleistocene and the area was inundated by the sea.
>
> In the Holocene a series of uplifts began. One of these, only a few hundred years ago, diverted the river to an outlet in the vicinity of Seal Beach, 18 km northwest of the present river mouth. A large flood in 1825 (Sherman, 1931) swung the river to approximately its present position. The



57'
117 56'
55'
NEWPORT
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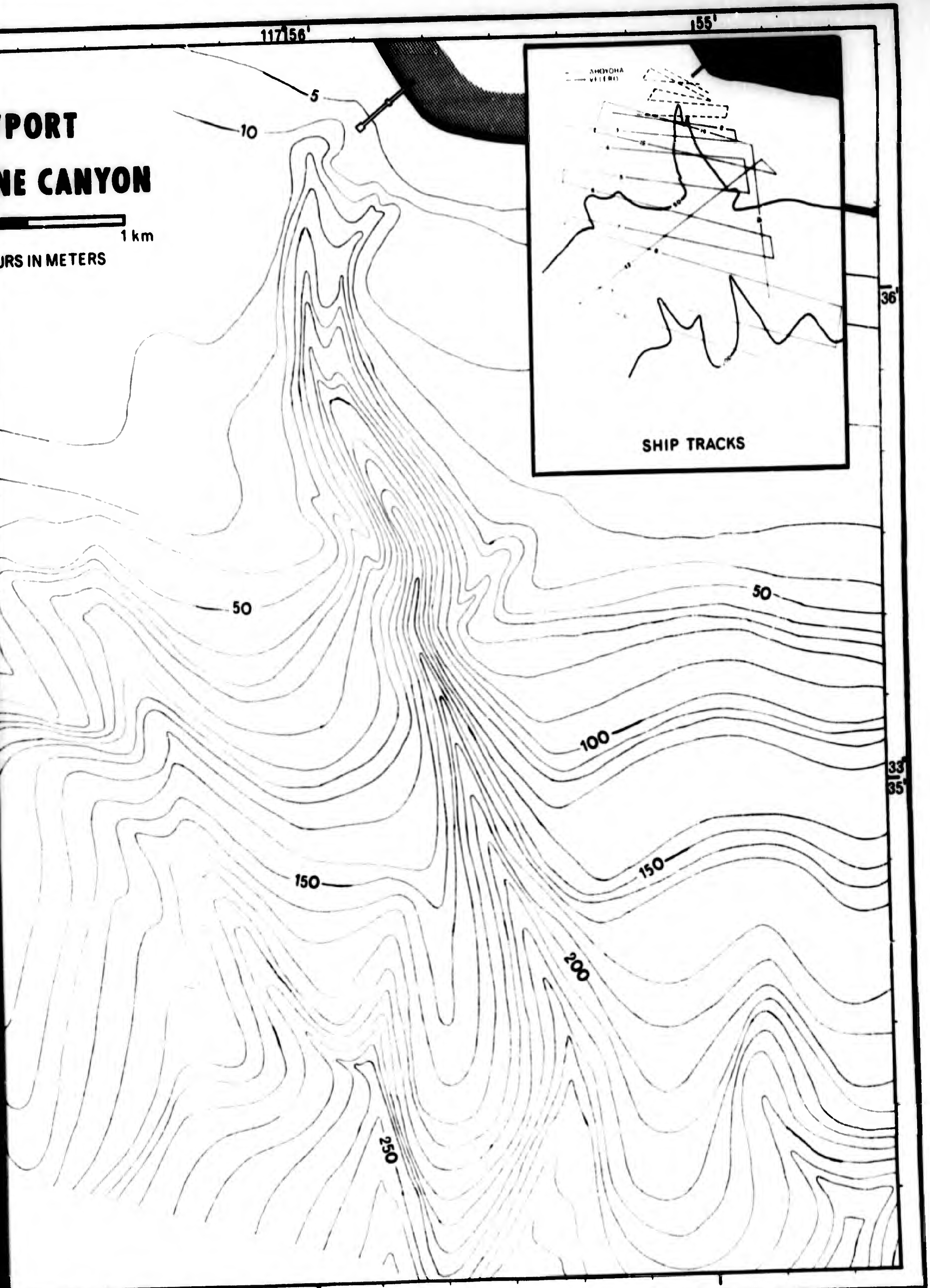
250



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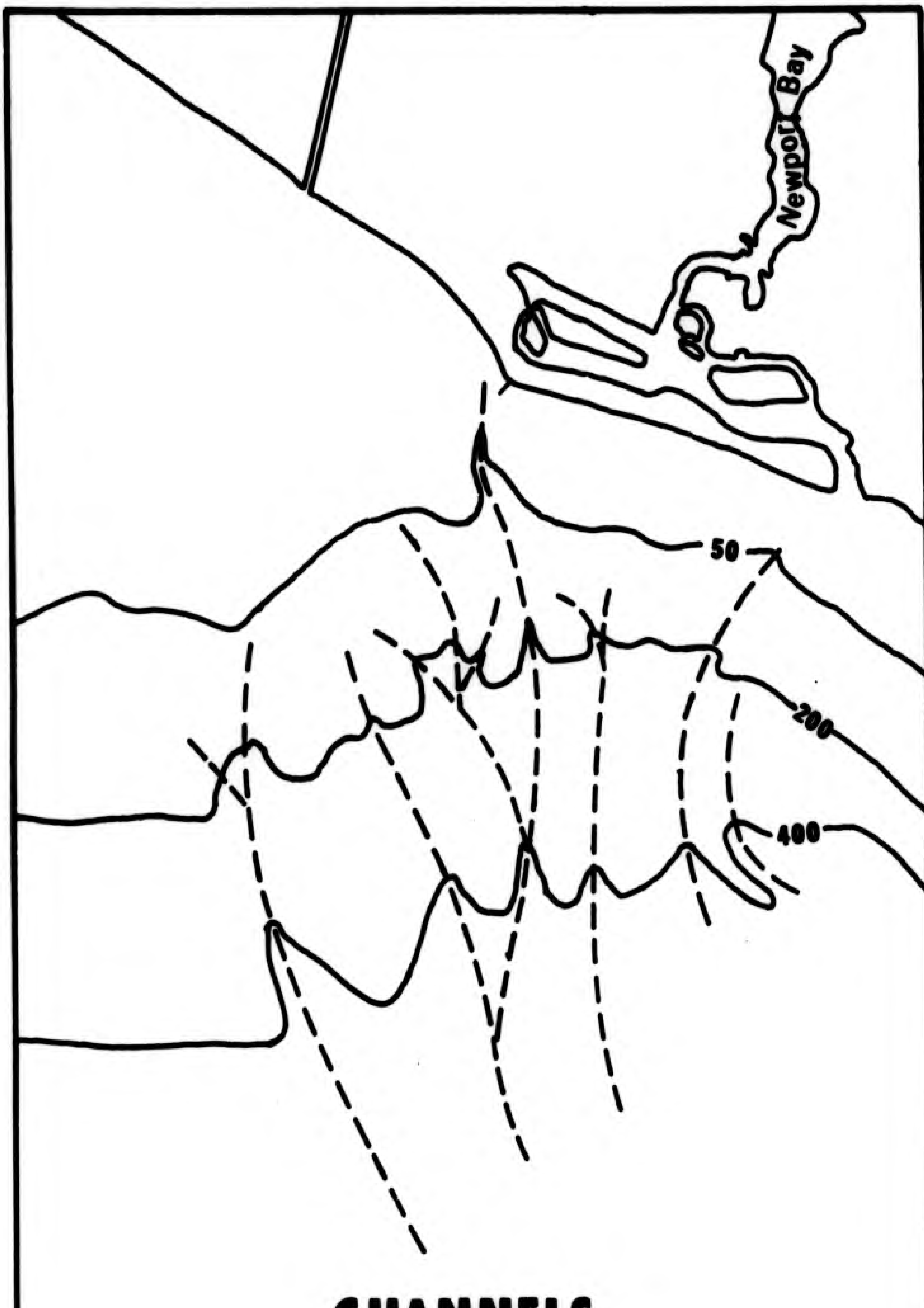


CHANNELS

CUT IN SHELF OFF NEWPORT BEACH

SANTA ANA RIVER - MID PLEISTOCENE

large quantity of sediment carried by the flood started to build the Newport barrier beach (Balboa Peninsula) and diverted the river to the western side of the Bay. A still greater flood in 1861 built the barrier to nearly its present size. The barrier continued to enlarge on the bay side until 1920, when the present artificial river channel was constructed.

Evidence gathered during this study indicates that wandering of the river was either more extensive than conceived by Stevenson, or started earlier than mid-Pleistocene. The evidence is in the form of physiographic features described below.

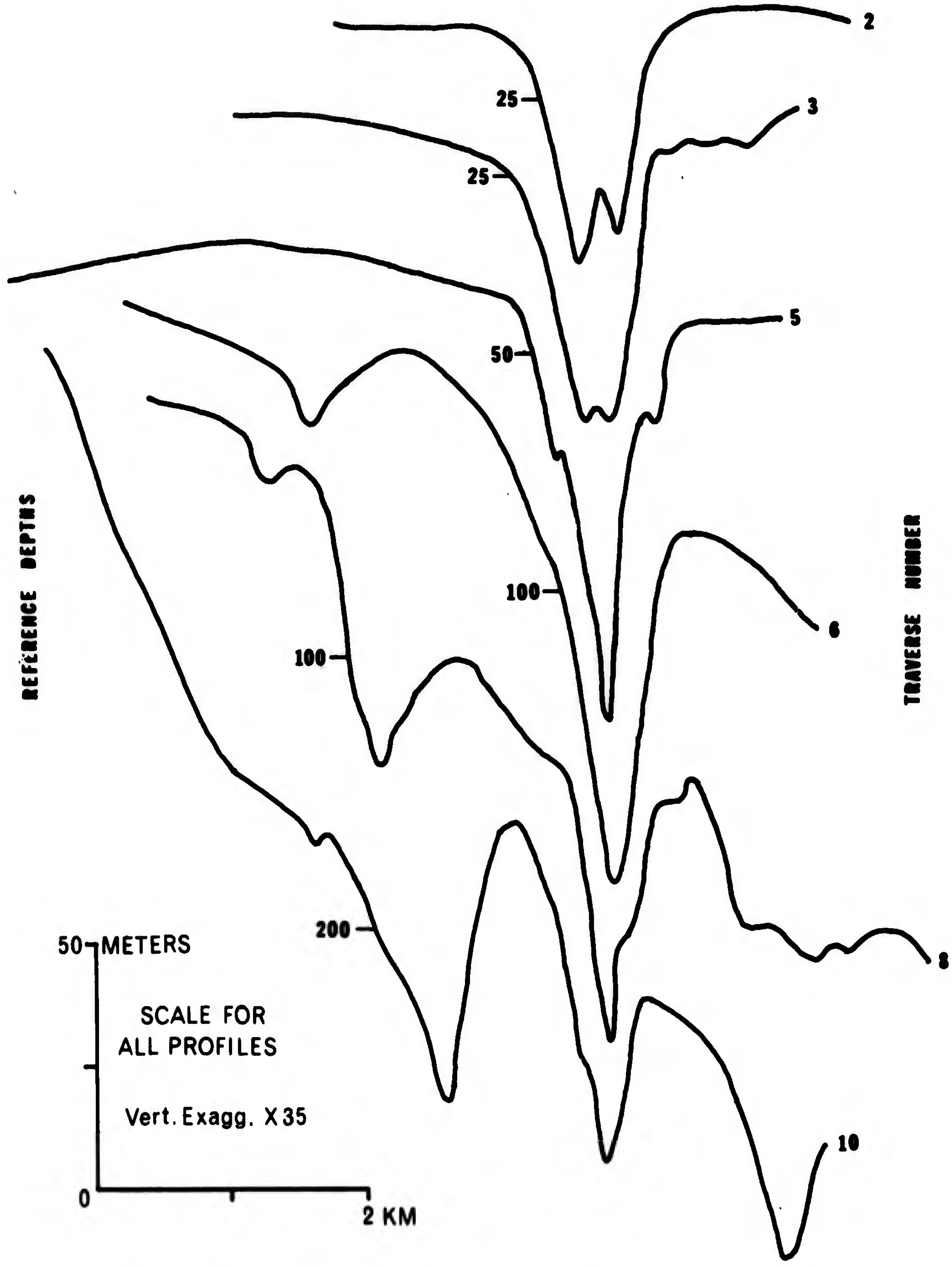
Interpretation of Physiographic Features

The general trend of the upper canyon is to the south along a sinuous path. Beyond the area of investigation it turns to the southwest and terminates in the San Diego Trough. Gradient of the main axis is 1.8°, with the inshore end slightly steeper at 2.5°. The walls are quite steep, averaging 13°.

Width of the main channel for the first 4 km rarely exceeds 1 km between the pronounced break in slope on either side. The most striking change in canyon shape is the "necking-down" of the main channel between 2 and 3 km from the head. Below this section the canyon abruptly widens. All samples indicate a mud substrate, so changes must be controlled by underlying bedrock.

The major channel commences as two tributaries of equal size which bound the Newport pier on the east and west. The western tributary extends toward the beach, terminating as a teacup-like depression in water 8 m deep only 150 m from the beach. The eastern tributary divides into two smaller chutes before ending in 10 m of water. The interesting aspect about these bifurcating channels is not that they are peculiar to Newport Canyon (such heads are the rule in Redondo, Scripps, La Jolla and other active canyons), but that this pattern occurs at depths of 50, 150 and 240 m, implying that considerable submergence has taken place if all were formed in shallow water. Submergence of such magnitude (240 m) is slightly in excess of the limits set by Shepard (1963) for sea level changes along static coasts during maximum Pleistocene glaciation (120-200 m). Considering the instability of the California coastal belt, a 240 m sea level change is possible. Emery (1960) cited the presence of presumably wave-cut terraces at similar depths off Santa Catalina Island.

Several episodes of valley rejuvenation are evidenced by benches or terraces on the flanks of the main channel and several of its tributaries. The most obvious terrace is found at a depth of 260 m in the main channel. This begins far up the canyon, first observed in profile number 8 (Fig. 6). Terraces are not confined to either side of the channel, and can often be correlated with those in other tributaries and benches on the shelf. These observations favor the development of terraces through erosion of the lower parts of the system at several intervals. Correlation among terraces in inter-connected valleys is strong evidence against an origin by slumping, and the merging of canyon and shelf terraces negates the possibility of turbidity current erosion.



BATHYMETRIC PROFILES

An example of rejuvenation was noted 2 km south of the pier where two small tributaries enter the main channel with steep gradients. They were contoured as "hanging" valleys because of their appearance in profile number 5 and their absence in profile number 6, 400 m further down the canyon (Fig. 6). Present tributaries, including those as small as the "hanging" valleys, may have been the main channel of the system at various times in the past. Changes in the river course eroded a new, intersecting channel and a Y-shaped pattern was produced. In the case of the present main channel, an extension north of the "hanging" tributaries could have been accomplished either subaerially by the river or through headward erosion via slumping and turbidity currents.

As observed today, the system consists of many partially filled valleys similar to the "hanging" tributaries. Is is possible that other completely filled channels lie beneath the modern sediment cover, particularly on the deeper parts of the shelf. Recent sedimentation is rapidly reducing the overall relief and a smooth shelf can be expected in the future, barring additional marine regression or coastal uplift.

Geomorphic History

The origin of the canyon system and bifurcated heads can be explained through the actions of two processes, neither of which are presently active. First, changes in the Santa Ana River which occurred in the Pleistocene and Holocene, alternating with periods of high relief and channel cutting, and secondly, a confluence of longshore currents at various points along the coast during each of the several low sea-level stands.

Wandering of the river is believed to be responsible for the many independent channels which incise the outer portions of the continental shelf and slope, and for the tributaries which enter the main channel (Fig. 4). Recalling the history of the Santa Ana River prior to formation of the barrier beach in the last century, the river emptied directly into the ocean. The cluster of channels is clearly restricted to that portion of shelf off the present barrier beach, a barrier which formed following the cessation of river wandering.

Evidence that the tributaries were eroded by the Santa Ana River, rather than its subaerial tributaries, is found at the southern edge of the surveyed area. Here, at similar distances from shore, a large tributary is deeper than the main channel (profile number 10, figure 6). This arrangement only could have developed if the present tributary-like channel was cut by the river and later abandoned when the river moved to a new position. The river did not have sufficient time to cut the new channel to the same elevation as the old before it was again diverted. Hanging valleys and canyon terraces indicate that erosion of the main channel occurred several times, even though Stevenson (1954) places it here only once. Several gravel-filled channels, bottoming as much as 50 m below the present surface, have been reported several kilometers inland of the coast (Poland, et al., 1956). These serve to delineate the degree of erosion in earlier times.

The origin of the bifurcated and/or teacup-shaped heads of channels can be explained by the action of longshore currents which are producing similar heads in active canyons. Convergence of such currents in the vicinity of canyon heads, and their erosional potential, was advocated by Crowell (1952) as a possible origin for canyons which cannot be correlated with terrestrial streams. At the present time currents do not converge at the head of Newport Canyon. Convergence has been noted over the heads of several other canyons with cup-like heads, so it is possible that a similar situation existed at Newport prior to the change in shoreline configuration resulting from formation of the barrier beach. The barrier changed the alignment of the coast from northwest-southeast to east-west. Likewise, it may have shortened the distance between the beach and canyon head, producing strong refraction and currents which diverge from the head.

OCEANOGRAPHY

Current Patterns

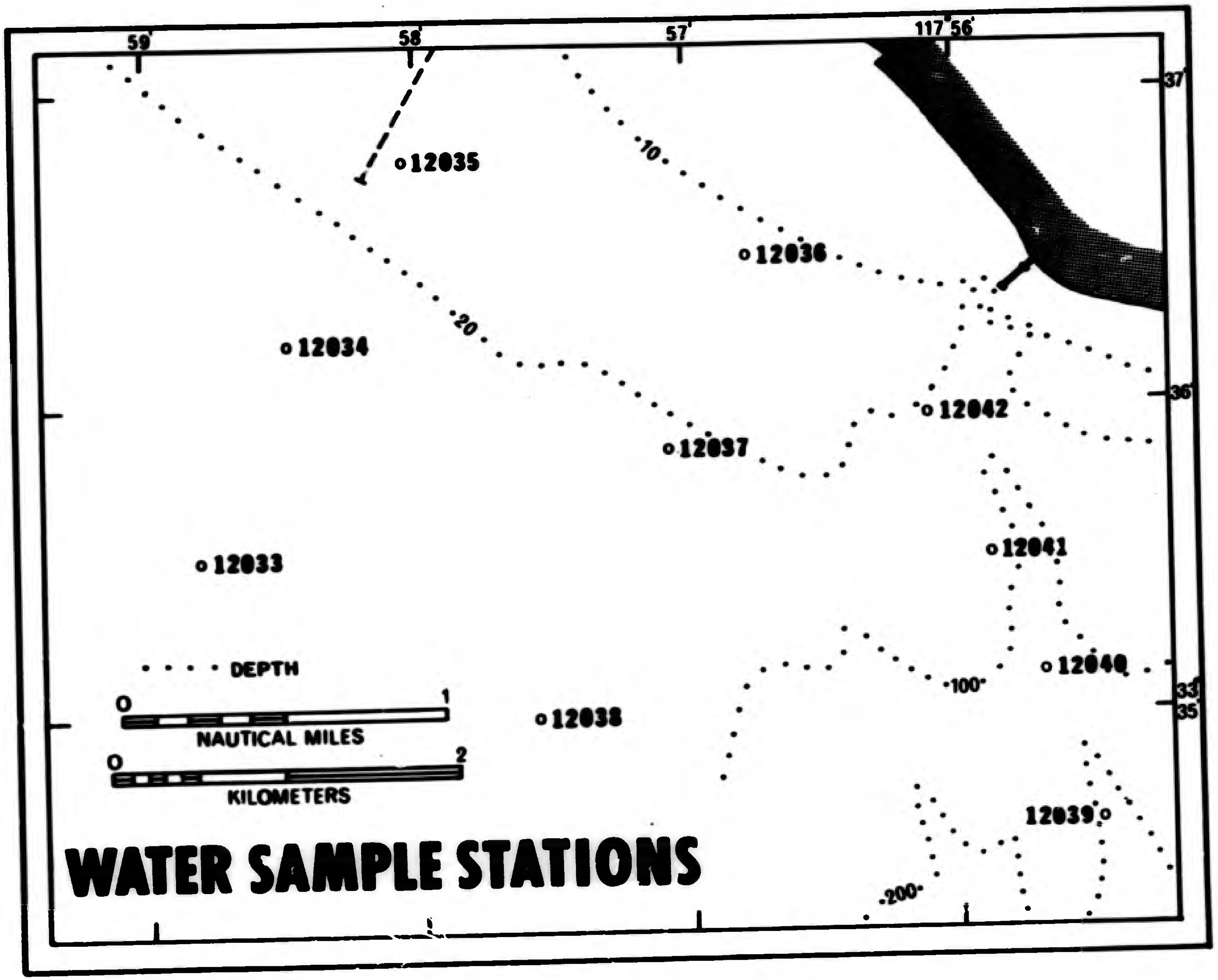
Offshore currents flow predominantly in northwest and southeast directions under the influence of local winds, or tide when there is no wind. The role of these currents in the sedimentation system is to transport fine sediment and organic debris from the river mouth and sewer to the canyon.

Average directions of longshore water movements, considering strength and direction over the period of a year, form a divergence away from the pier. This is caused by refraction of energy away from the canyon, regardless of the direction of wave approach. During periods of northwest waves, refraction is sufficiently strong to cancel any southward currents produced by the approaching waves. Southern swell, on the other hand, serves to amplify refraction currents along West Newport Beach. Northward drift is contrary to generally accepted patterns of littoral movement in southern California. The motion should be south in response to northwest and west waves (which dominate throughout the year) meeting the northwest-southeast trending coast line. As mentioned in the preceding section, the southward drift and divergence pattern are believed to be a recent development following changes in coastal alignment and a decrease in distance between shore and canyon.

Temperature

Although submarine canyons are considered to be likely areas for upwelling, the reverse situation exists at Newport. A study of temperature throughout the water column was carried out on March 29, 1968. Measurements were taken at 10 stations (Fig. 7).

Surface water warms as the canyon is approached from either side (Fig. 8), and slightly depressed isotherms in the canyon (Fig. 9) show that weak downwelling is the cause of this temperature distribution. Inasmuch as a large-scale temperature study was not undertaken, reasons for the downwelling are unknown. Control of currents by the abrupt bend in the coast may be an important factor. The permanence of the downwelling was confirmed during several trips to the canyon aboard the Ahovoha which is equipped with an electric thermometer. On every traverse, surface water was warmer over the canyon than on either side. Discussions with other workers at the Allan Hancock Foundation reveal that this is the usual situation. Such a phenomenon is significant in the dispersal of suspended sediment. Isotherms in shallow water essentially are parallel to density surfaces, and such surfaces provide "slides" for suspended matter entering the canyon. Recent work by Beer (1968) in Redondo Submarine Canyon failed to confirm upwelling in this area, so upwelling may not be as ubiquitous over canyons as believed.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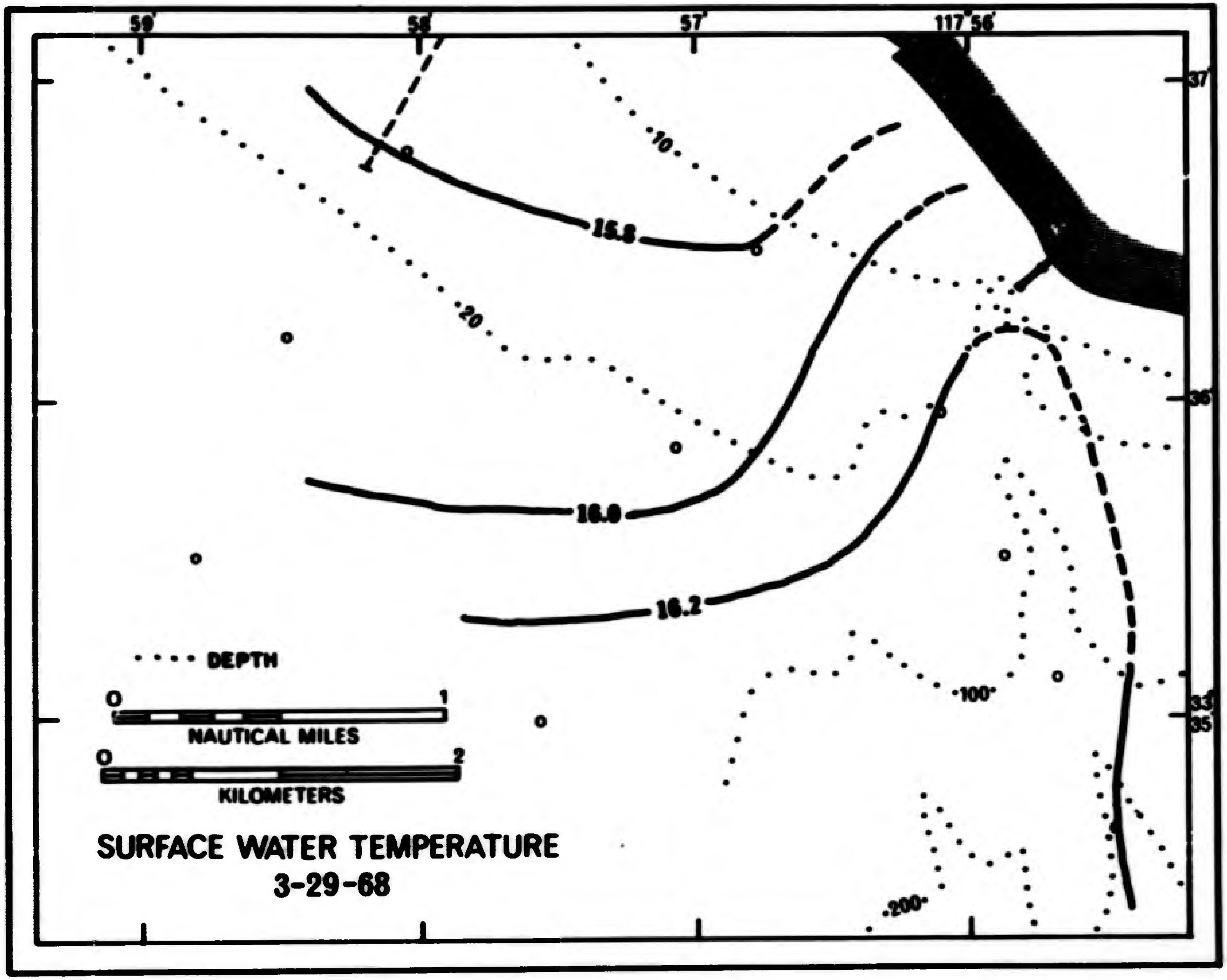
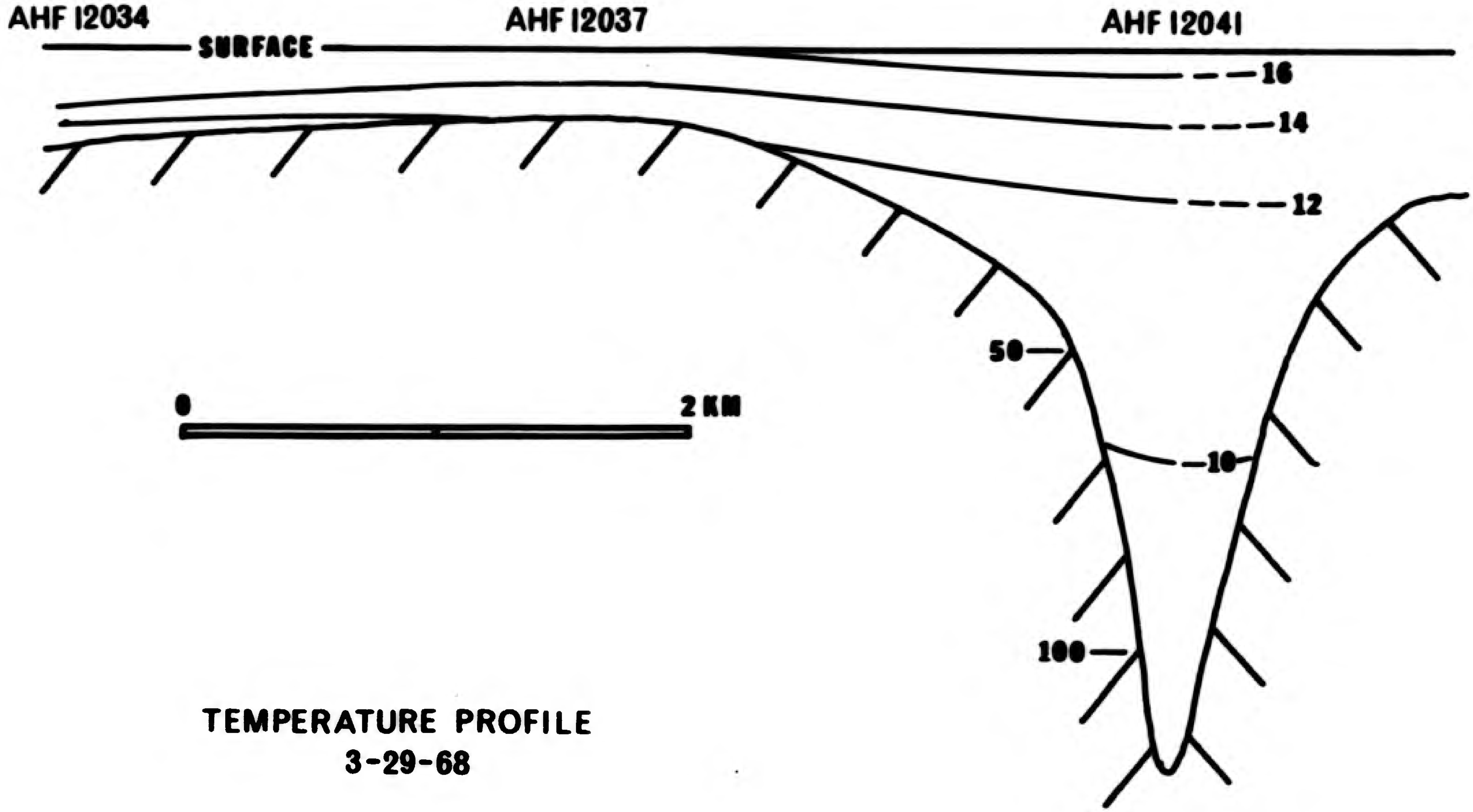
WATER SAMPLE STATIONS



SURFACE WATER TEMPERATURE
3-29-68



TEMPERATURE PROFILE
3-29-68

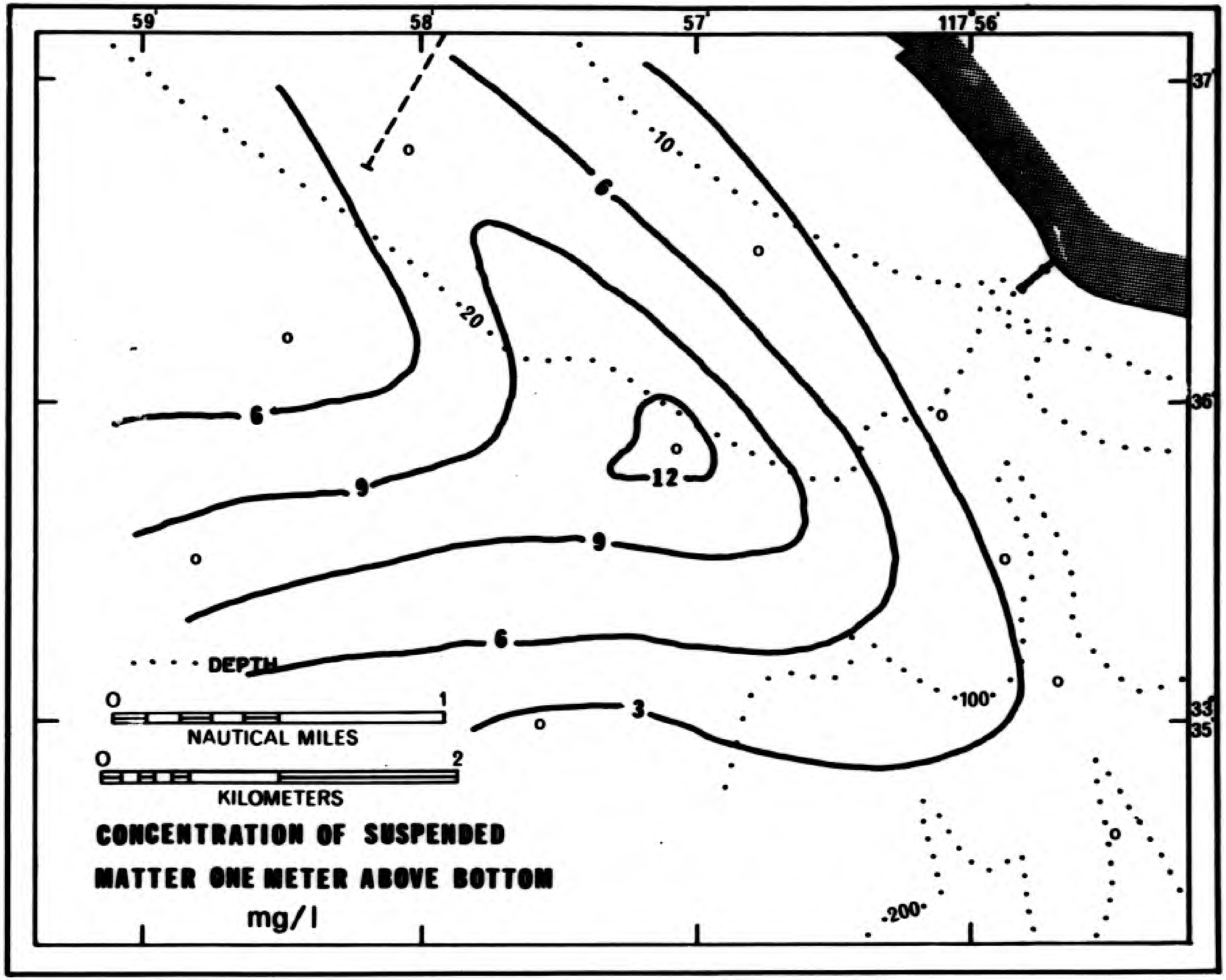
SEDIMENTOLOGY

Suspended Sediment

In contrast to many portions of southern California coast, the water off Newport Beach is frequently discolored at the surface by the addition of suspended material in high concentration. Diving observations reveal that this condition exists throughout the water column. Fine muds which comprise the canyon sediments are probably derived from suspension, so large volume water samples were taken from several depths at 10 stations (Fig. 7) to determine the nature and distribution of suspended matter.

At the time of measurement (March 29, 1968), concentration of suspended matter between the surface and thermocline was uniform at 2 mg/liter. Immediately above the thermocline, however, a strong pattern of high values over the shelf and low values within the canyon existed (Fig. 10). The exceptionally high concentration over the shelf can be attributed to one or a combination of the following: (1) a seaward flow of sediment-laden water originating near the beach, (2) wave surge, resuspending previously deposited fines, (3) surge generated by internal waves, (4) a strong bottom current winnowing fines transported away from the beach at an earlier time, and (5) a transport path for water-borne suspended material from sources outside the study area passing over this portion of shelf.

Because there was no significant swell on the sampling day, the first two possibilities are unlikely. The northwest-southeast


59'
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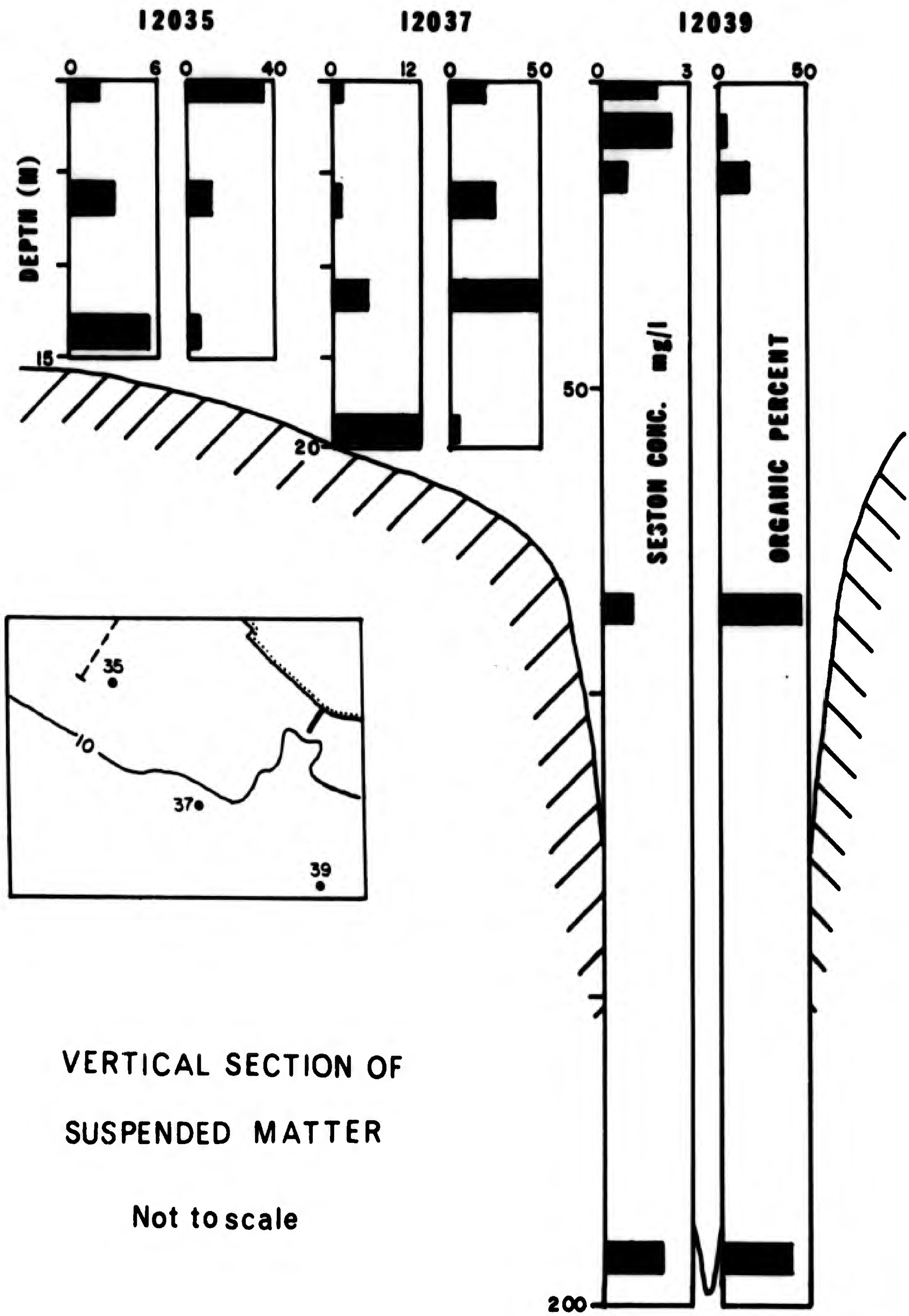
12
9
6
3
DEPTH
0
1
NAUTICAL MILES
0
2
KILOMETERS
CONCENTRATION OF SUSPENDED
MATTER ONE METER ABOVE BOTTOM
mg/l

elongation of the distribution pattern (Fig. 10), on the other hand, supports the latter two choices and implies that the sewer outfall may be the point of origin for much of the deep suspended matter. Turbulence from internal waves would not be a major factor in shallow water.

A northwest-southeast vertical section of suspended load concentration and organic content (Fig. 11) shows the dissipation of suspended matter throughout the deeper water column as it "pours" into the canyon. The highest organic content is in the vicinity of the outfall; the lowest in the canyon. The small size and low density of the organic particles is reflected by their concentration in the water column above the levels of highest total suspended matter.

Mineralogy of suspended clays is similar to those in the river and canyon (Table I). The ratio of various clay minerals changes in response to their rate of flocculation. Montmorillonite is the dominant clay in river sediment, but does not flocculate into sufficiently large particles to settle in the relatively turbulent nearshore waters; thus, it is not in a position to be resuspended by wave surge. Kaolinite and illite dominate the inorganic suspended fraction comprising more than 90 percent. The montmorillonite loss may be a result of laboratory technique, which employed filters of 0.8 μ opening. Montmorillonite generally flocculates in masses smaller than this (Whitehouse, et al., 1958).

The size of grains and floccules suspended over the shelf is approximately 0.024 mm, whereas over the canyon they are larger



VERTICAL SECTION OF

SUSPENDED MATTER

Not to scale

Table I

Ratios of Clay Minerals in Three Sedimentary Environments

Sample Location	Canyon axis			Suspensate 1 m above bottom		Santa Ana River 1 km upstream
Sample Number	[illegible]-7	[illegible]-1[illegible]	[illegible]-15	AHF 12035	AHF 12036	
Illite	70	66	[illegible]	69	50	33
Montmorillonite	7	9	15	2	4	54
Kaolinite	13	12	25	27	44	13
Chlorite	10	[illegible]	11	2	2	

Santa Ana River data from [illegible]. J. Lyne.

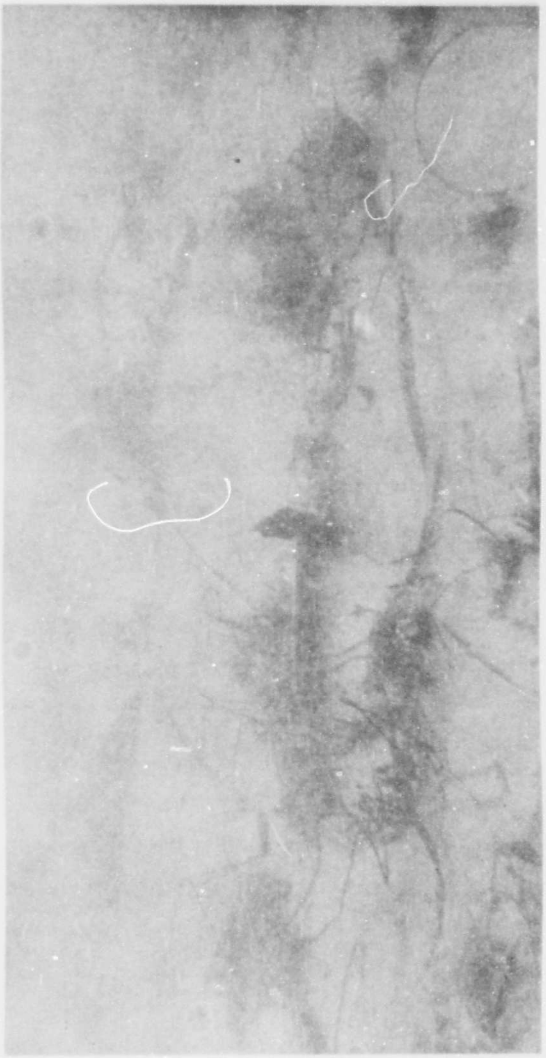
(0.050 mm). This probably reflects flocculation in the quiet water over the canyon. No definite relationship exists between size of particles and organic percentage in suspended sediment samples.

Bottom Sediment

Diving Observations

The first SCUBA investigation of the canyon by the author was made in April of 1967 in connection with a study of the engineering properties of canyon head sediments (Felix, 1967). The conditions observed in the first study were found to be unchanged in January of 1968 when a series of five dives into the canyon head and along the walls began. Visibility was poor in all except the last dive of this series, generally less than 2 m. The first four dives between January and June showed a surprising lack of debris in the canyon head. This is in strong contrast to conditions in the heads of other nearshore canyons such as Redondo and Scripps-La Jolla which also have been investigated by the author. These are full of bottles, cans and swim fins, as well as thick accumulations of kelp and eel grass at various times of the year. On the final dive into Newport, made in July of 1968, debris was beginning to collect (Fig. 12), but not in what would be called a thick accumulation.

Apparently the canyon intercepts small quantities of debris under the proper conditions, possibly when weak northwest and south waves approach simultaneously in the mid-summer. *In situ* measurements of shear strength increase with depth, until a weak layer at



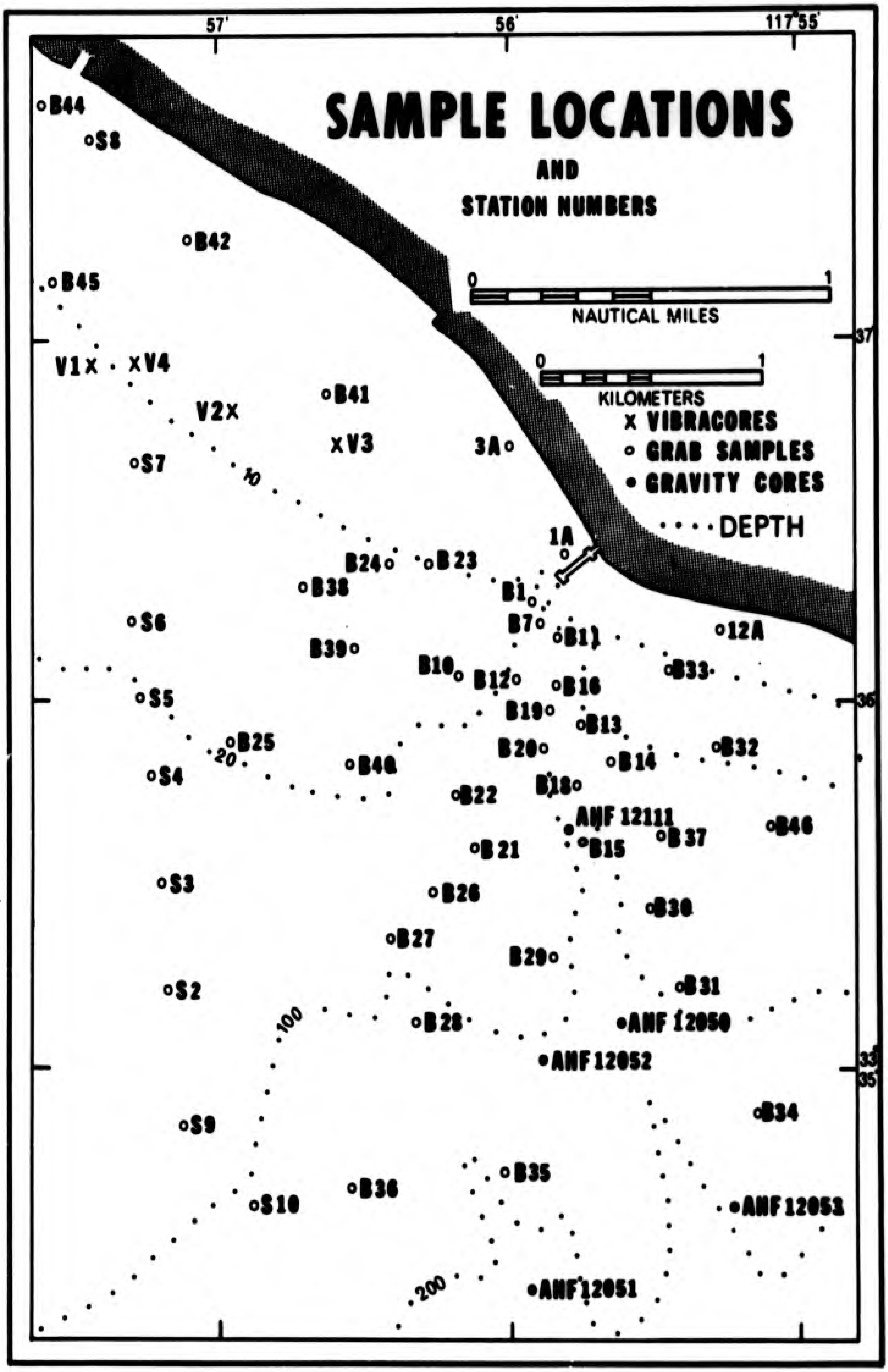
16 cm reduces the shear reading to one-half of that at 12 cm (Felix, 1967). This most likely represents a zone of decomposing vegetable matter. Sand is present in minor quantities in all canyon sediment samples, but nothing which could be called a sand has been observed in the canyon head.

Early in June of 1968 dives were undertaken at various locations between the pier and the groin, just outside of the surf zone. Depth averaged 6 m. Much of the bedrock had been scoured clean, and channels were cut perpendicular to shore into the fine sand which remained. Such an alignment requires that the channels be eroded by rip currents. A high velocity flow through the channels was suggested by the collection of such material as gravel, shells, cans and bottles within them. The time of scouring and channel cutting could not be determined, as rip currents occur throughout the year along this stretch of beach.

A dive to 10 m depth during a period of strong southern waves revealed that considerable bottom surge exists at such times, at least in the vicinity of the groin where the dive was made. This surge maintains fine sand in suspension as a thin (8 cm) layer immediately above the bottom. Surge-induced suspension plays an important role in the sedimentation system, and is discussed in a later section.

Sediment Types and Distribution

A total of 71 samples of surface sediment were studied to determine the nature of modern sediment groups in the Newport area. Positions of the offshore samples are shown in Figure 13.

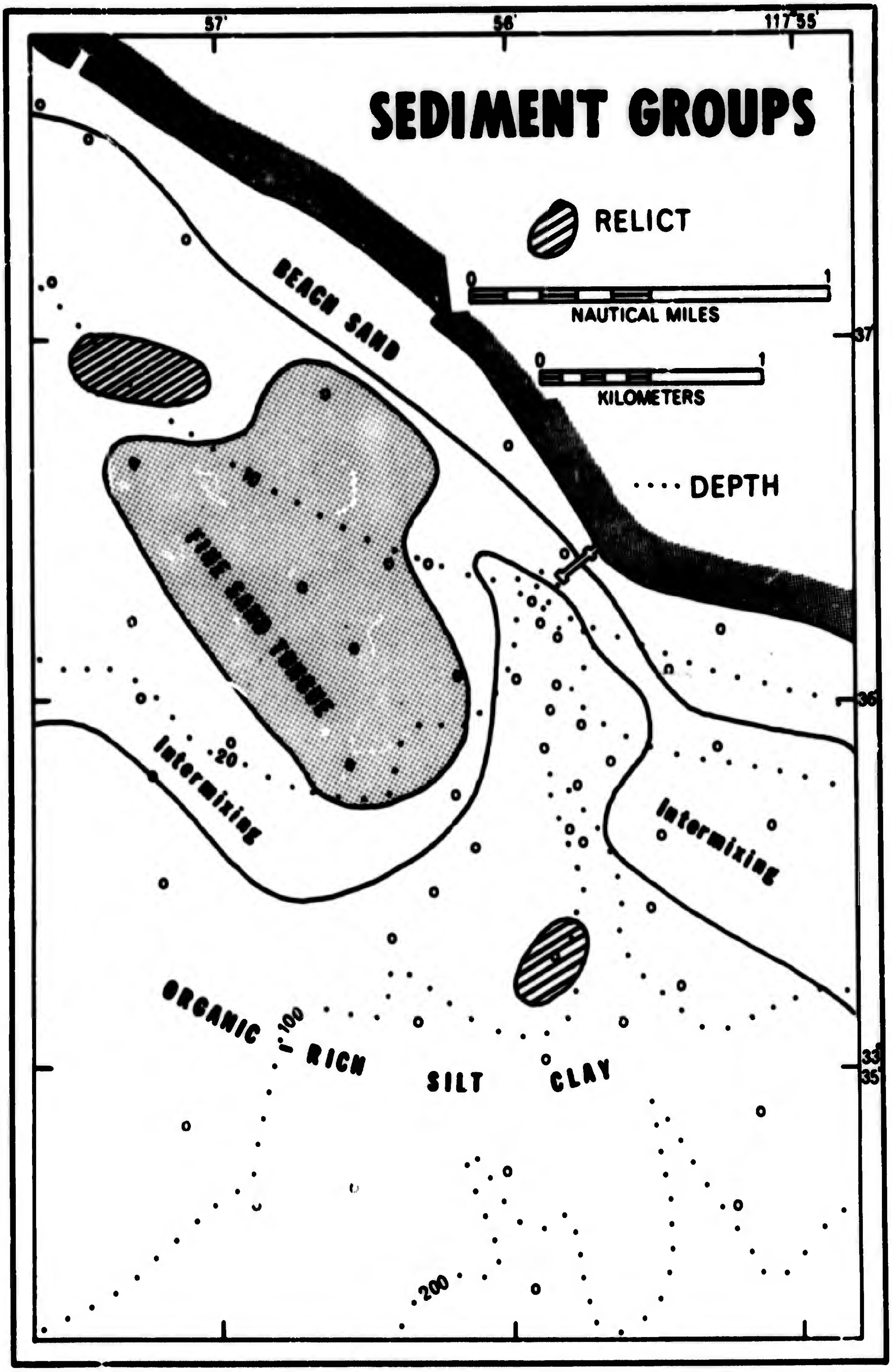

SAMPLE LOCATIONS
AND
STATION NUMBERS
NAUTICAL MILES
KILOMETERS
x VIBRACORES
o GRAB SAMPLES
• GRAVITY CORES
.... DEPTH
57'
56'
117°55'
B44
S8
B42
B45
V1
V4
V2
V3
B41
3A
S7
1A
B24
B23
B38
B1
S6
B7
B11
12A
B39
B10
B12
B16
B33
S5
B19
B13
B25
B20
B32
S4
B40
B14
B22
B18
ANF 12111
B37
B46
B21
B15
S3
B26
B30
B27
B29
S2
B31
B28
ANF 12050
ANF 12052
B34
S9
B35
S10
B36
ANF 12053
ANF 12051
10
20
100
200

Four sediment groups (Fig. 14) have been defined on the basis of color, size statistics, chemistry, and mineralogy, namely: (1) Modern beach sand, (2) a patch of fine sand in the shape of a tongue, centered 1.5 km off the groin, (3) organic-rich silt and clay in the canyon and deep water surrounding the tongue, and (4) relict sediment, small areas of which are exposed but which, for the most part, is buried under a thin layer of modern material.

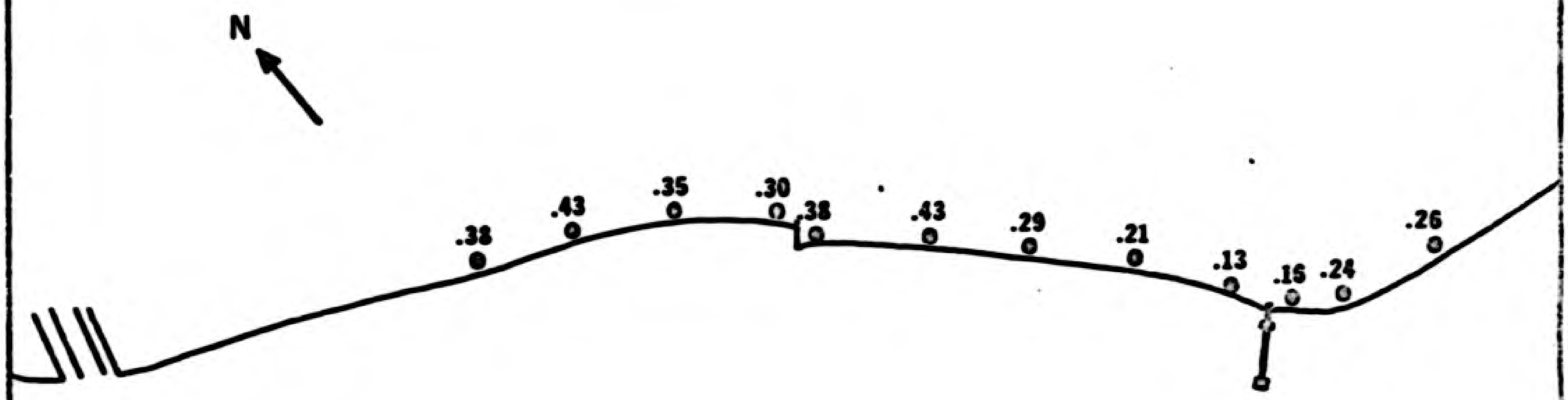
Modern Beach Sand

Grains are subrounded to very round, medium to very fine quartz, feldspar and rock fragments. Orange-stained grains are present in varying abundance in all samples. Sand north of the groin has a pale orange color, but this changes to medium gray toward the pier as platy minerals become more abundant.

Changes in mean sediment diameter along the beach reflect changes in the nearshore energy environment (Fig. 15). Small waves dominate just inshore from the canyon head (to the north of the pier), whereas refraction away from the canyon produces high waves, and thus coarser sand, on either side of the pier. Before the groin at 40th Street was constructed in February, 1968, the portions of the beach 0.5 km on either side of this point underwent severe erosion during periods of southern waves. The groin halted erosion on its southern side by preventing sand from migrating to the north. A low energy pocket slightly to the north of the groin accumulates fine sand under normal west and northwest waves, but during a south swell is badly eroded. Rip currents transport the eroded fine sand offshore and coarser material is pushed north by longshore currents.



SEDIMENT GROUPS
RELICT
NAUTICAL MILES
KILOMETERS
DEPTH
57'
56'
117°55'
37'
36'
33°35'
BEACH SAND
FINE SAND TONGUE
Intermixing
Intermixing
20
100
200
ORGANIC RICH SILT CLAY



MEAN DIAMETER OF BEACH SEDIMENT

IN mm.

• SAMPLE LOCATIONS

Fine Sand Tongue

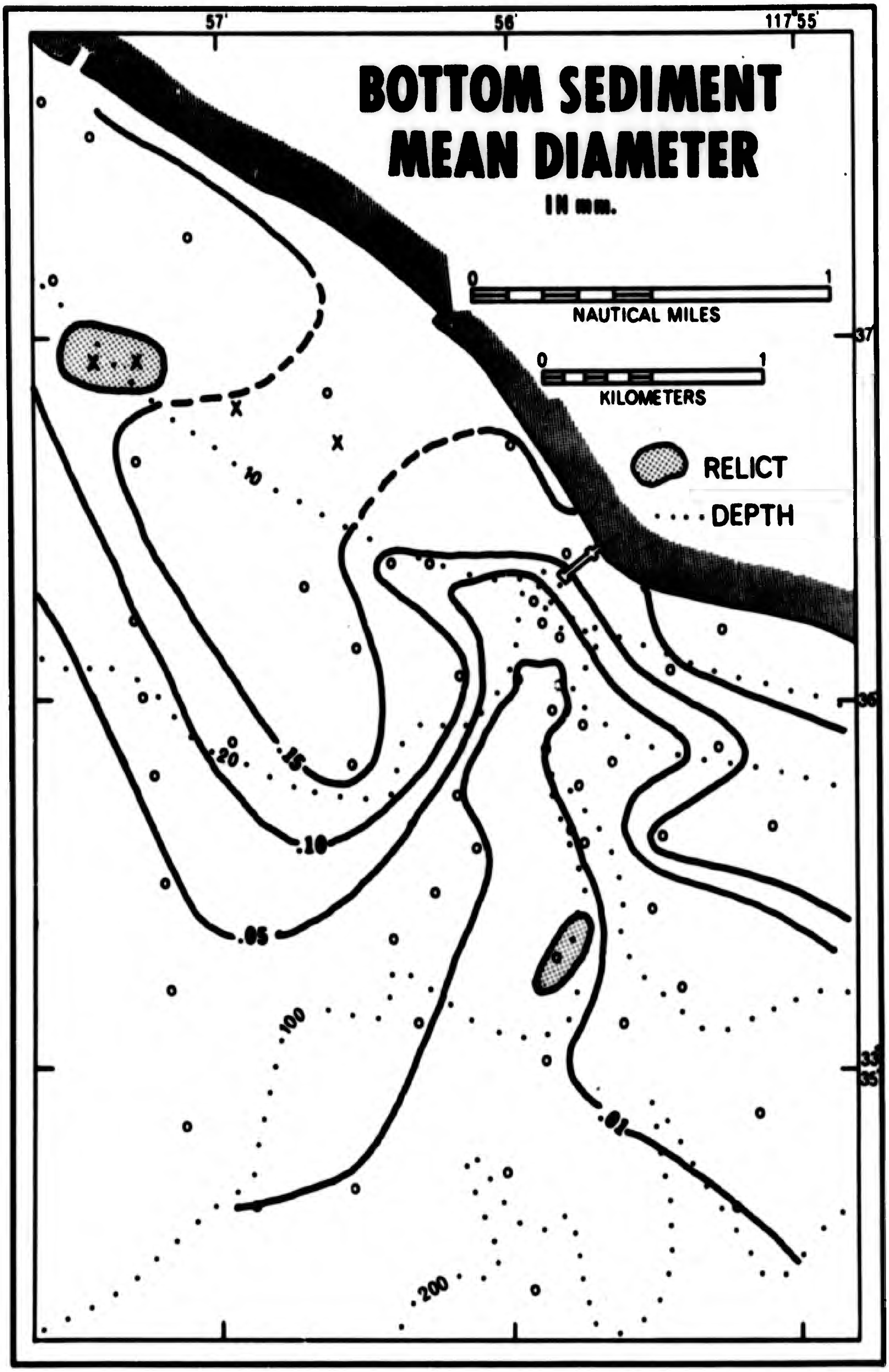
When isopleths of mean sediment diameter are plotted for the offshore area, a tongue-shaped deposit is immediately apparent (Fig. 16). Size of the tongue sediment is centered at 0.15 mm, with the bulk of the material between 0.5 and 0.062 mm. A light olive gray color and a pronounced lack of platy grains serve to delineate the tongue from its surroundings. Minerals present are quartz, feldspar and about 25 percent heavies; all are subangular to subrounded. Nitrogen averages less than 0.04 percent.

Organic-rich Silt and Clay

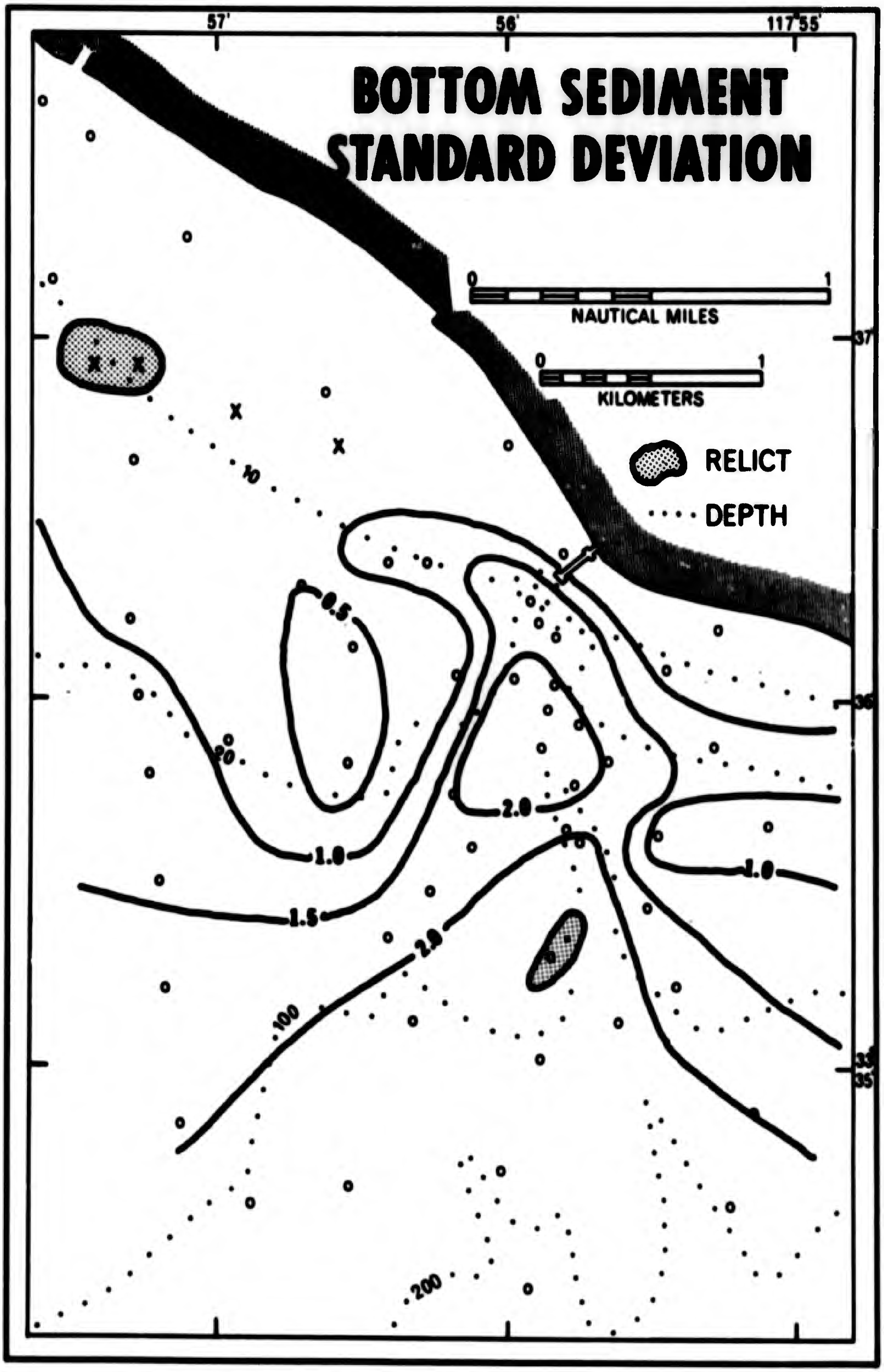
Very fine (0.02 mm) dark olive silt and clay predominate in the canyon and on the deeper parts of the shelf. Poor sorting (Fig. 17), and a wide range of angularity within the sand fraction, indicate the multiple sources of supply.

Organic matter from the sewer outfall is transported to the canyon and deeper water, resulting in the nitrogen content being an order of magnitude higher in these environments than in those closer to the outfall. This difference is not simply a reflection of bottom sediment grain size in these environments, since similar material is found close to the outfall and on the upper flanks of the canyon.

Sand and silt fractions are dominated by platy minerals. Those equidimensional grains which are present are frequently coated with an orange-colored iron oxide. Wood fragments and platy aggregates are restricted to the upper portions of the main channel, but subangular to rounded rock fragments are characteristic of the



BOTTOM SEDIMENT
MEAN DIAMETER
IN mm.
57'
56'
117°55'
0
1
NAUTICAL MILES
0
1
KILOMETERS
RELICT
DEPTH
37
36
35
10
20
.15
.10
.05
.01
100
200



BOTTOM SEDIMENT
STANDARD DEVIATION
57'
56'
117°55'
NAUTICAL MILES
KILOMETERS
RELICT
DEPTH
10
20
100
200
0.5
1.0
1.5
2.0

sand fraction in deeper water. Samples from the axis and western flank of the canyon rarely have more than 2 percent sand (all less than 0.125 mm diameter), whereas the east wall samples contain as much as 35 percent sand.

Clay minerals (2 μ and less) from axial samples occur in the approximate ratio of 60 percent illite, 20 percent kaolinite, and 10 percent each of montmorillonite and chlorite. The three clay samples which were analyzed exhibit an interesting change in relative mineral percent in the down-canyon direction; illite decreases while the others increase. A change in ratios demonstrates that the mode of clay deposition is suspension throughout the canyon rather than initiation of slumps and turbidity currents from any one locality which would result in uniform ratios.

Relict Sediment

Two patches of relict sediment, formed at different times by different processes, were located. Their small size implies that other exposed remnants may exist between the sampling stations. On the west wall of the canyon at 71 m depth, a mixture of all grain sizes from gravel to the finest clay was obtained. The larger cobbles and sand are obviously not in equilibrium with the present environment, and characterize this as river sediment deposited during a high velocity flow at a time of considerable relief. The fine sand and silt-clay are contemporary, but were deposited so slowly that the gravel is not yet buried more than a few centimeters. Coarse sand is dominated by subangular to subrounded rock fragments; cobbles and pebbles are all well-rounded.

Considering the position of this gravel deposit, high on the wall of the canyon but still below the level of the shelf, it appears to be a layer which has been exposed during cutting of the canyon. Extensive, gravel-filled channels found several kilometers inland have their base 40 m below sea level (Poland, et al., 1956). This gravel is referred to as the Talbert water bearing zone which was deposited by the ancestral Santa Ana River. Formation of the trench in which the river flowed occurred in the late Pleistocene, and the Talbert gravels were laid down in the early Holocene so the time of cutting for the present canyon must be post early Holocene times. The Talbert gravels were most likely deposited in a pre-existing canyon or channel and subsequently exhumed, so an "ancestral" Newport Canyon may have existed through most of the Pleistocene.

The second patch of relict sediment is a high energy beach and beach dune sand deposited during the last sea level stand 12 m below present sea level. Mean diameter of the relict sand is 0.30 mm. Grains are subrounded to round, and many are coated with an orange-colored film of iron oxide, indicating a considerable period of subaerial exposure. Approximately 50 percent frosting is visible on most of the clear grains, which indicates reworking by wind into beach dunes. Except for the orange-coated grains, mineralogy and general appearance are the same as sand from the Santa Ana River; and identical to, though slightly smaller than, modern beach sediment.

INTERPRETATION OF CONTEMPORARY SEDIMENT SOURCES AND DISPERSAL PATTERNS

General Statement

Sediment sources and transport paths in coastal areas cannot be clearly defined because of reworking and temporary storage in unstable environments such as beaches. Along the southern California coast, this problem is compounded by the presence of ancient emerged and submerged beach and stream deposits derived from the same sources as modern sediments. A synthetic classification has been devised for the Newport area, but it must be remembered that it represents only an approximation of the true situation.

Primary Sediment Sources

Most marine sediments are originally derived from the continents. In the semi-arid climate of southern California, runoff is intermittent and occasionally torrential. Larger streams which drain the interior are now dammed and confined to concrete channels (Norris, 1964), so they supply little sediment to the ocean. Sediment which reaches the coast is transported either off or along shore in response to energy conditions and hydraulic characteristics of the grains.

The north Orange County coast is exceptional in that man has effectively eliminated most sources of new sediment, and slowed down the littoral transport of that which does reach the shore.

Long Beach Harbor to the north of Newport prevents sand from moving south, and Newport Canyon and the Newport Harbor jetties act as a barrier to any northward transport. Damming of all rivers within this isolated segment was completed 20 years ago; nothing but the finest sediments have managed to reach the coast since that time. The maximum size sand in the Santa Ana River, 1 km upstream from its mouth, is 0.50 mm and mean sand diameter is 0.21 mm. Sediment of the San Gabriel River to the north has an even finer mean diameter of 0.11 mm. Minor amounts of coarse sand are undoubtedly contributed by local runoff during the brief, torrential rains of winter and spring.

Fine sand, silt and clay comprise the bulk of sediment which eventually reaches the ocean. Sand is deposited either at the mouth of the Santa Ana River or a short distance offshore, while clay may continue across the entire shelf if not diverted by local currents. Many of the silt and flocculated clay particles settle in shallow water so that they can be resuspended during the large waves, or are carried directly into the canyon by subsurface and bottom currents.

X-ray diffraction study of the minus 2 μ clays from the river, suspended and canyon sediments, leaves little doubt that the river is the source of much of the clay found in suspension off Newport Beach and in Newport Canyon.

Offshore Relict Sources

Relict Pleistocene beach deposits on the shelf provide the only sources of "new" beach sediment to many sections of the California coast. Two small accumulations were located off Newport but only one, a beach and beach dune deposit 1 km from the river mouth, is in sufficiently shallow water to serve as a source of beach sediment. The relict character of surficial sediment is being destroyed by the admixture of fine grains more in equilibrium with the modern environment, but cores provide evidence of the old depositional regimes.

Orange-stained grains are abundant in the relict material. In response to modern energy conditions, they occasionally move onshore. Large quantities are present on the beach inshore of the relict patch. As the orange grains are larger than those in the tongue or canyon sediments, they are rare in these sediment groups. During strong northwest waves, relict sediments are brought into the surf zone and transported south to the vicinity of the canyon head. After such periods, the color of the beach inshore of the canyon head changes from its normal olive buff to a pale orange.

The Beach as a Sediment Source

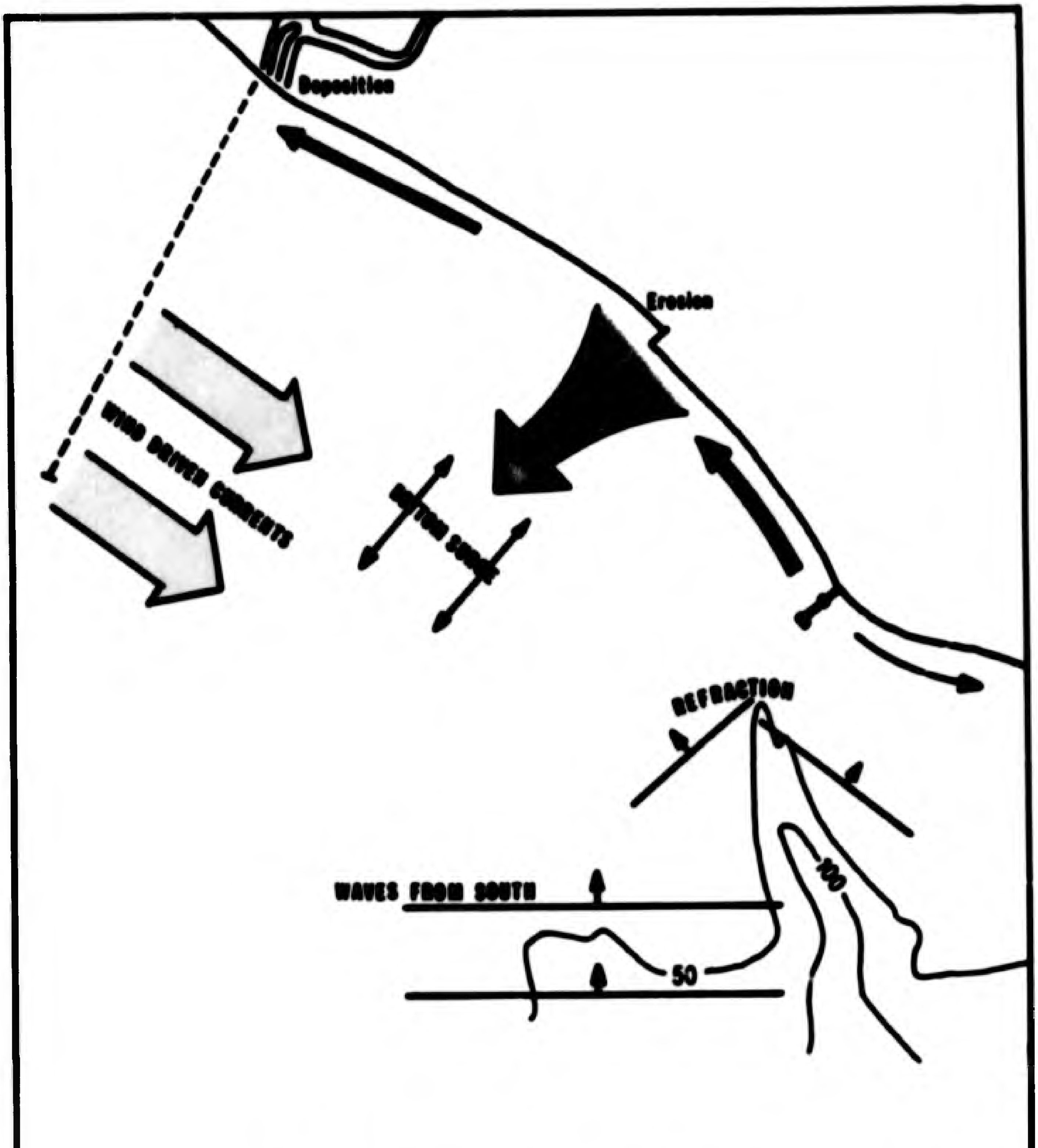
Erosional Sand Losses

Late summer and fall have been periods of severe coastal erosion at Newport since the 1930's. It was in the preceding decade that man began to cut off sources of new sediment and to impede the movement of littoral materials. Prior to this time, sand was lost from the beach but was always replaced by natural processes.

Seasonal variation in strength and direction of the waves approaching Newport are the most significant factors in removal of beach material. A sharp inflection in the coast at the head of Newport Canyon and its nearshore head serve to segregate the beach segments on either side of the pier. Permanent erosional damage is experienced only by that portion of beach to the northwest of the pier locally known as West Newport.

Waves generated by storms in the northwest Pacific do not produce surf as large as those from the south. This is a result of stronger storms in the southern hemisphere because of greater fetch, alignment of the southern California coast, and the presence of the Channel Islands to the north which diminish wave energy from that direction. Although southern waves reach the coast for only short periods of time, the current patterns they establish are much stronger and more significant in the transport of littoral sediments than currents produced during the majority of the year by weak northern waves.

West Newport receives southern swell at a low angle which, when combined with refraction away from the canyon, results in strong northward flowing longshore currents (Fig. 18). These currents generate rip currents which carry fine sand offshore, while medium and coarse grains are transported to the river jetties where accretation occurs. During years of prolonged southern waves (such as 1968), sand builds out around the end of the jetties and drift continues uninterrupted to the north. That portion of Newport Beach which lies to the southeast of the pier suffers little permanent damage under these wave conditions because waves



SOUTH SWELL CURRENTS

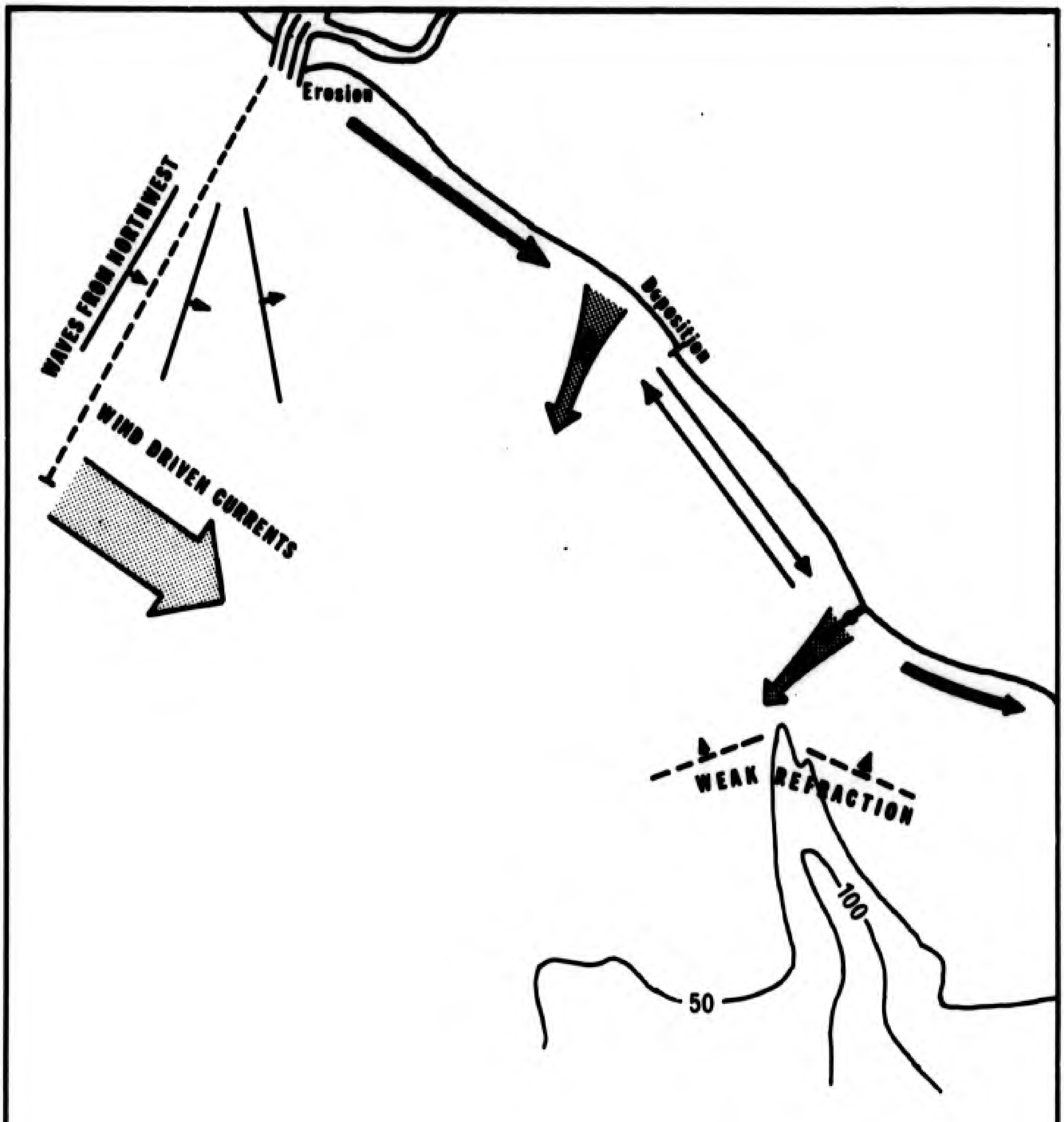
approach parallel to the east-west shore line and carry the sand to offshore bars rather than outside of the system.

Waves from the west and northwest are generally small and tend to return sand from the bars to the beach. At the same time they generate weak, southward currents along West Newport Beach. At times refraction over the canyon is sufficient to produce counter currents which negate this southward drift (Fig. 19). Studies made for the United States Army Corps of Engineers in 1964-1965 demonstrated (through the use of dyed sand) that the net directions of transport over a one year period are such as to produce a convergence of drift material in the vicinity of the groin.

Transport Away from the Beach

The nature of beach erosion strongly suggests that a large portion of the losses, notably fine sand, is to be found in the tongue-shaped sand deposit on the shelf. A considerable body of direct and indirect evidence has been collected which can be used to outline the probable method of transport from the beach and collection of the sand in a localized sedimentary environment.

Rip currents, as presently understood, do not provide the mechanism for transport far beyond the surf zone. Rip channels in the vicinity of the groin, however, clearly demonstrate that rip currents can carry material in tractional as well as suspended load and may be significant agents of transportation. Evidence concerning the nature and quantity of suspended load carried by rips was gathered during a period of southern waves in August of 1968. A large rip current off the groin was sampled for suspended sediment 3 m below the water surface using open cans, anchored on taut lines,

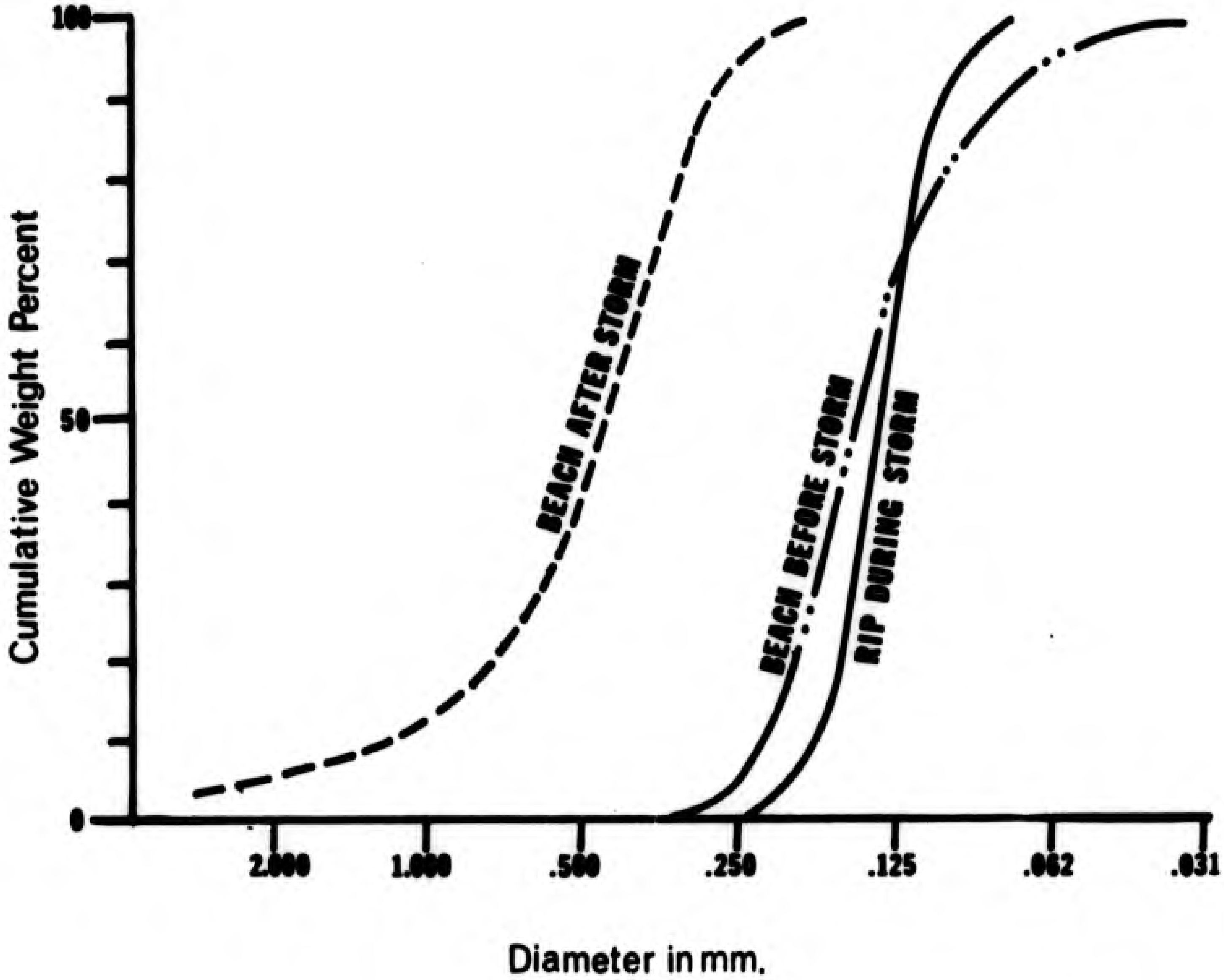


NORTH SWELL CURRENTS

as traps. Samples collected in the traps were compared texturally with beach sand samples obtained before and after the southern waves at stations immediately adjacent to the north and south sides of the groin. The bulk of the fine sand removed from the beach north of the groin matches almost exactly the size distribution of the rip material (Fig. 20). The beach on the north side of the groin was eroded 15 m during this storm. Erosion on the south side, in comparison, was insignificant and there was no change in the size distribution of the sand.

Observations made during dives at the time of the southern swell reveal that strong bottom surge has the ability to maintain a dense sand suspension immediately above the bottom. Fine sand, winnowed from the beach by rip currents, is carried in suspension until the current dissipates. It is then transported by bottom surge farther offshore. The preceding types of transport have been documented by Vernon (1966) and also were observed by the author. Distribution of this surge-suspended sand is accomplished by local bottom currents so that it is deposited in a tongue, parallel to the current direction.

The limits of the tongue are sharply defined by closely spaced mean diameter isopleths. Thirty meters appears to be the maximum depth at which surge and/or currents can maintain a sand suspension. This agrees well with experimental data from Vernon, et al. (1966) which shows that orbital velocity 10 cm above the bottom will range from 13 to 65 cm/sec in response to waves 30 to 120 cm high. These data are for a water depth of 26 m, the average depth of the tongue. Average size of sand in the tongue is 0.13 mm which, according to



BEACH AND RIP SEDIMENT

NORTH OF GROIN

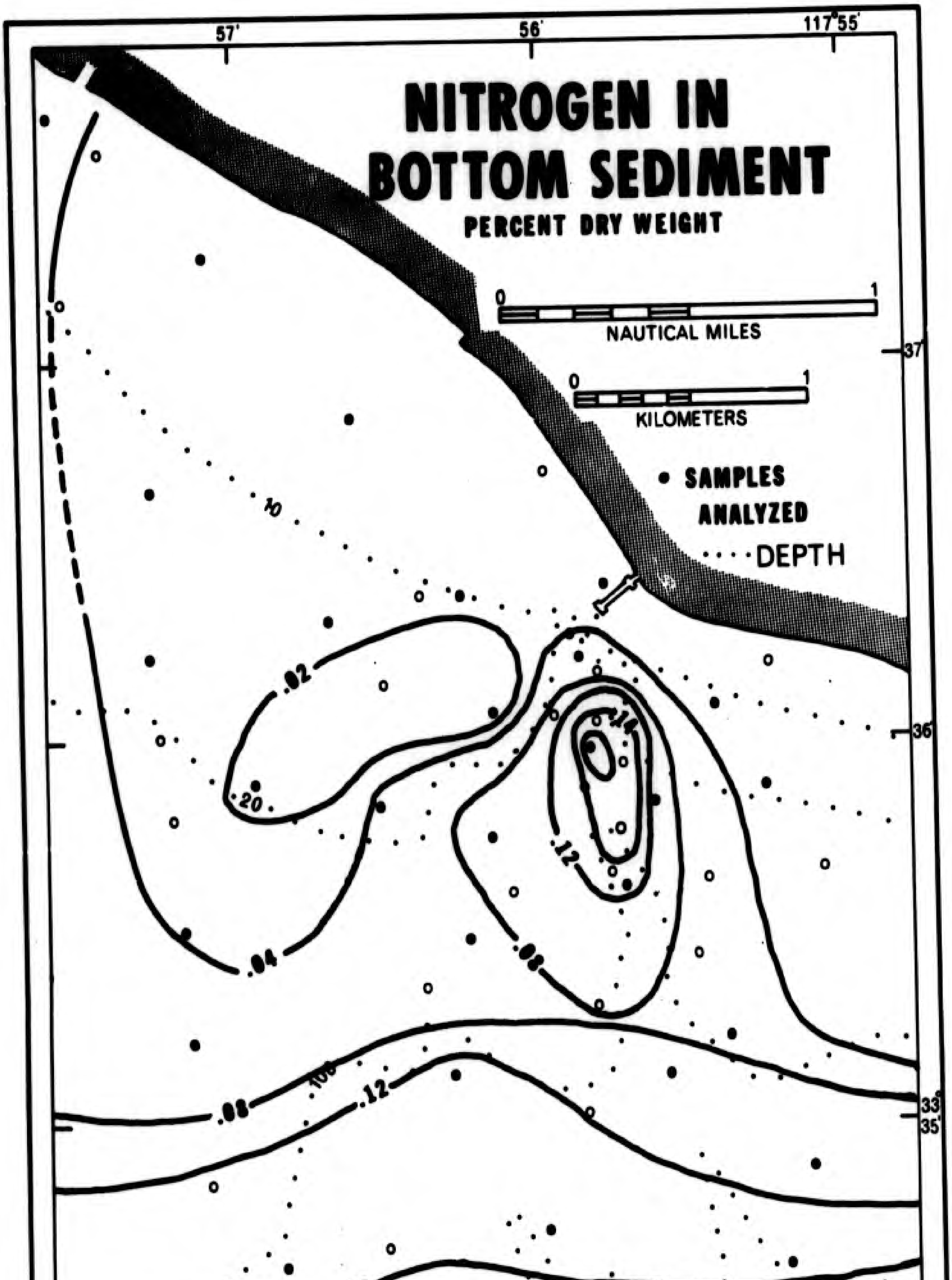
Vernon, et al. (1966) has an experimental threshold velocity of approximately 8 cm/sec on a 1° slope such as that on the inner portion of the shelf off Newport Beach; such material could easily be suspended by waves as small as 30 cm.

Simple calculations serve to demonstrate that the tongue has sufficient volume to accommodate the 1.5 million cubic meters of sand removed from the beach between 1939 and 1966 (United States Army Corps of Engineers, 1967). The surface area of the tongue is approximately 2 million square meters, therefore, all sand losses could be accommodated if the tongue is 75 cm thick throughout. Of course, not all of the sand has moved to the tongue; much of the coarse material has moved north along the beach. Vibracores taken at the edge of the tongue show that the upper layer of fine-grained tongue sand thickens as one moves toward the center of the tongue.

Sand is not being removed from the tongue along any detectable path at present. Some sand enters the canyon over the flanks, but is rapidly diluted by the flood of fines coming out of suspension.

Organic Contribution

Visual confirmation of a thin, fluffy surface layer throughout the canyon, and the foul smell of sediment, attests to the fact that sewage is being transported into the canyon by natural processes. The fine size of organic particles, and the inorganic grains to which these adhere, is reflected in the plot of nitrogen content (Fig. 21) which is inversely correlated with mean sediment diameter. A high nitrogen content is not ipso facto proof of sewage origin, but other sources of organic material are precluded



NITROGEN IN BOTTOM SEDIMENT
PERCENT DRY WEIGHT
57'
56'
117°55'
0
1
NAUTICAL MILES
0
1
KILOMETERS
• SAMPLES ANALYZED
····DEPTH
37'
36'
35'
10
.02
.20
.04
.08
.12
.14
100
.08
.12
.16
200

by environmental conditions. High biologic productivity is unlikely because of the persistent downwelling. Plant debris which collect in the canyon head occasionally do not move any significant distance down the axis as a coherent mass, so these could not be the source of the nitrogen.

Changes in the last decade have increased nitrogen content by nearly an order of magnitude in the canyon sediments, whereas values in shallow water sediment have remained constant. A study of sediment chemistry performed in the late 1950's by Bandy, et al. (1965) provides the basis for comparison. Such a marked increase could only be attributed to man's activities, that is, the increase in sewer waste.

Transport paths of organic matter in the canyon sediment can be traced from the sewer by means of carbon and nitrogen content of various sediments between the source and depositional area. As it leaves the treatment plant, the sewage contains 77 percent organic matter and has a carbon-nitrogen ratio of 34. During transportation toward the canyon by southeast currents, sewage effluent undergoes fractionation in the water column in response to density differences among effluent particles. Figure 11 shows how organic particles are concentrated at the surface in the vicinity of the outfall, and sink to deeper levels as they are absorbed by flocculating clays in the down-current direction. Total digestable organic content of the suspended matter ranges from 0 to 70 percent, depending on level in the water column, with an average of 30 percent. Upon reaching the deeper water of the canyon, suspended matter dissipates but is again reconstituted in the bottom sediment. Some intermixing of shelf sand and river sediment occurs in the canyon, while the addition of planktonic plant and animal debris increases the nitrogen content. The result is a carbon-nitrogen ratio of 9 in surficial sediment of the canyon. The presence of hair, both in the effluent and canyon surface sediments, provides supplementary evidence for sewage in the canyon.

Highest nitrogen concentration is found in sediments on the west flank of the canyon, the same position as the finest inorganic particles. Sedimentation of this fine material must occur rapidly after entering the canyon, although some does cross to the eastern shelf.

RECENT SEDIMENTATION HISTORY

Canyon Sedimentation

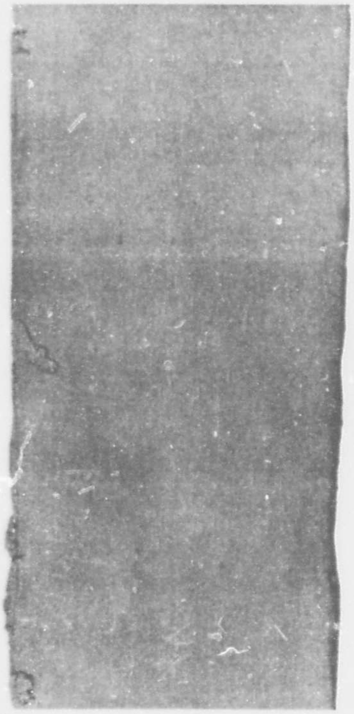
Summery of Gravity Core Data

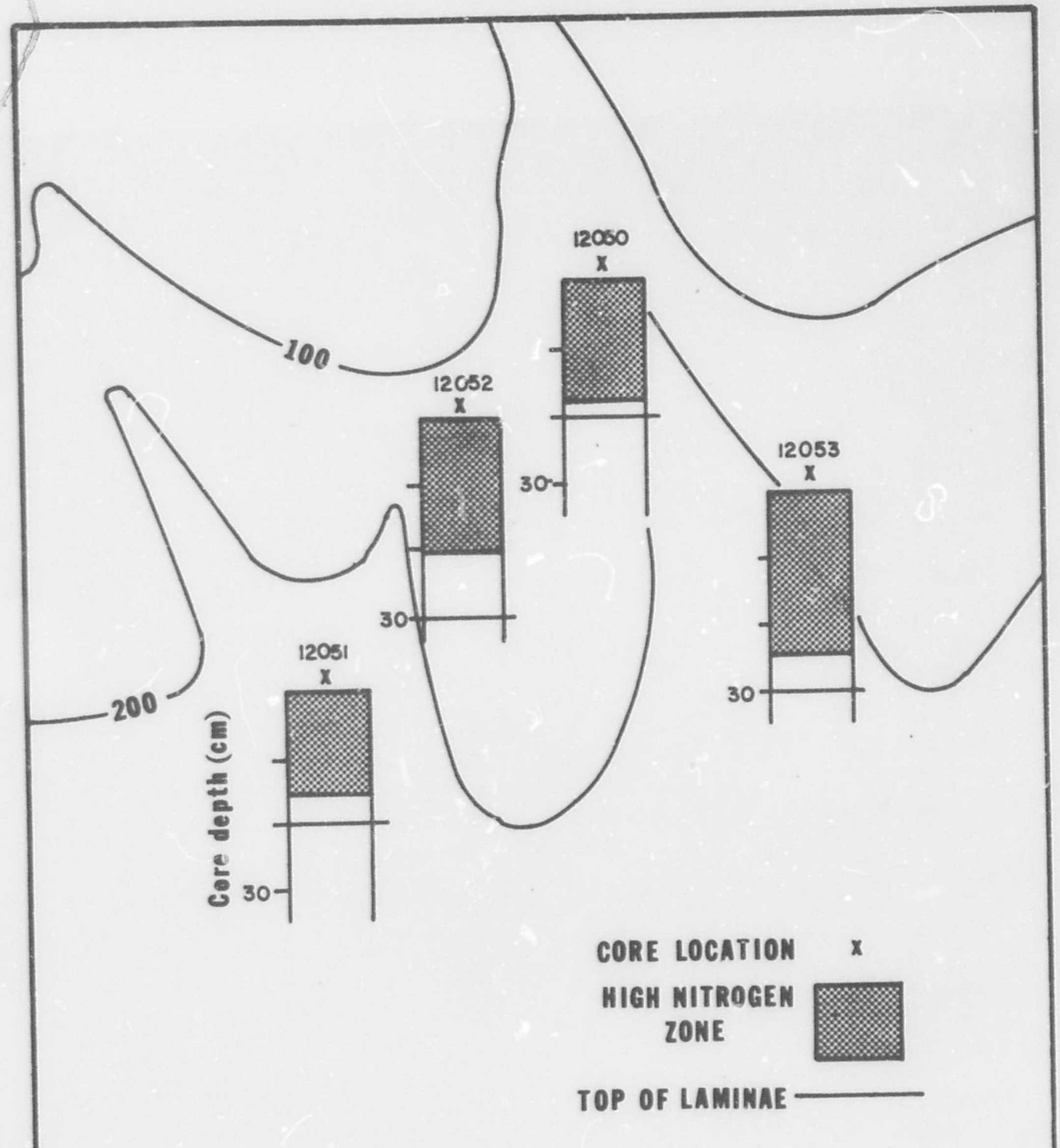
The five gravity cores from the walls and axis of the canyon differ only in detail. All are dark olive gray in color, except for occasional sand-filled burrows which are more of a buff color. Mean diameter of sediment throughout every core is 0.01 to 0.02 mm, while sorting is poor (2.0 phi standard deviation).

The most striking feature visible to the eye is the presence of laminae in the lower portions of two cores. These laminae are composed of thin, light and dark layers representing sand-silt or silt-clay alternations. Radiographs reveal that the laminae are a result of size differences. Figure 22 is presented as an example of laminae which cannot be seen by the camera or eye, but which are distinguishable by their relative permeability to X-rays. Coarse sediments permit the X-ray to pass more readily than fine sediments and appear as lighter laminae on the radiograph print in Figure 22.

Laminae are present in every core, occurring with frequencies of 5 to 10 per centimeter. There is no consistency to the laminae pattern, or to the thickness of individual layers. A single light or dark layer may range from a fraction of a millimeter to 2 mm thick within a core. The upper limit of laminae preservation ranges from 9 to 30 cm below the sediment-water interface; deeper levels are found at greater water depths (Fig. 23).

Nitrogen content in the upper 5 cm of each core correlate well





HIGH NITROGEN AND LAMINAE
LIMITS IN GRAVITY CORES

with nitrogen in grab samples from surrounding areas. Because bacterial action breaks down organic compounds into their basic constituents, the relative percentage of ammonoid nitrogen in a core would be expected to decrease with increasing depth and age of material, providing other factors (sedimentation rate and sources) have remained constant. In the relatively short geologic time represented by these cores, bacterial decomposition should be inconsequential and uniform. Nevertheless, a decrease in nitrogen content is found in every core except the shortest. The decrease is not gradual but abrupt. A drop of 30 to 60 percent occurs within an interval of a few centimeters at varying depths in each core (Fig. 23).

Discussion

Laminae appear to be the normal type of depositional pattern for canyon sediments. They are absent, however, from the most recent sediments. Because of textural differences between each of the layers in a pair (as indicated by radiographs) and poor sorting, the most logical explanation of laminae formation involves either two sources of sediment or two sedimentation mechanisms. Fine silt and clay deposited out of suspension are periodically overwhelmed by coarser material, probably carried from the shelf in temporary suspension during periods of storm surge. Most of this coarse sediment would have to be of silt size, since there is not enough fine sand in the canyon sediments to produce the laminae (generally less than 5 percent). Every core has a small amount of sand which is visible as burrow linings and occasional irregular layers. An exception is AHF 12050 from an interfluve which contains over 20 percent sand, some of which is 0.50 mm in diameter. The universal nature of laminae in canyon cores favors the deposition of these coarse grains in the same manner as fines from suspension.

The preservation of any sort of sedimentary structure requires either that benthic communities (dominated by polychaete worms in Newport Canyon) be small or non-existent, or that sedimentation is so rapid that burrowing cannot take place. The absence of laminae in the upper sections of the cores can be explained by the converse of the previously stated conditions; activity of the benthic population has recently increased, or deposition has almost ceased. All field evidence shows that sedimentary processes are still active, so changes in the activity of the benthic population are considered to be the significant factor in termination of laminar deposition.

Suspended sediment studies show that abundant nutrients, in the form of sewage, are being transported into the canyon (suspended sediment averages 30 percent organic content). It is reasonable to assume, therefore, that the time of construction of the present sewer should correspond to the time of increased bottom activity and a concomitant end of laminar deposition. The present sewer was constructed in 1954 but is not the first outfall to be located in this area. The first sewer was constructed in 1929 (John Sickler, personal communication), but it discharged only a fraction of the quantity of the modern outfall. The present rate of discharge is over 400 million liters per day.

In all cores except the shortest, an abrupt decrease in nitrogen takes place at a sediment depth which ranges from 15 to 25 cm. The upper limit of laminae preservation occurs a few centimeters below the nitrogen decrease. This is to be expected, since benthos would continue burrowing a short distance beyond the lower limit of food supply before reversing their path.

Deeper water should be the area with the most uniform sedimentation rate, so material 25 cm below the sediment surface (Fig. 23) should have been deposited shortly after construction of the present sewer in 1954. Rate of deposition in deeper water is 1.7 cm/year in the 14 years since 1954.

The possibility must now be considered that sedimentation proceeds at a much more rapid rate than has been calculated, possibly one or even two orders of magnitude faster, and preservation of the laminae reflects the inability of the churning benthos to "keep pace" with the rapid influx. Such a condition would place the present study in a period of rapid canyon filling which will be terminated in a short time by massive flushing of the sediment. Then a brief period of sand transport in the manner of other active canyons can be anticipated, followed by a canyon-filling stage once again.

None of the cores recovered during the present study penetrated sand layers of any consequence but one reported by Hand (1962), beyond the limits of the present area of interest, contained coarse sand and gravel layers below 200 cm. If it is assumed that this coarse material corresponds to the last possible influx of such sediment into the canyon during the flood of 1825 (which kept the river from entering the ocean directly), a depositional rate of

1.4 cm/year since that time can be calculated for the main channel.

A second method of figuring the absolute maximum sedimentation rate in recent times would be to assume that all of the sewage effluent is being deposited in the main channel. Allowing for an average discharge rate of 300 million liters per day in the period 1954-1968, a solids concentration of 2 gm/l and long-term preservation of only the 70 percent inorganic portion of the suspended sediment (which includes nonsewage inorganics), the present day sedimentation rate becomes 1.2 cm/year. Add to this a small amount of sand and silt contributed from temporary suspension during storms and the rate still cannot be much greater than that which predates construction of the outfall.

Rapid flushing of accumulated sediments from time to time would require the presence of slumps or turbidity currents in the upper reaches of the canyon. Differences in clay mineralogy of axial sediments eliminate the possibility of such mass movements which would produce uniform clay mineralogy.

Shelf Sedimentation

Summary of Vibracore Data

Obtaining cores in sandy sediments is nearly impossible using conventional gravity samplers. In recent years, however, a device which rests on the sea floor and vibrates a core barrel into the sand has been developed. The value of this method is questioned by many because vibration tends to destroy layering and structure in sand. It is of value, nonetheless, in that subsurface samples can be obtained which reveal long-term changes in high energy environments.

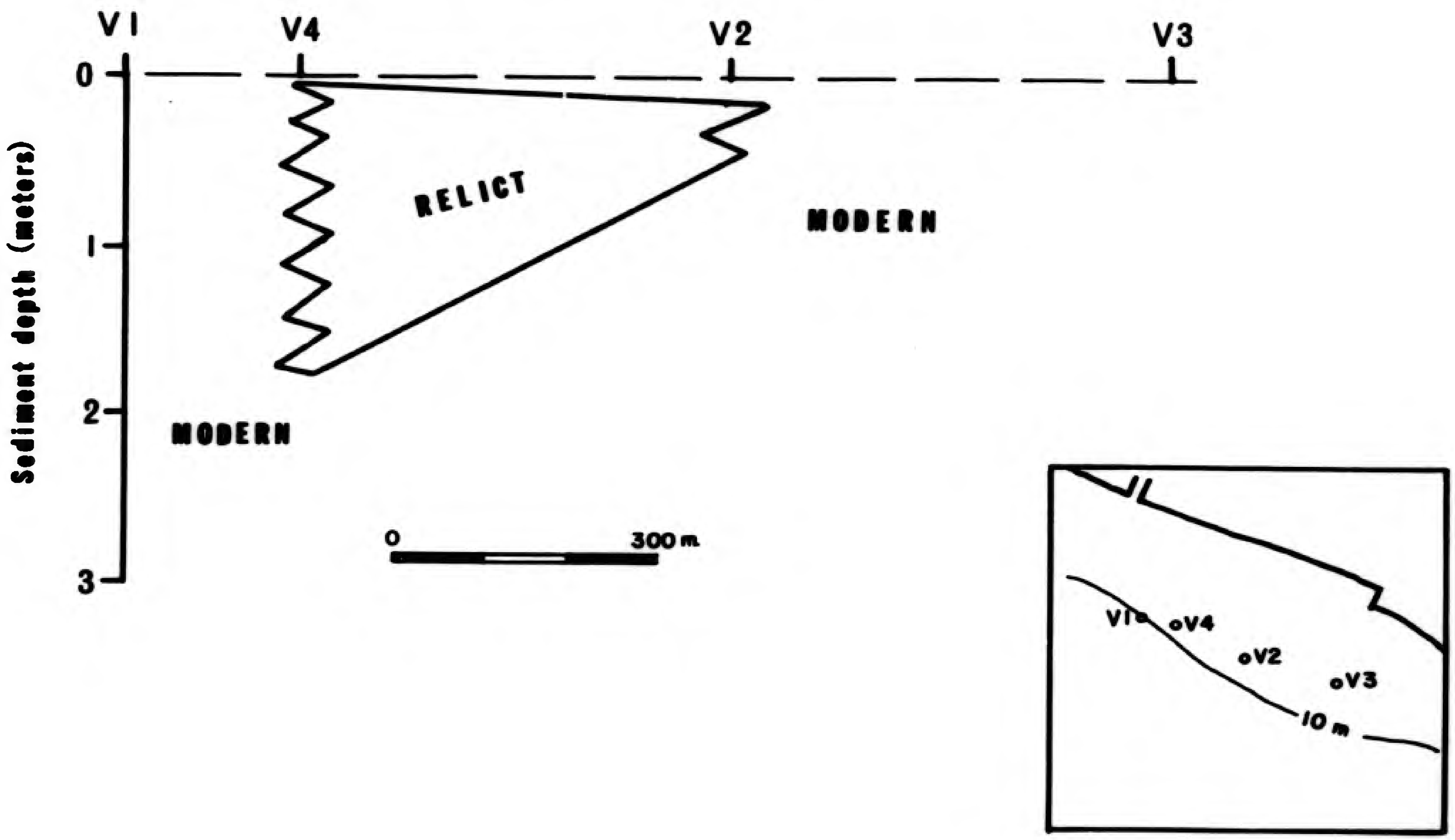
Six vibracores were obtained in the area of the sand tongue and off the Santa Ana River mouth by Ocean Science and Engineering during a test of the coring device. These were purchased by the Army Corps of Engineers and splits were made available to the author. Four of the six were used in the study; the other two were duplicates. Figure 24 is a cross-section of sediment types in the area of the four vibracores. This was constructed from field descriptions of the cores, before they were sectioned on the basis of lithology, and from laboratory examination of the various samples.

Discussion

The general characteristics of the contemporary portions of the cores are nearly identical with those of surface sediments in the area of the tongue and river mouth. It is evident that the zone of relict material which is bounded below, and in most areas above by modern sand, was deposited during a temporary halt in marine regression followed by transgression.

Frosted and well-rounded grains in the upper portion of the relict deposit indicate minor wind transport and beach dunes probably existed. In the ensuing sea level rise the beach and dune sands were intermixed to some extent, and modern sands have subsequently covered most of the area, leaving small "windows" of the relict material. The orange-stained grains which are common in the relict sand are presently being reworked into the modern beach but there has been little offshore or lateral movement, as revealed by the paucity of orange-colored grains in surface sediment adjacent to the relict exposures.

SECTION THROUGH RELICT
BEACH AND DUNE DEPOSIT



SUMMARY AND CONCLUSIONS

The complex channel system off Newport Beach, of which Newport Canyon is the largest channel, was incised by the Santa Ana River during generally lower sea levels of the Pleistocene and Holocene. Erosion of individual channels was halted by intermittent marine transgression and/or by frequent wandering of the river channel over the filled Los Angeles Basin.

At present the system (at least in the vicinity of Newport pier) is undergoing aggradation. Steep, mud-blanketed canyon walls and narrow flat channel floors indicate that filling started only recently, probably in the last century. Formation of a barrier beach prevented the Santa Ana River from reaching the ocean after 1825, and altered the longshore current pattern from one of convergence to divergence.

That portion of the canyon included in this study is presently inactive and probably dead in the generally accepted sense. Turbidite deposits in the San Diego Trough do not now originate in Newport Canyon, but quite possibly did prior to formation of the barrier beach in 1825.

Sedimentation rate in the canyon is calculated to be 1.4 cm/year since the time of canyon inactivation. A marker layer of high nitrogen content indicates time of construction of the Newport Beach sewer outfall in 1954, and confirms the above rate of sedimentation. Prior to the time of sewer construction, the sedimentation rate was too rapid for benthos to churn the bottom, and a laminar pattern of silt and clay deposition was preserved. The increased supply of nutrients (sewage) in recent times have resulted in thorough mixing of the upper 20 cm of sediment by benthos.

Sedimentation is in the form of material coming out of suspension in the quiet water over the canyon. Small amounts of sand are carried into the canyon when strong wave surge carries it over the flanks, but normal sediment is organic-rich sewage and silt-clay from the sewer and river. Currents, generated by local winds and tides, move sewage into the canyon at all times, while any stronger energy input, such as storm waves, places large amounts of previously deposited river sediment into temporary suspension immediately above the bottom and carries it to the canyon.

Although it lies only 150 meters from the shore, the canyon head does not intercept beach sand. A littoral cell does not exist in the Newport area. Small amounts of very fine sand and debris are the only materials which reach the head, and these do so only under restricted wave conditions. Configuration of the coast and refraction of wave energy close to the beach are not conducive to formation of currents which would carry debris to the canyon head.

Contemporary sedimentation patterns are controlled by a combination of rip currents, bottom surge, and local currents. Nearshore processes have been altered by the activities of man. Damming of the Santa Ana River and other coastal streams eliminated material in the medium to coarse sand size which is required for natural maintenance of the beaches. The result is severe erosion of beaches at their mouths. Locally exposed patches of relict sediment on the shelf are able to supply only small amounts of replenishment material to the beach.

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APPENDIX I

SAMPLE DATA-GRAB SAMPLES

Station No.	Mean Diameter	Standard Deviation	Percent N
B 1	.015 mm	1.89	
B 7	.017	1.96	.057
B 10	.130	0.77	.016
B 11	.041	1.80	
B 12	.009	2.02	
B 13	.016	2.08	
B 14	.021	1.97	.086
B 15	.007	2.10	.151
B 16	.005	1.99	
B 18	.030	2.06	
B 19	.012	2.13	.177
B 20	.004	1.82	.141
B 21	.030	2.54	
B 22	.011	2.20	.115
B 23	.102	1.38	.022
B 24	.091	1.22	
B 25	.117	0.89	.014
B 26	.035	1.64	.070
B 27	.036	1.72	
B 28	.012	2.12	.113
B 29	1.170	3.93	
B 30	.035	1.72	
B 31	.039	1.68	.053
B 32	.085	1.48	.038
B 33	.154	0.71	.014
B 34	.017	2.02	.097
B 35	.031	1.35	.116
B 36	.013	2.27	
B 37	.115	0.54	
B 38	.167	0.50	.033
B 39	.163	0.44	
B 40	.098	0.36	.048
B 41	.120	0.65	.019
B 42	.094	0.67	.024
B 44	.137	0.72	.042
B 45	.115	0.84	
B 46	.125	0.78	
S 2	.049	1.70	.041
S 3	.044	1.44	.040
S 4	.041	1.61	
S 5	.085	1.33	

APPENDIX I (Continued)

SAMPLE DATA-GRAB SAMPLES

Station No.	Mean Diameter	Standard Deviation	Percent N
S 6	.068	0.72	.037
S 7	.164	0.89	.024
S 8	.103	0.71	
S 9	.024	1.95	
S 10	.013	2.12	.119
1 A	.115	0.49	.028
3 A	.132	0.64	
12 A	.139	0.56	

SAMPLE DATA - CORES

Core No.	Depth in Core	Mean Diameter	Standard Deviation	Percent N
AHF 12050	0-5 cm	.018 mm	2.35	.091
	10-12			.051
	10-15	.026	1.77	.077
	16-18			.149
	21-23			.100
	25-30	.020	2.26	.087
	46-51	.015	2.22	.084
	51-67	.029	2.16	.066
AHF 12051	0-5	.008	2.04	.176
	10-15	.007	1.82	
	15-17			.166
	20-25	.009	2.14	.149
	30-35	.009	2.17	.145
	45-50	.016	2.03	
	65-70	.014	2.09	
	90-95	.013	2.13	
AHF 12052	0-5	.013	2.11	.096
	18-20			.111
	20-25	.027	1.71	.060
	35-40	.024	1.71	.049
	50-55	.023	1.87	.050
	63-68	.023	1.89	.065
AHF 12053	0-5	.008	2.06	.145
	15-20	.009	1.95	.147
	22-24			.152
	30-35	.017	1.98	.095
	45-50	.015	2.03	.044
	55-60	.015	2.04	
	80-85	.012	2.10	
	123-128	.017	1.92	
AHF 12111	0-3	.005	1.71	
	6-8			.156
	10-14	.024	1.67	
	11-13			.137
V 1	0-92	.173	1.05	
V 2	0-104	.202	0.94	
V 3	0-10	.145	0.96	
V 4	0-30	.382	1.32	
	92-168	1.980	2.44	
V 5	0-92	.185	0.86	
	457-549	.170	0.76	
V 3	142-218	.181	0.50	

APPENDIX II

SUSPENDED SEDIMENT

Station No.	Depth (m)	Total Suspended Matter (mg/l)	Organic (Percent dry weight)
AHF 12033	0	2.6	39
	6	3.1	39
	20	1.3	32
	25	9.2	6
AHF 12034	0	1.9	26
	3	2.4	8
	13	1.6	54
	21	2.7	40
AHF 12035	0	2.1	34
	6	2.7	11
	14	5.5	7
AHF 12036	0	2.1	51
	4	1.5	57
	10	3.1	30
AHF 12037	0	2.2	18
	7	2.4	26
	12	4.8	44
	18	12.3	5
AHF 12038	0	2.6	70
	5	3.0	43
	12	1.7	30
	25	0.8	33
	45	2.8	0
AHF 12039	0	2.0	0
	6	2.5	3
	16	0.8	19
	87	1.0	46
	192	2.3	41
AHF 12040	0	2.2	7
	15	1.4	28
	40	1.2	26
	153	1.8	0

APPENDIX II (Continued)

SUSPENDED SEDIMENT

Station No.	Depth (m)	Total Suspended Matter (mg/l)	Organic (Percent dry weight)
AHF 12041	0	2.2	0
	28	1.8	13
	94	1.6	5
AHF 12042	0	2.4	23
	20	2.2	9
	30	Sample lost in transport	
	45	Bottle touched bottom	

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13. ABSTRACT
Newport Canyon is the largest of several channels which cut the continental margin off Newport Beach, California. All of the channels were initiated subaerially by the Santa Ana River during the Pleistocene and Holocene. Submarine erosion may have continued until early in the last century. Prior to 1825, the river provided sediment directly to the ocean in the canyon head area. Subsequent construction of a barrier beach by the river caused its diversion into Newport Bay and a change in coastal alignment which altered longshore current patterns.
The upper portions of the canyon are now being filled with organic-rich silt and clay at the rate of approximately 1.4 cm/yr/ The primary sources of this material are the Orange County outfall and the Santa Ana River. Suspension of fine sediment on the shelf and deposition in the canyon is the normal mode of transport for all modern canyon sediment. Collection of sand and debris in the nearshore head is precluded by the divergence of longshore currents from the head under most wave conditions. The canyon is presently inactive and cannot be the source of modern turbidites in the San Diego Trough.

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Suspended sediment transport						
Newport Submarine Canyon						
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Changes in coastal configuration near Newport Beach, California						
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