U. S. DEPARTMENT OF COMMERCE
Maurice H. Stans, Secretary
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
Robert M. White, Administrator
RESEARCH LABORATORIES
George S. Benton, Director

ESSA TECHNICAL REPORT ERL 93-POL 2

SEAMAP Deep-Sea Channel

PAUL J. GRIM

PACIFIC OCEANOGRAPHIC LABORATORY
SEATTLE, WASHINGTON
January 1969

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Price 35 cents.

TABLE OF CONTENTS

SEAMAP DEEP-SEA CHANNEL

Paul J. Grim[1]

The SEAMAP deep-sea channel is a relic feature on the Aleutian abyssal plain south of the Aleutian trench. Along most of its 370-km length it has well-developed levees that are generally asymmetrical and differ in height. Typically the channel is about 50 m in depth and 6 km in width. From its northern end on the south wall of the Aleutian trench the channel floor rises towards the southwest from a depth of 4800 m to a minimum depth of 4590 m near its midpoint. Continuing in the same direction it deepens again to 4750 m. This gradient reversal precludes turbidity currents from flowing through the channel and supports the thesis that the Aleutian abyssal plain is a relic feature that has been cut off from its supply of turbidite material by the downbowing of the Aleutian trench. The channel apparently has been destroyed by slumping on the south wall of the trench north of the 4800-m contour. For much of its length, it is subparallel to the trench and from a topographic standpoint occupies the crest of the outer ridge south of the trench.

I. INTRODUCTION

As a result of ESSA's SEAMAP project in the central north Pacific, the SEAMAP deep-sea channel (Grim and Naugler, 1969) has been found on the Aleutian abyssal plain south of the Aleutian trench. Figure 1 shows its location in relation to the channels and abyssal plains in the northeast Pacific.

---

[1] Now at Marine Geology and Geophysics Laboratory, Miami, Florida.

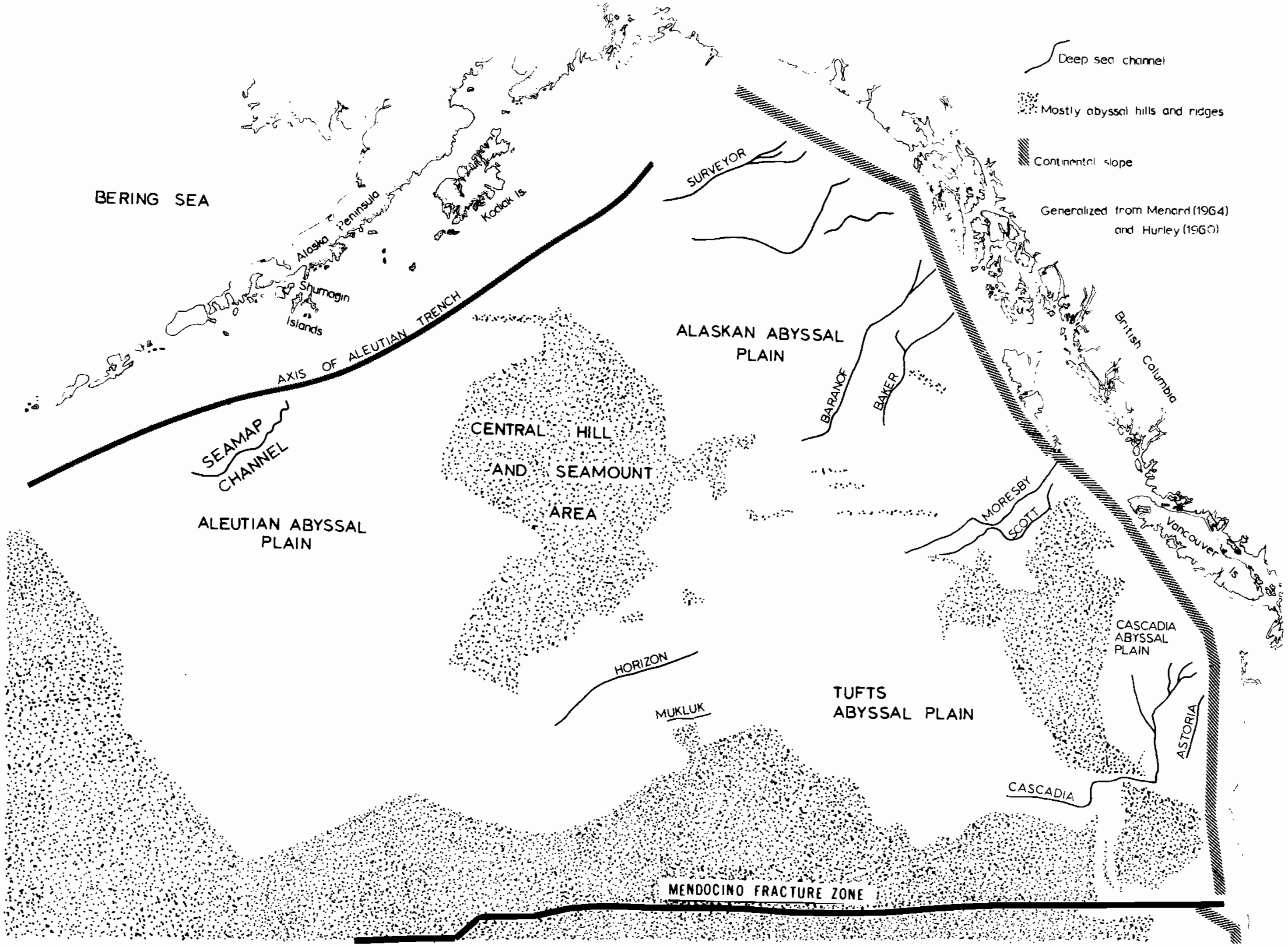

Figure 1. Generalized map of the northeast Pacific showing the SEAMAP channel, other deep sea channels and abyssal plains.

The most unusual aspect of the SEAMAP channel is the reversal of its axial gradient which precludes turbidity currents from flowing through it. It is the only known deep-sea channel that cannot be traced to a potential supply of turbidite material on the continental slope. This gives striking support to the thesis suggested by Hurley (1960) from bathymetric observations that the Aleutian abyssal plain is a "fossil" or relic plain that was cut off from its supply of turbidite material by the downbowing of the Aleutian trench and that the only present supply of sediment is pelagic material settling from the overlying water column.

Hamilton (1967) has given additional evidence of the fossil nature of this plain from seismic reflection results. He points out that, in addition to the plain sloping downward to the south and being blocked from turbidity currents on the north, east, and west, (1) the thickness of turbidite layers decreases towards the south and (2) the Aleutian abyssal plain (where he crossed it in an east-west direction between 47° and 48°N) is covered by an acoustically transparent 50- to 100-m layer of sediment that appears to be pelagic (this is supported by the fact that no turbidites have been cored on this plain).

The SEAMAP channel was first revealed by fathograms taken with a Precision Depth Recorder (PDR), a continuous echo sounding recorder that can be read to about ± 2 m. These were obtained by the U. S. Coast and Geodetic Survey ship PIONEER during the period 1961-1963. In April 1968, a 3-day study was conducted from the USC&GS ship OCEANOGRAPHER, and six crossings of the western part of the channel were made by the USC&GS ship

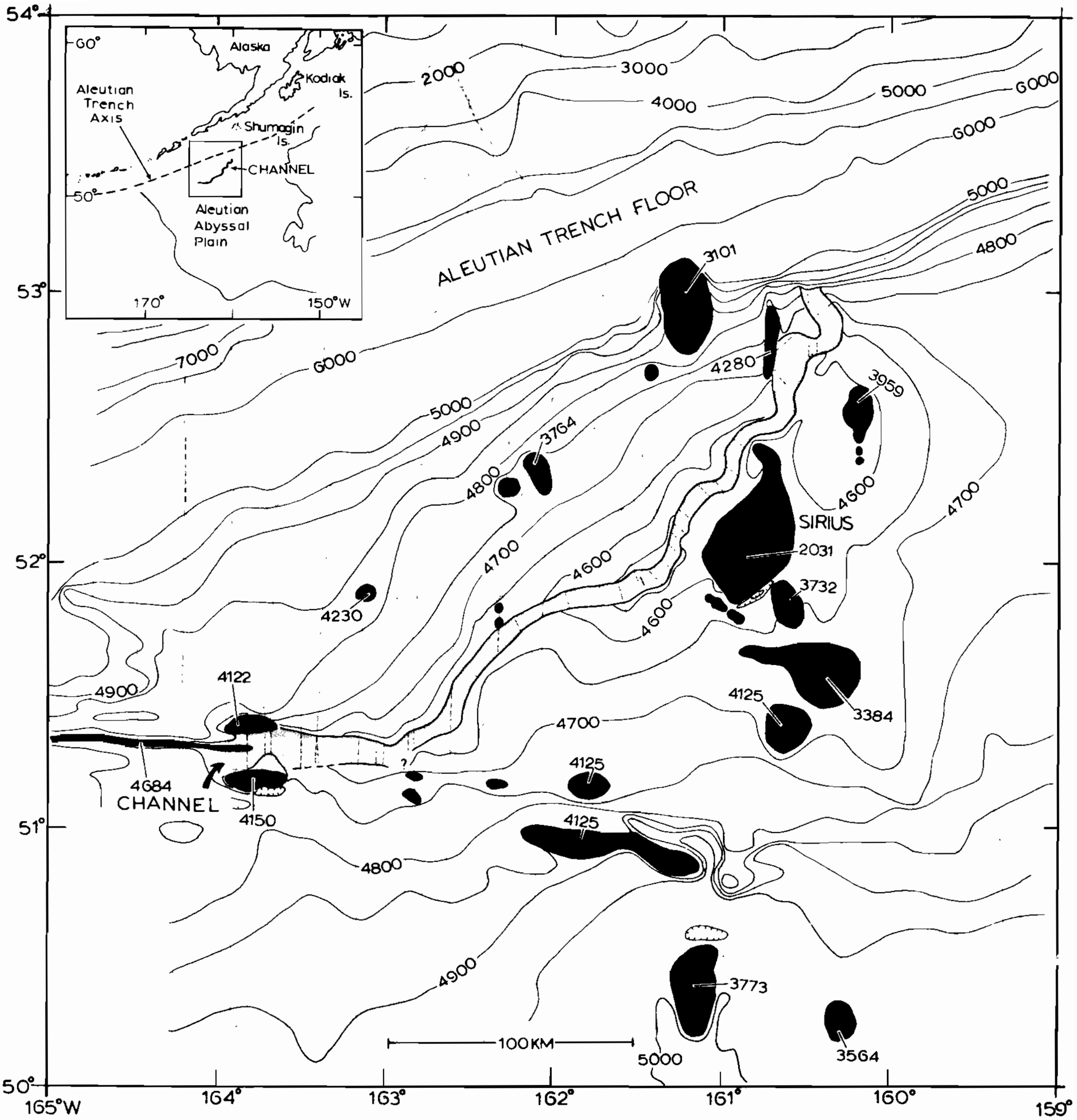

Figure 2. Bathymetric map of the SEAMAP channel area. Depths are in corrected meters. The contour interval varies as indicated. Ridges, seamounts, and abyssal hills are shown in black. Tracklines are indicated by dashed lines.

SURVEYOR in June 1968. Navigational control for the OCEANOGRAPHER was by satellite, which has an average error of about 300 m or less (Paulsen, 1966; Talwani et al., 1966), and for the PIONEER and SURVEYOR by Loran C, which has an accuracy of about 1/2 km in this region. All soundings were converted to corrected meters according to the method described by Ryan and Grim (1968).

In this report, "upstream" (towards the northeast) is the direction from which turbidity currents flowed when the channel was active. For easier correlation with location maps, all bathymetric profiles are presented with the channel viewed upstream.

2. CHANNEL DESCRIPTION

Figure 2 shows a bathymetric map of the channel; survey tracklines crossing the channel (arbitrarily serialized) are presented in figure 3. The channel has a general northeast-southwest trend, forming a slight angle with the Aleutian trench. Typically it is about 6 km wide and 50 m deep (measured from the tops of the levees to the channel bottom). The contours clearly show that the channel occupies the crest of a "ridge" (to be discussed below) along most of its course.

The northeast end of the channel is located on the south wall of the Aleutian trench at about the 4800-m contour. Farther north it has apparently been obliterated by slumping. North and west of Sirius seamount, there are meanders with an average "wavelength" of about 35 km. The channel floor rises irregularly along this segment (crossings 1 to 24) to a depth of about 4590 m and then deepens again towards the

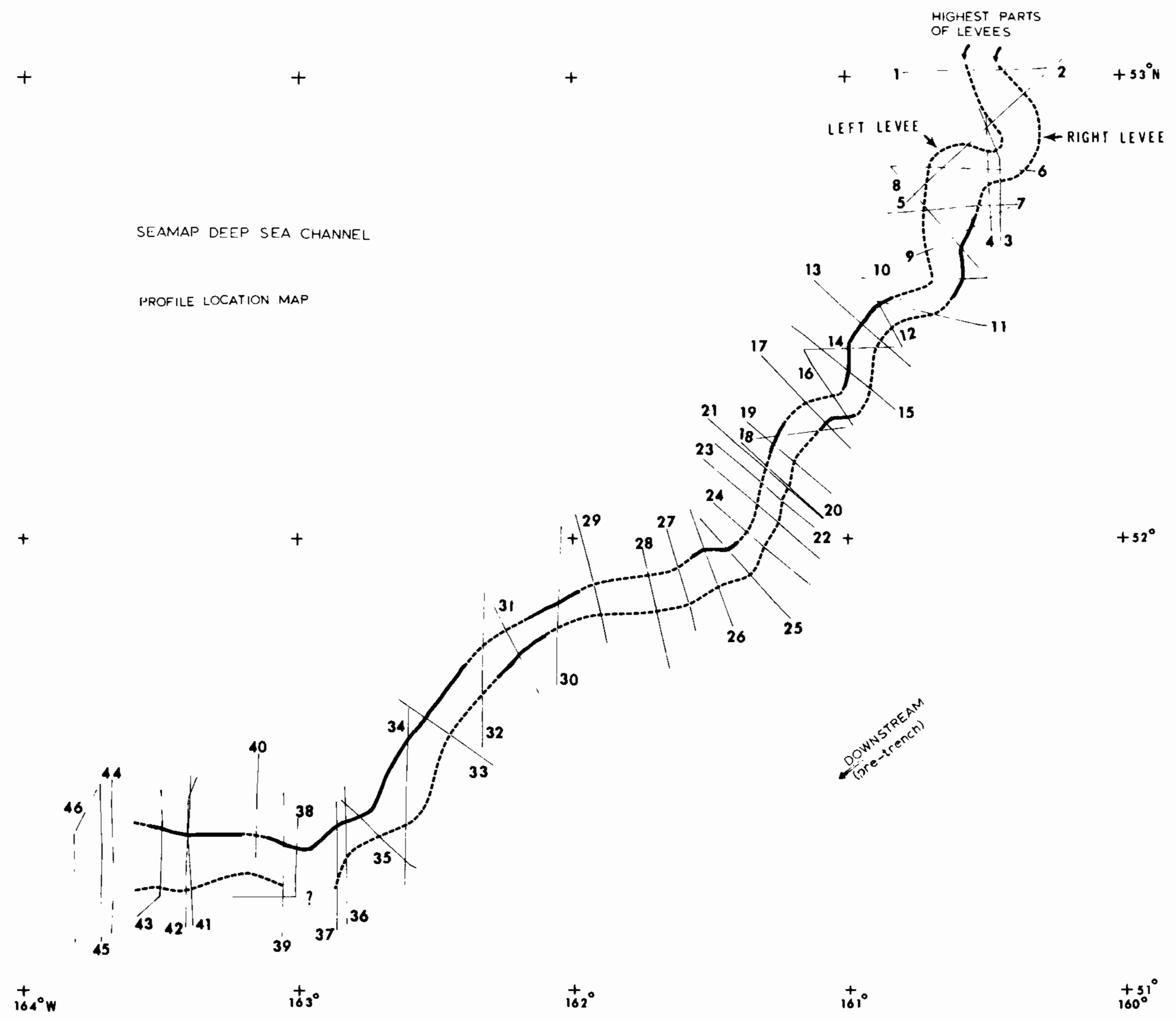

Figure 3. Profile location map for Precision Depth Recorder (PDR) tracings shown in figures 4, 5, 6, and 7. Where significant height differences seem to exist, the highest parts of the levees are indicated by solid lines.

southwest. At crossings 36 to 38 it bends sharply towards the west, widens, and at a depth of about 4750 m passes between two ridges (see fig. 2). West of the ridges it cannot be traced as a single feature.

Tracings of PDR records are presented in figures 4 through 7, where the horizontal scale is based on a ship speed of 15 kt. The error in this scale for individual profiles is judged to be less than 10 percent.

Profiles 1 to 8 (fig. 4) were made where the channel makes a very pronounced meander. The regional tilting caused by the Aleutian trench is clearly indicated in several of the crossings. Crossings 5, 6, 7, and 8 show that the channel is bordered on the west by a north-south trending ridge.

The PDR profiles in figure 5 were taken over the central part of the channel. The reversal of the axial gradient is clearly seen in this figure, i.e., the channel deepens both upstream and downstream from crossing 24. At crossings 20 and 21 the sharpness of the top of the right levee suggests that this may be a structural feature rather than a true levee.

In figure 6 the channel can be followed easily from profiles 30 to 37. Downstream from crossing 37, it bends abruptly to the west, probably as a result of structural control from underlying east-west trending ridges. At the bend itself there is a suggestion that the turbidity currents may have overridden the right levee and flowed to the south. However, fathograms are not available to substantiate this. At crossing 38 the channel is difficult to identify because of the very

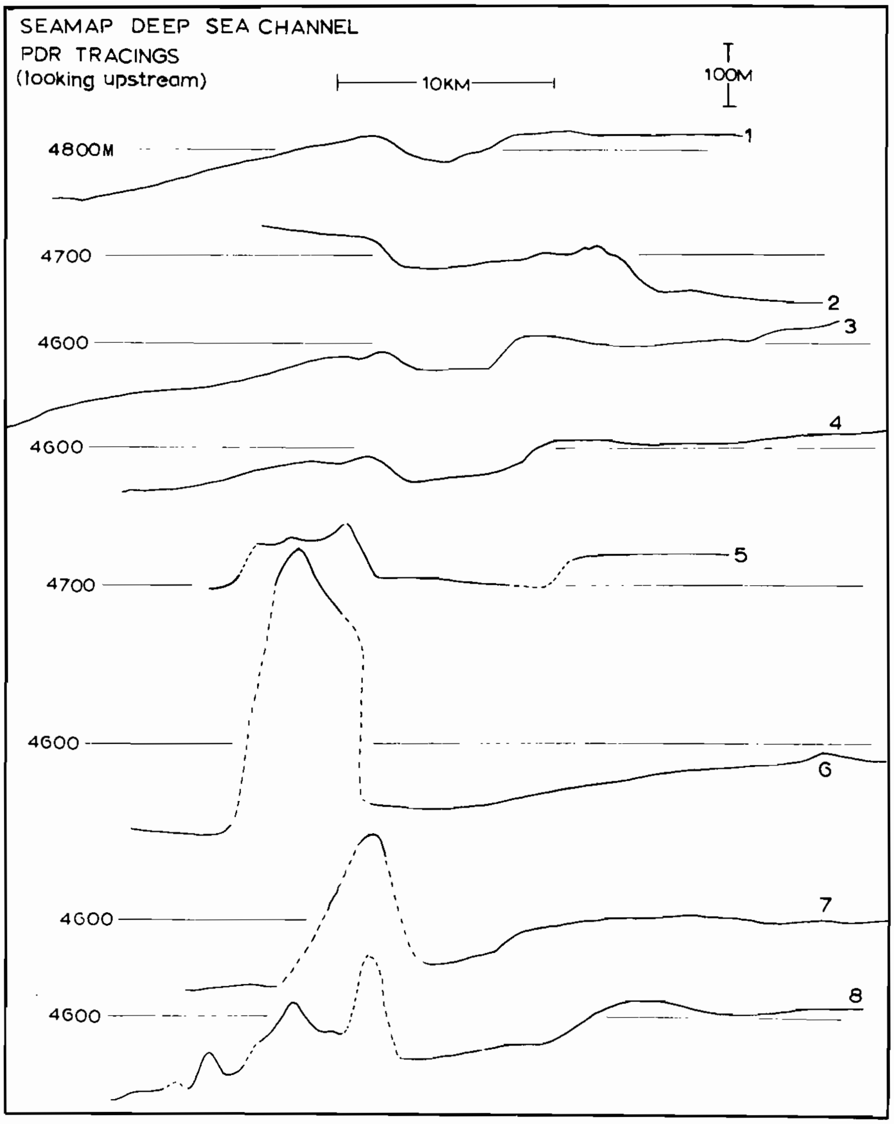

Figure 4. PDR tracings 1 through 8. See figure 3 for locations. Vertical exaggeration is about 30.

small right levee. This abrupt bend in the channel is further complicated by the secondary channel-type features seen in profiles 36 and 37. Farther to the west (crossings 41, 42, and 43) the channel widens and loses its distinctive shape.

To the west the channel passes between two ridges (fig. 7). Crossings 44 and 45 show a distinct single channel-like feature between the ridges but crossing 46 suggests that the turbidity currents probably flowed on either side of the small ridge between the large ridges. West of the ridges, i.e., west of profile 46, the flow was apparently more as sheet flow rather than channelized flow, since it is impossible to identify a single feature as the channel. Several channel-type features, such as relatively abrupt topographic changes similar to levees, occur, but these generally cannot be correlated across the tracklines run in this area (see fig. 2).

The channel profiles presented in figures 4 through 7 vary greatly. Much of this variation is caused by obvious structural control, e.g., profiles 5, 6, 7, and 8; some variations are the result of probable structural control, e.g., the right "levees" of profiles 20 and 21. Most of the profiles that appear to be unaffected by structure also show that the channel varies considerably in shape and cross-sectional area (with the angle of the crossing taken into consideration). For example: The shapes and relative heights of levees change appreciably over very short distances (crossings 13 to 17); some crossings (17 and 18) show a flat channel floor; others have a rounded floor or one that changes its slope very abruptly (crossings 31 and 33); and there is considerable variation

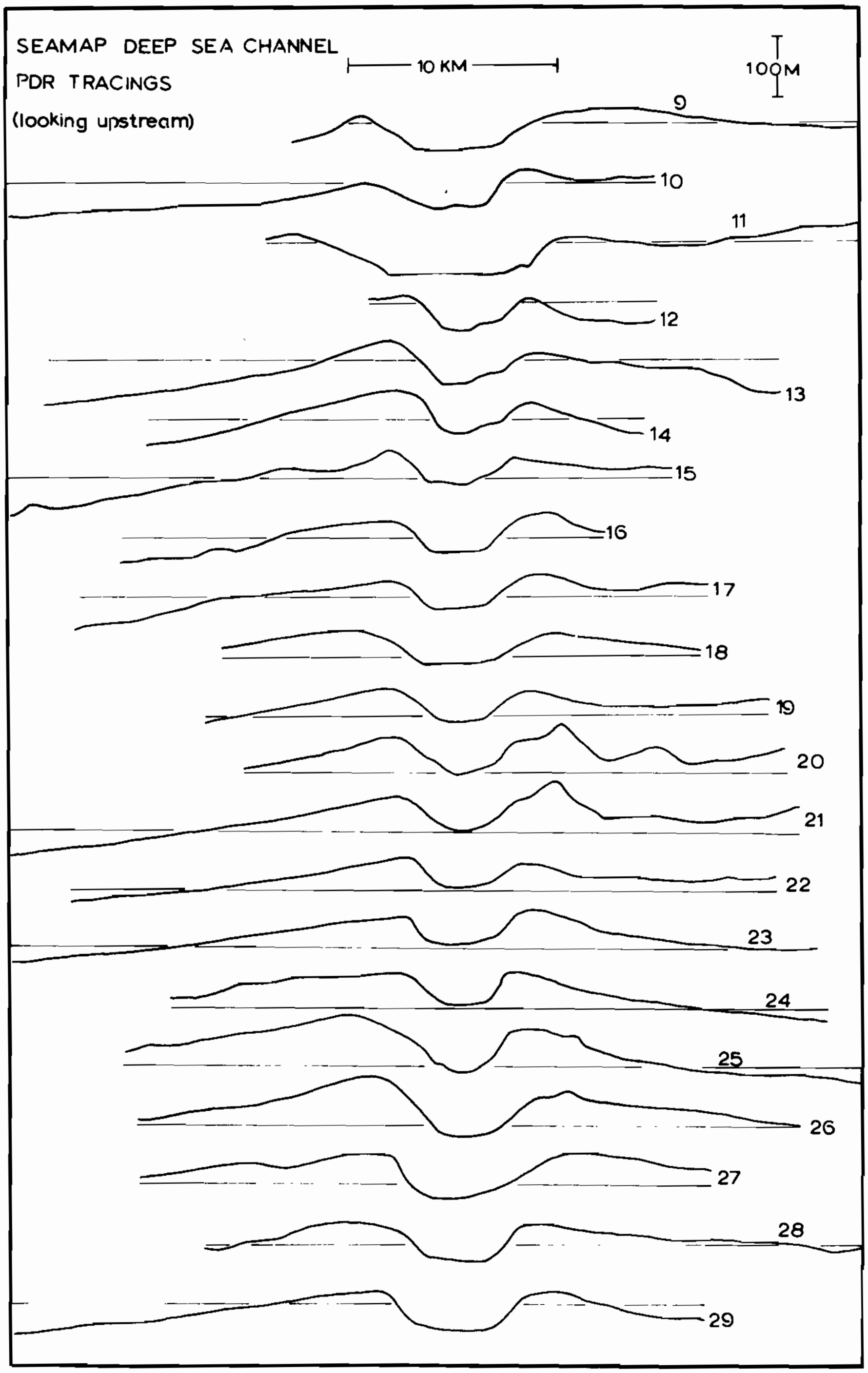

Figure 5. PDR tracings 9 through 29. A depth of 4600 m is indicated for each tracing. See figure 3 for locations. Vertical exaggeration is about 30.

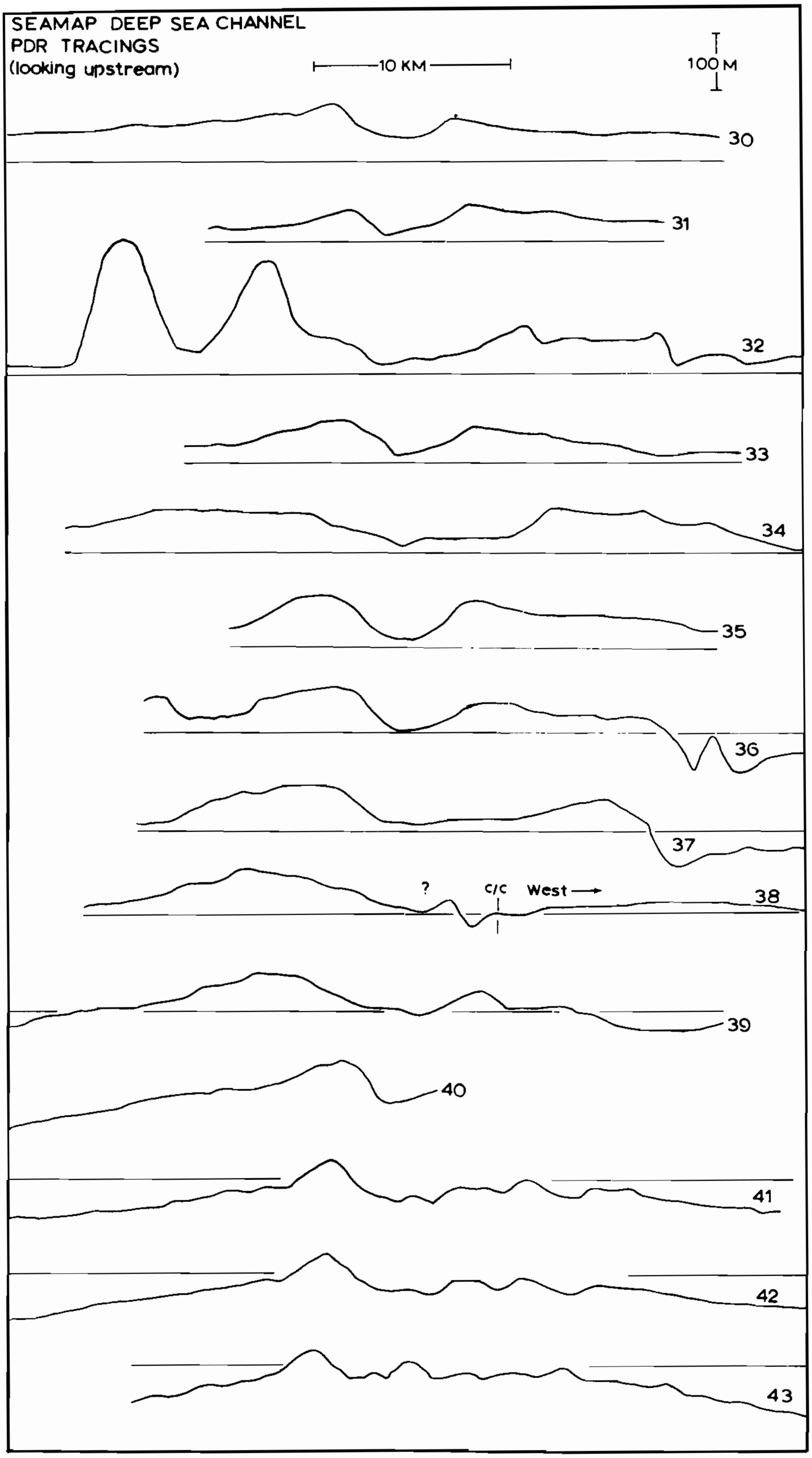

Figure 6. PDR tracings 30 to 43. A depth of 4700 m is indicated for each tracing. See figure 3 for locations. Vertical exaggeration is about 30.

in the cross-sectional area over short distances (crossings 25 to 31). Profiles 41, 42, and 43 are remarkably different in that they all display a rather indistinct right levee and a very irregular channel bottom.

3. DIRECTION OF FLOW

Turbidity currents must have flowed to the southwest when the channel was active because (1) the only plentiful supply of material for turbidites is continental North America,which is north and east of the channel, (2) in general the Aleutian abyssal plain deepens towards the south, and (3) the right levee (looking downstream) is consistently higher than the left levee between crossings 32 and 44 (where the relative heights of the channel levees have apparently been little affected by the formation of the trench, and where the channel does not meander). This is consistent with observations that in the northern hemisphere, looking downstream, the levee on the right side is higher because of the Coriolis effect. In addition, the SEAMAP channel is roughly parallel to the other active or potentially active channels in the northeast Pacific, all of which have a downstream direction towards the southwest (fig. 1).

4. THE AXIAL PROFILE

Figure 8 shows levee heights and the channel bottom plotted as a function of distance along the channel. From crossing 1 (the deepest part of the channel) the floor rises very irregularly with an average gradient of about 1.0 m/km to its highest point at crossing 24. Three prominent secondary "peaks" occur at crossings 3, 10, and 15. Downstream

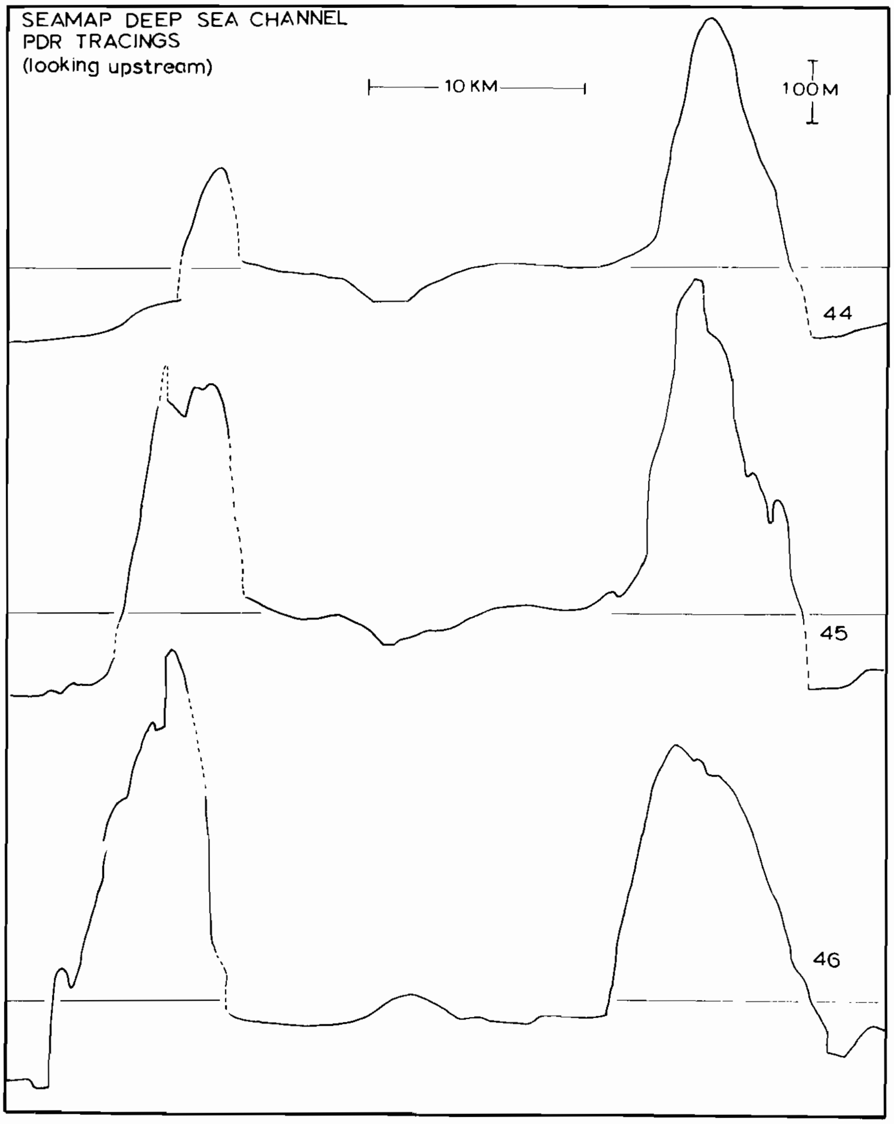

Figure 7. PDR tracings 44, 45, and 46. A depth of 4700 m is indicated for each tracing. See figure 3 for locations. Vertical exaggeration is about 30.

from crossing 24 the channel deepens with a relatively constant gradient of 1.4 m/km to crossing 31. Between crossings 31 and 37 the channel's gradient is essentially zero, and downstream from crossing 37 the channel deepens with a gradient of about 0.8 m/km to crossing 46.

The three secondary peaks upstream from crossing 24 may be, for the most part, the result of an irregular pre-trench axial gradient that was not uniformly downbowed by the trench. (The meanders cause the channel to "approach" the trench in an irregular manner, which would result in this uneven downbowing).

Because the channel consistently deepens from crossings 24 to 46 (with the exception of several minor gradient reversals) with gradients similar to known active or potentially active deep sea channels, the axial profile in this segment of the channel is probably similar to that which existed when the channel was active. The minor gradient reversals suggest that some minor changes, perhaps caused by the formation of the trench or post-trench processes, have occurred to alter the relative depths of different parts of this segment of the channel.

5. LEVEE HEIGHT DIFFERENCES

As shown in figure 8, the comparative heights of the right and left levees differ. Between crossings 11 and 19, where the channel meanders, the higher levee corresponds to that part of the channel where a turbidity current, flowing towards the southwest, would tend to overflow the channel because of the current's inertia (fig. 3). This agrees with the suggestion made by Buffington (1952) and Dietz (1958) that

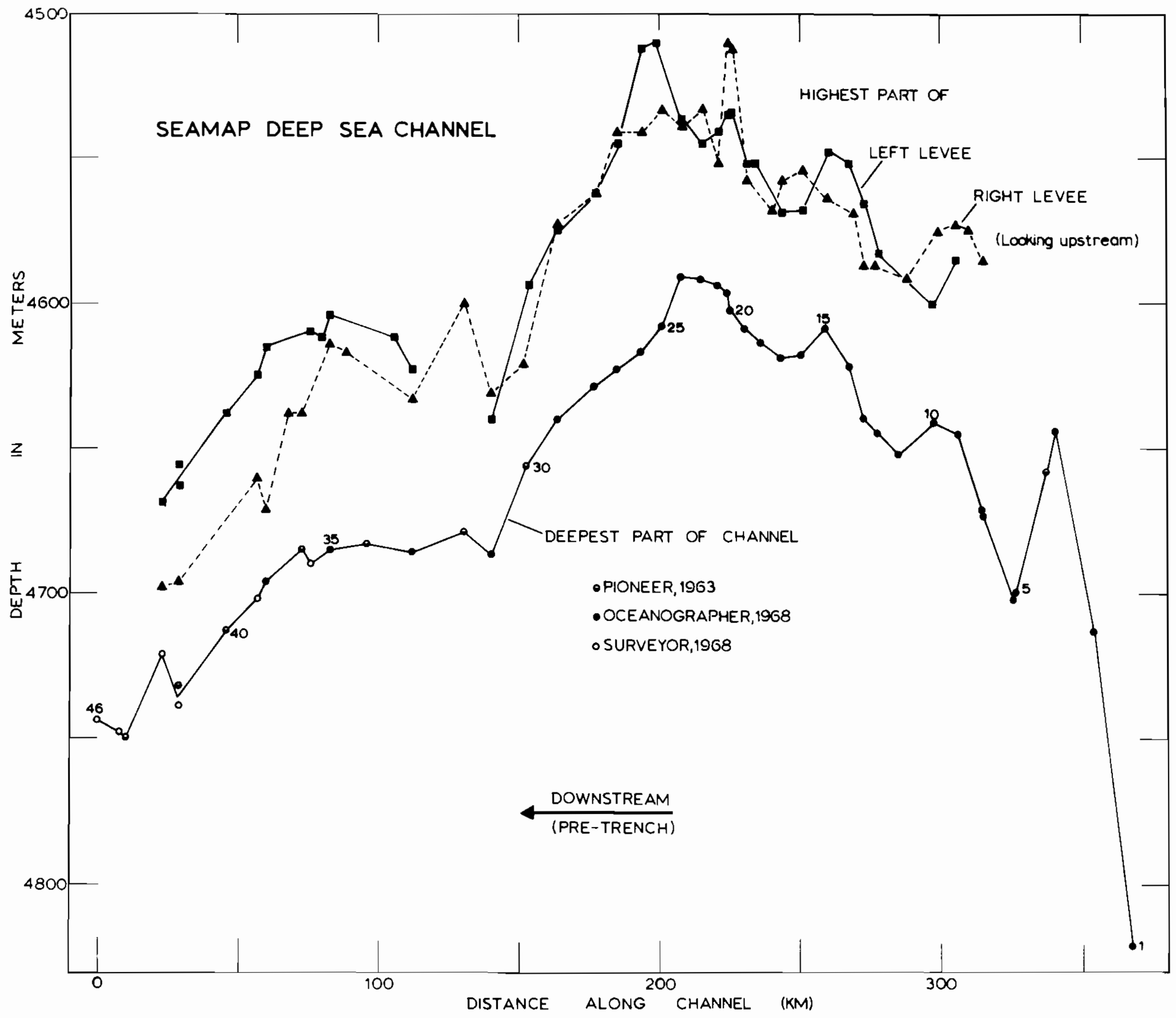

Figure 8. Depths of highest parts of levees and deepest part of channel as a function of distance along the channel. No levee depths are given where the channel is obviously flanked by a ridge or abyssal hill and in the northern section where it is judged that the tilting of the Aleutian trench has been strong enough to significantly alter the original differences in levee heights.

turbidity currents would tend to deposit more sediment on the levee of the outside bend of a channel, making this levee higher and resulting in an asymmetrical channel cross section.

Downstream from crossing 32, where the channel is straighter (except for the sharp bend near crossing 37), the left levee is consistently higher than the right levee. This is in accord with the proposal that, in the northern hemisphere, the Coriolis force causes the surface of turbidity currents to be tilted, so that when looking downstream the right side of the surface is higher than the left, resulting in a higher right levee being built (Menard, 1955; Menard et al., 1965; Hamilton, 1967). (Note that figures 4 through 7 are drawn as one would view the channel looking upstream).

Thus, between crossings 11 and 19 and downstream from crossing 32, the geometry of the levees supports both ideas advanced to explain levee height differences. For other parts of the channel, however, these explanations do not seem to be valid and in considering the causes of such differences the following complicating factors must be taken into account: (1) It is difficult to assess the relative contributions expected from the inertia and Coriolis effects; (2) apparently structural control influences levee heights to a considerable degree; for example, the shape of the right "levee" at crossings 20 and 21 suggests this may be a structural feature (fig. 5); and (3) the original relative heights may have been significantly changed by the effects of trench-forming or post-trench processes.

At crossings 25 and 26, the sharpness of the bends in the channel would suggest a higher right levee from the inertia effect, rather than the higher left levee shown. This is possibly due to structural control but, if so, it is not indicated by the profiles in figure 5. Similarly, a higher right levee would be predicted from considerations of the inertia effect at crossings 36, 37, and 38. There, however, the channel appears to be complicated by structural control and the right levee may have been partially destroyed in this section of the channel, possibly in a late stage of channel development.

6. ELEVATION

Along most of its length the channel lies on the crest of a "ridge" south of the Aleutian trench (figs. 2 and 9). Hamilton (1967) has observed similar, but less pronounced, channel elevations in other areas of the northeast Pacific. His seismic reflection results clearly show that deep-sea channels are depositional features. This suggests that the SEAMAP channel is located on an unusually thick accumulation of sediments.

The near-parallelism of much of the channel (and ridge) with the trench appears to be coincidental. It seems very likely that this ridge is a sedimentary feature unrelated to the structural outer ridge of the Aleutian trench because (1) the channel occupies the exact crest of the ridge and its distance from the trench is not constant and (2) as shown in figure 9, for tens of kilometers on either side of the channel, bathymetric profiles tend to be concave upwards and roughly symmetrical, except for seamounts, abyssal hills, and ridges.

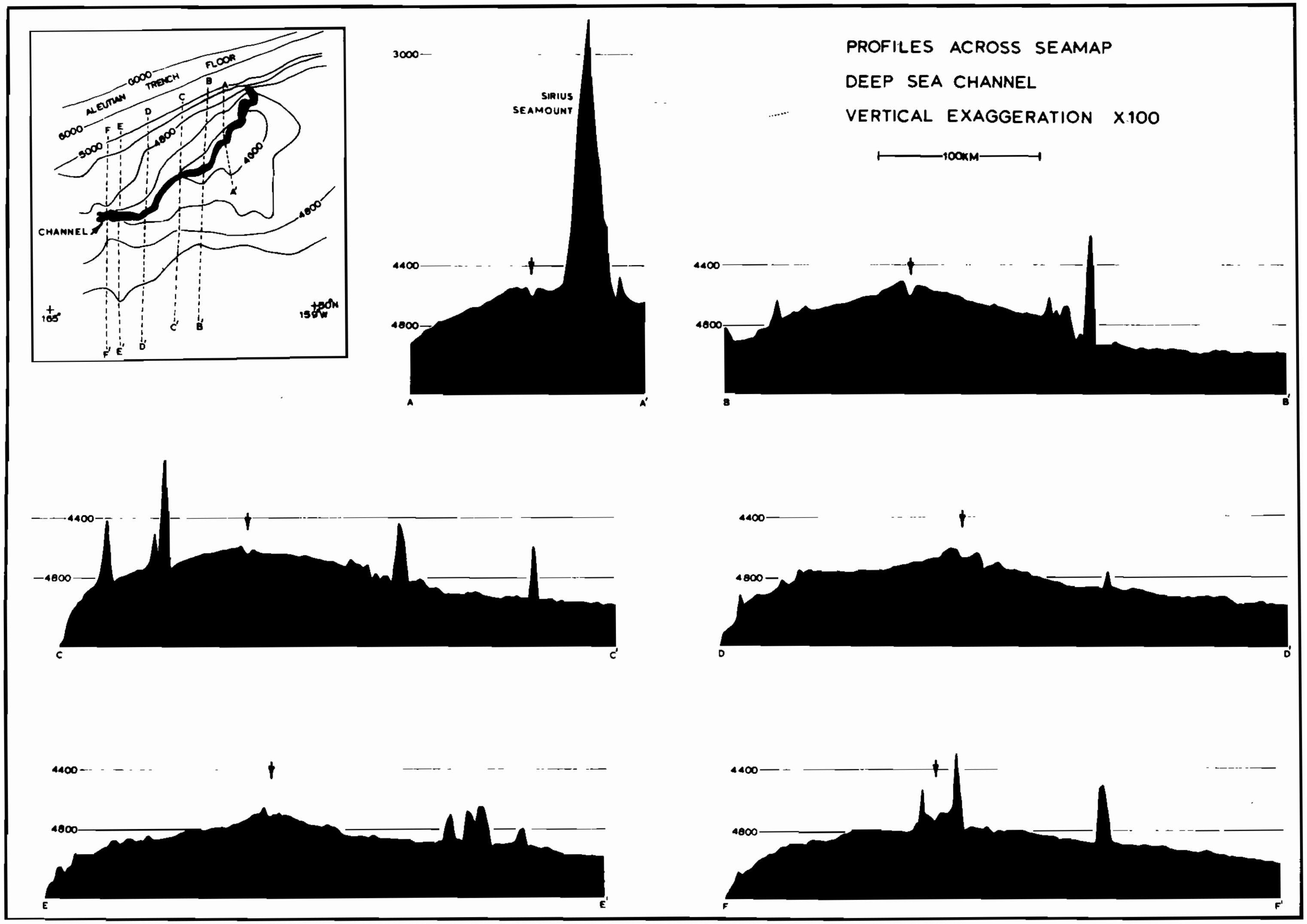

Figure 9. Profiles across channel with vertical exaggeration of 100. The channel is viewed looking upstream with arrows indicating the axis. Bathymetry of inset map is generalized and does not show seamounts, ridges, or abyssal hills.

The SEAMAP channel and its ridge of sediments pose many questions that may be answered when seismic reflection results become available. Some of these questions pertain to (1) the location of the outer ridge south of the trench as defined by basement; (2) the effects of buried ridges and abyssal hills on the course of the channel, especially near 163°W where it bends abruptly to the west; (3) the thickness of the pelagic sediment cover that overlies the turbidites; (4) the depositional development of the channel and the ridge and the possible lateral migration of the channel as shown for other deep-sea channels in the northeast Pacific by Hamilton (1967); and (5) the relation of the channel to the two ridges it passes between (profile FF' in fig. 9 and crossings 44, 45, and 46 in fig. 7) before losing its identity as a single feature west of the ridges.

7. ORIGIN

Assuming that the pre-trench gradient is approximated by that portion of the channel southwest of crossing 24, we can compare it with that of other active channels. The mean gradient from crossings 24 to 46 is about 0.75 m/km, but as pointed out above the gradient varies greatly from almost zero between 31 and 37 to 1.4 m/km between 24 and 31. Cascadia channel (fig. 1),whose axial profile is similar to that of other channels in the northeast Pacific, has gradients of 1.83, 1.67, and 1.17 m/km at respective distances of about 165, 275, and 435 km from the base of the continental slope (Hurley, 1960). Shepard (1966) shows that the gradient of the Monterey fan valley (upstream and continuous with the Monterey deep-sea channel) increases from 11 m/km on the inner fan close to Monterey canyon to 3.8 m/km at a meander about 75 km southwest of Monterey peninsula in California, and Heezen et al., (1959) have found that in the northwest Atlantic the midocean "canyon", where it is thousands of kilometers from its source, has a gradient generally ranging from about 0.25 to 0.5 m/km.

Although there are many difficulties in using such comparisons to obtain an approximate distance between the channel section from crossings 24 to 46 and the ancient source of turbidites, the comparisons suggest that this section was at least several hundred kilometers from the sediment source. On the other hand, as pointed out above, the location of the channel on top of a ridge implies an unusually thick accumulation of sediment, suggesting that the source area of the channel may have been relatively close, perhaps in the region between the Shumagin Islands and Kodiak Island (fig. 1). Our echo soundings, taken mainly along north-south lines, have not revealed the presence of the channel north of the trench. It seems likely that north of the segment discussed in this paper the channel has been obliterated.

An alternate explanation for its origin (suggested by R. Nayudu, personal communication) is that the channel may have been the downstream part of one of the channels in the northern part of the Gulf of Alaska, such as the Surveyor channel (fig. 1). This would mean that the part of the channel that looped over the area about to be downbowed was destroyed when the trench formed.

8. AGE OF ALEUTIAN TRENCH

Since turbidity currents cannot flow through the SEAMAP channel at present and cannot reach any part of the central and northern Aleutian abyssal plain because of the intervening Aleutian trench, dating of the top of the turbidite sequence should give the age of the trench, although, as will be shown, this is not necessarily true if the sea floor south of the trench is being thrust into the trench by the mechanism of sea-floor spreading. This age has been estimated by Hamilton (1967) at about 50 million years, based on a thickness of about 100 m of acoustically transparent sediment (the covering of pelagic material) and a sedimentation rate of 0.2 cm/1000 years. Using other combinations of thickness and sedimentation rates, he gives a range from about 20 to 100 million years. The sedimentation rate of 0.2 cm/1000 years is based on Scripps Chinook core 11 (Goldberg and Koide, 1958) located about 650 km west of the Aleutian abyssal plain. However, more recent rates derived from paleomagnetic studies of cores in the same area are much higher, suggesting a more probable average rate between 0.75 to 1 cm/1000 years (Ninkovitch et al., 1966). According to these rates, the pelagic cover would be 10 to 15 million years old.

9. THE SEAMAP CHANNEL AND SEA-FLOOR SPREADING

Because of its unique nature and its location south of the Aleutian trench, it is of interest to examine the SEAMAP channel in the light of the hypothesis of sea-floor spreading (Hess, 1962; Dietz, 1961), whereby oceanic crust, and the sediment accumulated on it, is carried to the trenches and thrust downward along active seismic zones. (For a current, well-documented discussion of this hypothesis, see Isacks et al., 1968). The SEAMAP channel, next to the active Aleutian trench (fig. 1), should, therefore, be carried into the trench where it will be destroyed within several million years. The hypothesis also predicts that much of the upstream part of the channel has already been so destroyed.

Recent studies show that sea-floor spreading is probably episodic, with the latest period beginning about 10 million years ago (e.g., Ewing and Ewing, 1967; Le Pichon, 1968; Isacks et al., 1968). The direction of spreading south of the trench for this period has been postulated as being from southeast to northwest (see, for example, McKenzie and Parker, 1967; Le Pichon, 1968; and Isacks et al., 1968). The amount of spreading can be estimated at about 500 km if we combine 10 million years with a spreading rate of about 5 cm/year, as deduced by Le Pichon (1968), for this part of the Aleutian trench. This agrees fairly well with the amount obtained independently by Isacks et al., (1968) who assume that the length of the seismic zones beneath island arcs is a measure of the amount of spreading in the last 10 million years. They show that the length of the seismic zone, and, therefore, the amount of spreading in this period, is about 350 to 400 km for this part of the Aleutian trench. Thus the SEAMAP channel 10 million years ago would have been about 350 to 500 km southeast of its present location.

If all of this is true, the following history of the SEAMAP channel is suggested. Ten million years ago the sea floor in this region was static, the Aleutian trench did not exist, and turbidity currents flowed through the SEAMAP channel onto the Aleutian abyssal plain. The channel was much longer, and the segment we see today was 350 to 500 km southeast of its present location. Spreading then started (which is in fair agreement with the 10 to 15 million years suggested in sec. 8 by pelagic sediment thickness and accumulation rates) and the Aleutian trench formed, cutting off the supply of the turbidite material from the SEAMAP channel and the Aleutian abyssal plain. The channel was carried towards the trench in a northwesterly direction at a rate of about 5 cm/year, and the upstream part was continuously destroyed as the sea floor was thrust into the trench. Today only 350 to 400 km of the channel remain. Continued spreading in a direction of about 50° west of north (as suggested by Le Pichon, 1968) will cause this part of the channel to be destroyed in about 2 or 3 million years.

Two aspects of the channel suggest, however, that it may have been close to its present position when the trench cut it off from its turbidite supply. The first, as pointed out above, is the probable presence of an unusually thick accumulation of sediment, which would indicate that the channel was relatively near a supply of turbidite material on the continental slope. The second is the well-developed meanders that occur only upstream (trenchward) of the gradient reversal (figs. 3 and 8), which suggest that these meanders are related in some manner to the formation of the trench, perhaps on a sea floor that was becoming flatter in response to the incipient formation of the trench, although it is of course also possible that the meanders result from structural control that by coincidence is far more dominant upstream than downstream from the reversal.

Another relationship between the channel and trench, based on the hypothesis of sea-floor spreading, is possible. Since the SEAMAP channel may be the downstream part of one of the channels in the Gulf of Alaska (fig. 1) as suggested above, turbidity currents could have continued to flow through it after the trench formed, since the sea floor was hundreds of kilometers southeast of its present location, with the result that the channel did not become isolated until an upstream segment of it was carried into the trench. If we accept this explanation, the time required for the pelagic cover of sediments to accumulate would be less than the age of the trench.

10. ACKNOWLEDGMENTS

I wish to thank the officers and crews of the U. S. Environmental Science Services Administration's Coast and Geodetic Survey ships PIONEER, SURVEYOR, and OCEANOGRAPHER whose care and skill in conducting the SEAMAP surveys provided the basic data used in this study. This paper has benefited from the comments of B. H. Erickson, F. P. Naugler, and T. V. Ryan.

II. REFERENCES

Buffington, E. C. (1952), Submarine natural levees, J. Geol. 60, 473.

Dietz, R. S. (1958), The channels on the deep sea floor, The New Scientist 2, 946.

Dietz, R. S. (1961), Continent and ocean basin evolution by spreading of the sea floor, Nature 190, 854.

Ewing, J., and M. Ewing (1967), Sediment distribution on the mid-ocean ridges with respect to spreading of the sea floor, Science 156, 1590.

Goldberg, E. D., and M. Koide (1958), Ionium-thorium chronology in deep-sea sediments of the Pacific, Science 128, 1003.

Grim, P. J., and F. P. Naugler (1969), A fossil deep-sea channel on the Aleutian abyssal plain, Science (in press).

Hamilton, E. L. (1967), Marine geology of abyssal plains in the Gulf of Alaska, J. Geophys. Res. 72, 4189.

Heezen, B. C., M. Tharp, and M. Ewing (1959), The floors of the oceans, I., The North Atlantic, Geol. Soc. Am., Spec. paper 65, 122 pp.

Hess, H. H. (1962), History of the ocean basins, Petrological Studies: A Volume in Honor of A. F. Buddington, ed. A. E. J. Engel et al., 599 (Geological Society of America, New York).

Hurley, R. J. (1960), The geomorphology of abyssal plains in the northeast Pacific Ocean, Scripps Inst. Oceanog. Ref. 60-7.

Isacks, B., J. Oliver, and L. R. Sykes (1968), Seismology and the new global tectonics, J. Geophys. Res. 73, 5855.

Le Pichon, X. (1968), Sea-floor spreading and continental drift, J. Geophys. Res. 73, 3661.

McKenzie, D., and R. L. Parker (1967), The North Pacific: An example of tectonics on a sphere, Nature 216, 1276.

Menard, H. W. (1955), Deep-sea channels, topography and sedimentation, Bull. Am. Assoc. Petrol. Geol. 39, 236.

Menard, H. W. (1964), Marine Geology of the Pacific, 271 pp. (McGraw-Hill, New York).

Menard, H. W., S. M. Smith, and R. M. Pratt (1965), The Rhône deep-sea fan, Submarine Geology and Geophysics, 17, Colston papers, ed. W. F. Whittard and R. Bradshaw, 271 (Butterworths, London).

Ninkovitch, D., N. Opdyke, B. C. Heezen, and J. H. Foster (1966), Paleomagnetic stratigraphy, rates of deposition and tephrachronology in north Pacific deep-sea sediments, Earth Planet. Sci. Letters 1, 476.

Paulsen, F. G. (1966), Navy satellite navigation system, NASA CR-612.

Ryan, T. V., and P. J. Grim (1968), A new technique for echo sounding corrections, Intern. Hydrograph. Rev. 45, 41.

Shepard, F. P. (1966), Meander in valley crossing a deep-ocean fan, Science 154, 385.

Talwani, M., J. Dorman, J. L. Worzel, and G. M. Bryan (1966), Navigation at sea by satellite, J. Geophys. Res. 71, 5891.

GPO 848-850