YALE
PEABODY
MUSEUM

P.O. BOX 208118 | NEW HAVEN CT 06520-8118 USA | PEABODY.YALE. EDU

JOURNAL OF MARINE RESEARCH

The *Journal of Marine Research,* one of the oldest journals in American marine science, published important peer-reviewed original research on a broad array of topics in physical, biological, and chemical oceanography vital to the academic oceanographic community in the long and rich tradition of the Sears Foundation for Marine Research at Yale University.

An archive of all issues from 1937 to 2021 (Volume 1–79) are available through EliScholar, a digital platform for scholarly publishing provided by Yale University Library at https://elischolar.library.yale.edu/.

Requests for permission to clear rights for use of this content should be directed to the authors, their estates, or other representatives. The *Journal of Marine Research* has no contact information beyond the affiliations listed in the published articles. We ask that you provide attribution to the *Journal of Marine Research*.

Yale University provides access to these materials for educational and research purposes only. Copyright or other proprietary rights to content contained in this document may be held by individuals or entities other than, or in addition to, Yale University. You are solely responsible for determining the ownership of the copyright, and for obtaining permission for your intended use. Yale University makes no warranty that your distribution, reproduction, or other use of these materials will not infringe the rights of third parties.

This work is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License. https://creativecommons.org/licenses/by-nc-sa/4.0/

SEARS FOUNDATION FOR MARINE RESEARCH
BINGHAM OCEANOGRAPHIC LABORATORY, YALE UNIVERSITY

JOURNAL OF
MARINE RESEARCH

VOLUME 13 1954 NUMBER 1

SOURCE OF WATER IN BASINS OFF SOUTHERN CALIFORNIA[1]

By

K. O. EMERY

University of Southern California

ABSTRACT

Water temperature and salinity measurements from most of the 14 basins off southern California, when compared with older data, show no detectable changes. The water in each basin is nearly isothermal and isohaline from the bottom to near the sill depth. Water temperatures indicate that the bottom water of most basins must have travelled from basin to basin in a general northwesterly direction while that of the outermost basins came directly from the open sea on the west. Each sill in the path of the water acts as a submerged dam which holds back the water that is deeper than the sill itself. The densest water which can cross, that near the sill depth, occupies each basin from its bottom to near its sill depth.

INTRODUCTION

An investigation of sediments from the floors of basins off southern California (Emery and Rittenberg, 1952) has indicated that certain characteristics of the sediment, such as the amount of organic matter and the depth of zero oxidation-reduction potential, are controlled in part by the nature of the overlying basin water. Conversely, the hydrogen-ion concentration, oxygen content, and sulphate-chloride ratio of the overlying water may be influenced by the sediment. Since the sediment and water are inter-related, additional work on the sediment could not be effective without more complete knowledge

---

[1] Contribution of Allan Hancock Foundation, No. 134.

of the water. For convenience, study of the water was divided into two parts: (1) An examination of the origin of the water mass, and (2) a study of the peculiar chemical properties near the bottom. The part on water origin has been completed and is presented herewith.

Most of the data for this study were obtained during the winter of 1952–1953 aboard the University of Southern California research vessel, VELERO IV. During four short cruises, vertical series of Nansen bottle samples were taken from nine basins as well as from five main basin sills and four secondary sills. Because of the importance attached to the interface between water and sediment, the samples at each station were spaced widely near the surface and more closely near the bottom, and usually an attempt was made to trip one Nansen bottle at the bottom. This spacing is the reverse of the usual oceanographic procedure. Supplementary data for two deep-sea stations and one station near a basin sill were obtained from records of fisheries research cruises made during 1949, 1950, and 1951 by vessels of the Scripps Institution of Oceanography (Staff, 1950, 1951, 1952).

In order to ascertain whether or not changes in the water of the basins had occurred during the past years, a search was made for older data. Unpublished data from three basins and a trough were obtained by John Lyman during 1940 while he was engaged in work at the Scripps Institution of Oceanography. In 1937 Sverdrup and Fleming (1941) obtained one observation below the sill depth of each of two other basins. Serial temperatures in another basin were measured by the U. S. Coast and Geodetic Survey in 1933 during a study of sound transmission in the water (Swainson, McIlwraith, and Dyk, 1934). Unpublished bottom temperatures for one of the basins that was sampled by Sverdrup and Fleming in 1937 were provided by Manley L. Natland, who had obtained them during 1931 and 1932 for a study of the depth distribution of Foraminifera (Natland, 1933).

TOPOGRAPHY

The sea floor off southern California is well sounded for such a large area, there being about 280,000 soundings in areas deeper than 100 m, mostly obtained by the U. S. Coast and Geodetic Survey between the years 1932 and 1938. From all available soundings, Shepard and Emery (1941) prepared charts at 50-fathom contour intervals. Fig. 1, simplified from the contour charts, shows the characteristics which are probably of greatest importance to bottom water circulation.

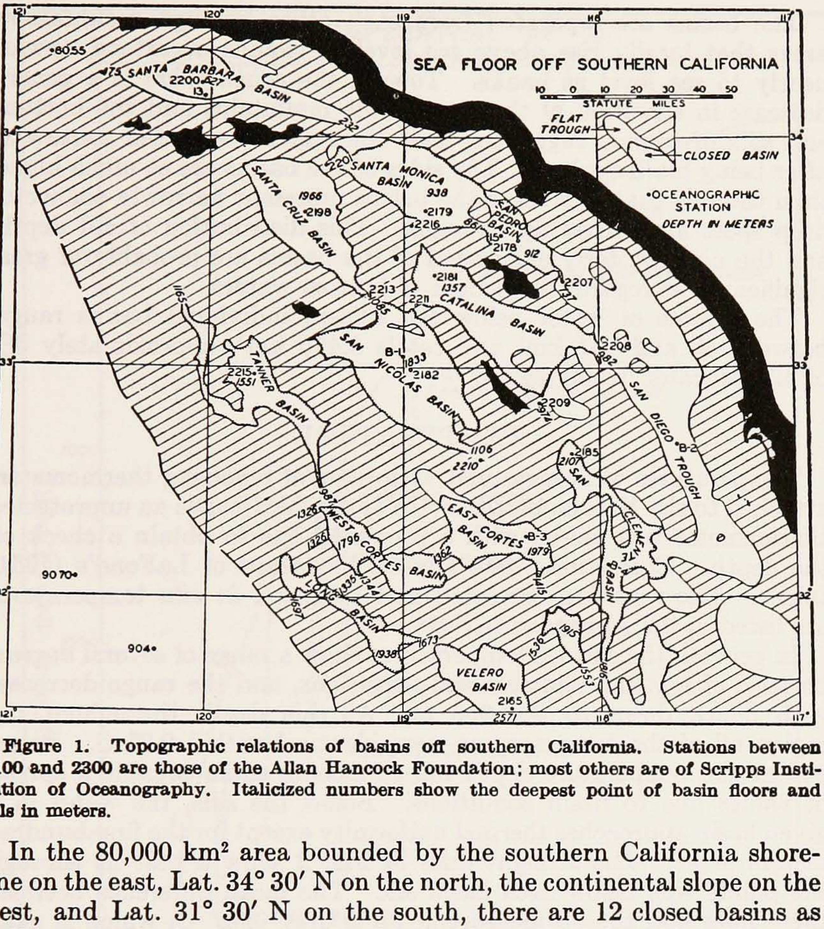

Figure 1. Topographic relations of basins off southern California. Stations between 2100 and 2300 are those of the Allan Hancock Foundation; most others are of Scripps Institution of Oceanography. Italicized numbers show the deepest point of basin floors and sills in meters.

In the 80,000 km² area bounded by the southern California shoreline on the east, Lat. 34° 30′ N on the north, the continental slope on the west, and Lat. 31° 30′ N on the south, there are 12 closed basins as well as parts of two more at the southern boundary (see Fig. 1). Thus, the region contains 14 basins, the bottom depths of which range from 627 to 2,571 m and the sill depths from 475 to 1,902 m below the sea surface. The differences between sill depth and basin depth for given basins vary from 152 to 881 m. Depth data for individual basins are presented in Table I and Fig. 1. Of the indicated depths, that of the sills is least certain because of the difficulty of determining the deepest point of a sill in the absence of extremely detailed surveys. Thus it is possible that reported sill depths have an accuracy no better than plus or minus 50 m. Curiously, each of four basins contains two sills that have indicated depths within 100 m of each other, and one basin has five sills of approximately equal depth.

The basins are separated from each other by high mountainous areas that locally rise above sea level as islands or extend upward nearly to sea level as banks. Toward the south there is a general decrease in elevation of the tops of the mountains and the bottoms and sills of basins, suggesting that the region was tilted southward after being block-faulted. The sides of the basins are so much higher than the sills that in a sense the basins represent narrowly connected deep spots along irregular troughs. This distribution of sill depths and the northwesterly elongation of the basins are probably of great significance as regards movement of bottom waters.

The volume of water below the sills in individual basins ranges between 43 and 961 km^3 and totals 3,470 km^3, approximately 5% of all the water in the region.

TEMPERATURE

Temperatures were measured with pairs of reversing thermometers attached to the Nansen bottles. On every third bottle an unprotected thermometer was paired with a protected one to obtain a check on the depth. Corrections were applied by means of LaFond's (1951) tables. The resulting corrected and averaged *in situ* temperatures are listed in the Appendix.

In general, the surface temperatures show a range of several degrees because of regional and seasonal variations, and the range decreases with depth down to 900–950 m. At this depth throughout the region all of the temperatures were identical within 0.2° C. Below 950 m the temperature-depth measurements again present a spread of values due to basin conditions. Below the sills, the water in a given basin approaches thermal uniformity except for the first hundred meters or so. The straight lines in Fig. 2 show a best fit through the points well below each basin sill. The mean difference between these lines and the 63 measurements is only 0.02° C, which is close to the limit of accuracy of the thermometers. Absence of secular or seasonal changes in temperature below the sills is indicated by the fact that 15 earlier (1931–1940) temperature measurements below the sills have a mean difference of only 0.01° C from the same straight line. The temperature is so constant with depth and time in fact that these areas may even prove useful for checking the calibration of thermometers.

In several of the basins a temperature decrease amounting to a few hundredths of a degree occurs in the first hundred meters below the sill, and in one basin (San Nicolas) it amounts to 0.13° C. Probably this gradient can be attributed to mixing. At greater depths, the

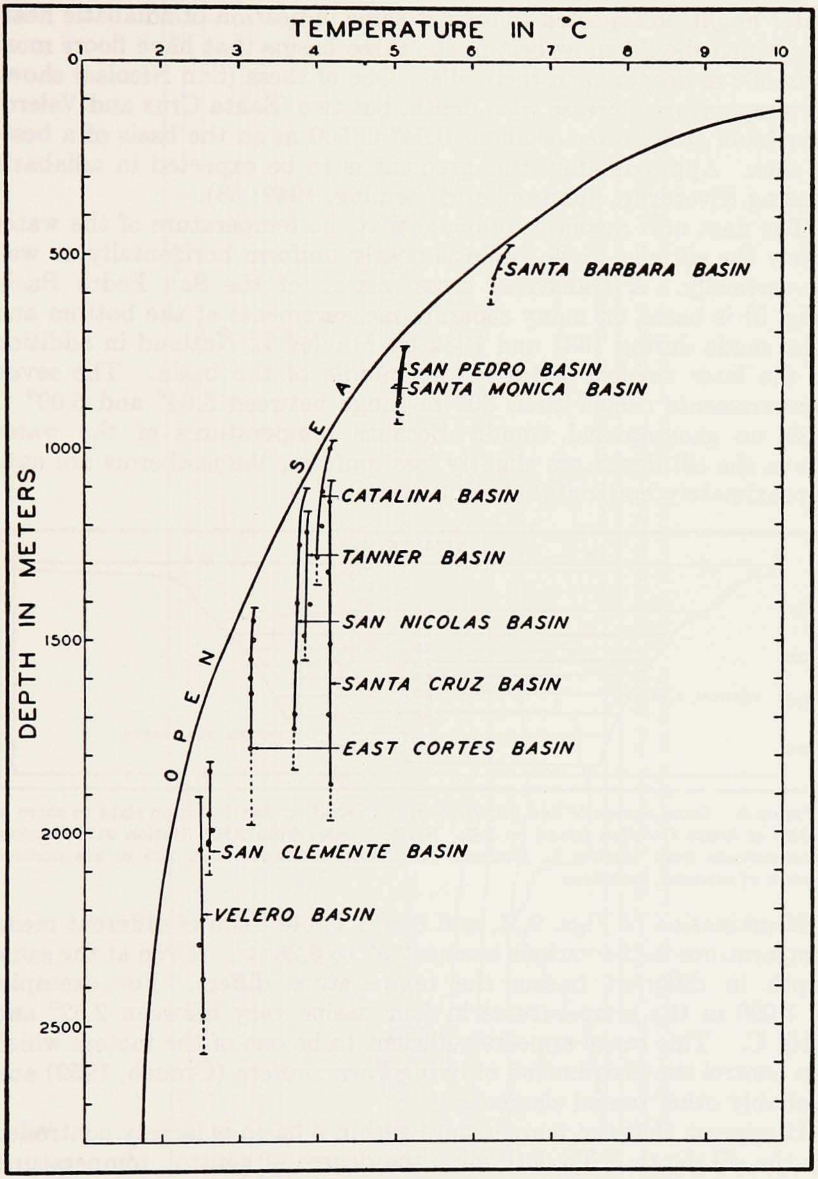

Figure 2. Temperature-depth curves for the open sea (St. 904) and for basin water below sills. Short horizontal lines indicate sill and bottom depths of basins. The dashed lines indicate water below lowest sample bottle plus difference in depth between station location and deepest part of basin.

water might be expected to exhibit some indication of adiabatic heating, which should show best in the three basins that have floors more than 650 m deeper than their sills. One of these (San Nicolas) shows no temperature increase with depth, but two (Santa Cruz and Velero) may have an increase of about 0.04° C/500 m on the basis of a best-fit line. Approximately this gradient is to be expected in adiabatic heating (Sverdrup, Johnson, and Fleming, 1942: 63).

The data now available indicate that the temperature of the water below the sill of a given basin is nearly uniform horizontally as well as vertically. A transverse cross section of the San Pedro Basin (Fig. 3) is based on many separate measurements at the bottom and sides made during 1931 and 1932 by Manley L. Natland in addition to the later vertical series in the middle of the basin. The seven measurements deeper than 800 m range between 5.04° and 5.09° C with no geographical trend. Because temperatures of the water above the sill depth are slightly less uniform, the isotherms are only approximately horizontal (Figs. 3 and 4).

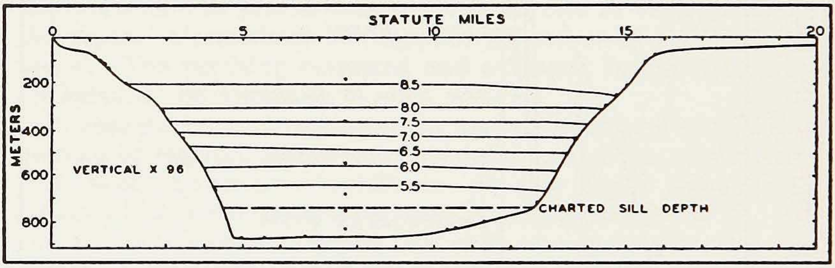

Figure 3. Cross section of San Pedro Basin from shelf off San Pedro on right to shore at middle of Santa Catalina Island on left. Vertical series from AHF Station 2178; bottom measurements from Manley L. Natland. Isotherms shallower than 200 m are omitted because of seasonal variations.

Examination of Figs. 2, 4, and 5 and Table I shows different mean temperatures in the various basins: 2.52 to 6.26° C. Even at the same depth in different basins the temperature differs. For example, at 1,900 m the temperatures in four basins vary between 2.52° and 4.15° C. This range appears sufficient to be one of the factors which can control the distribution of living Foraminifera (Crouch, 1952) and probably other faunal elements.

It appears that the temperature within a basin is largely controlled by the sill depth. To determine the degree of control, temperature-depth series were obtained as near as possible to the position of the lowest sill at each of five basins. The lowermost Nansen bottle was still 3 to 51 m above the lowest charted sill depth, and therefore the sill

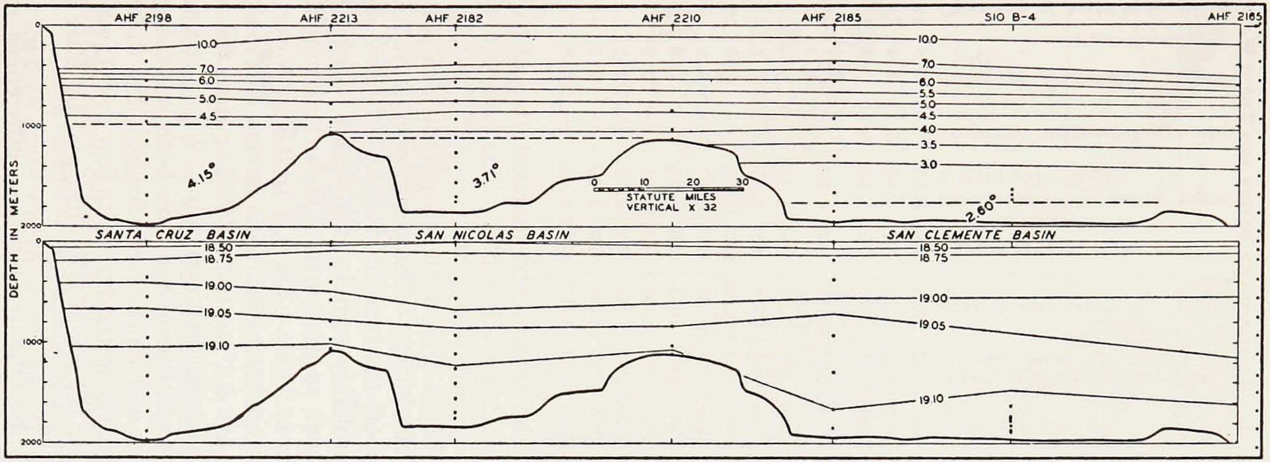

Figure 4. Longitudinal sections of San Clemente, San Nicolas, and Santa Cruz Basins. Isotherms in °C at top; isochlores in °/oo at bottom. Horizontal dashed lines indicate effective sill depth. Water at extreme right is assumed to be like that of Velero Basin.

TABLE I. PROPERTIES OF BASINS AND THEIR WATER

	Lowest sill depth from sea surface (m)	*Depth of bottom (m)*	*Difference between sill depth and bottom depth (m)*	*Area of basin (km^2)*	*Volume of basin (km^3)*	*Temperature of basin water below sill (°C)*	*Measured temperature at sill (°C)*	*Estimated temperature at sill (°C)*	*Chlorinity of basin water below sill (°/oo)*	*Effective sill depth (m)*	*Sonic minus effective sill depth (m)*
Santa Barbara	475	627	152	660	45	6.26	—	6.5	18.96	510	−35
San Pedro	737	912	175	655	78	5.06	5.11	5.1	18.98	750	−13
Santa Monica	737	938	201	1805	210	5.05	5.11	5.1	18.99	750	−13
Catalina	974 982	1357	383	2140	89	4.02	3.90 4.17	4.1 4.2	19.05	1010	−36
Santa Cruz	1085	1966	881	1780	879	4.15	3.85	3.9	19.11	980	+105
San Nicolas	1106	1833	727	2660	961	3.71	3.76	3.7	19.11	1100	+6
Tanner	1165	1551	386	1260	183	3.85	—	3.6	19.13	1060	+105
West Cortes	1362	1796	434	1005	160	3.3?	—	3.2	—	—	—
East Cortes	1415	1979	564	1055	216	3.13	—	3.0	19.11	1370	+45
No Name	1553	1915	362	307	43	2.9?	—	2.8	—	—	—
Long	1697	1938	241	830	63	2.7?	—	2.5	—	—	—
San Clemente	1816	2107	291	1490	120	2.60	—	2.5	19.13	1750	+66
Velero	1902	2571	669	1310	420	2.52	—	2.3	19.14	1700	+202

temperature had to be obtained by extrapolation of the temperature-depth curve to the charted sill depth. The extrapolations, indicated in Table I as "measured temperature at sill," range from 0.05° C above to 0.30° C below the mean temperature of the water deeper than sill depth in the basins. The temperatures at the depth of the sills were also read off the temperature-depth curve of the adjoining water mass that probably supplied the water which crossed the sill, usually the next basin to the south. These "estimated temperatures at sill," shown also in Table I are 0.1° to 0.3° C lower than the temperature of the bottom water in basins having sills deeper than about 1000 m, but they are 0.1° to 0.2° C higher than the temperature of water in basins that have shallower sills. Where the sill temperature is lower than that at the same depth in both adjoining basins (as in sills of the Catalina and Santa Cruz Basins), the difference must be due to a slight rise of the water during its flow over the sill, as discussed by Schott (1928) for the sill at Gibraltar and by Parr (1937) for sills in the Caribbean Sea.

Attempts to resolve the temperature differences of basin water and sill water led to the conclusion that the water which enters a

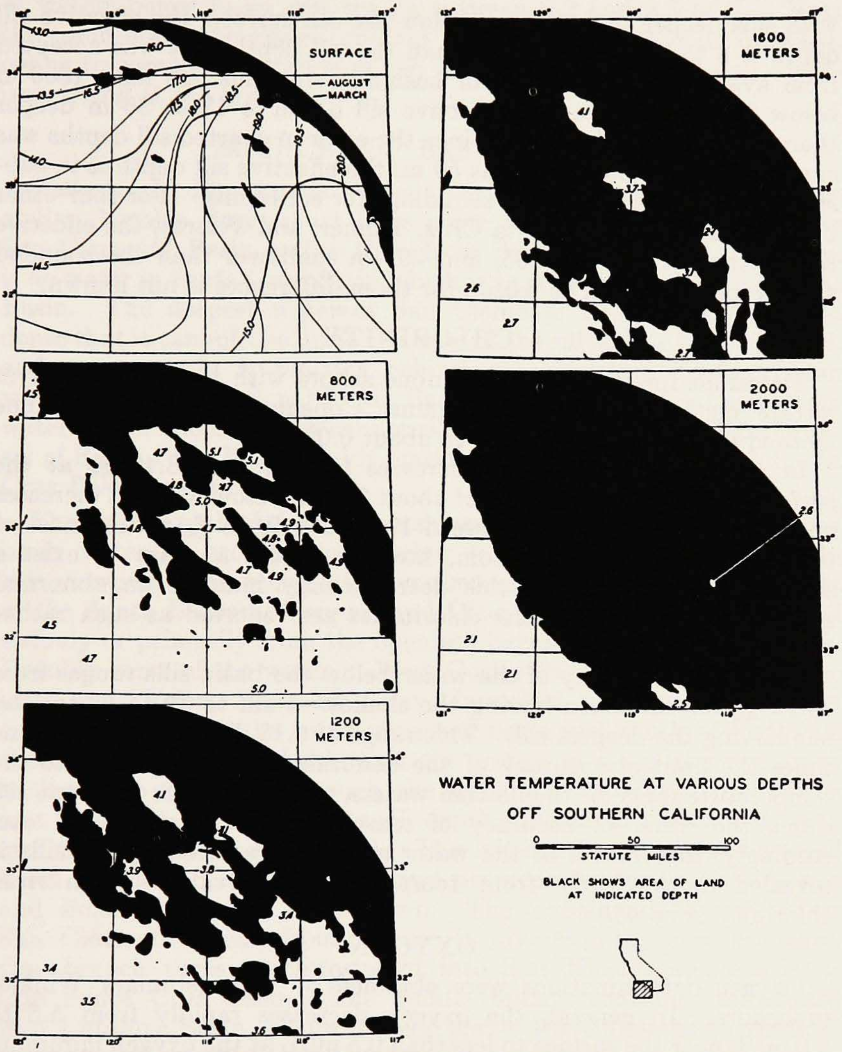

Figure 5. Maps of sea floor at 0, 800, 1200, 1600, and 2000 m. The solid black represents land areas at the various levels. Temperature in °C. Generalized isotherms for March and August at surface from Leipper (1947).

basin may come from some depth other than that of the exact lowest point of the sill. The average water temperature in any given basin is the same as that at some depth in an adjoining basin, and this depth was taken as the effective sill depth (see Table I). For basins with sills deeper than 1000 m below the sea surface, the effective sill depth is 6 to 202 m shallower than the sill depth that was accepted from available soundings. For basins having sills less than 1000 m below the sea surface, the effective sill depth is 13 to 36 m deeper than the charted sill depth. Since the error in charted sill depths was considered to be plus or minus 50 m, the effective sill depth is in substantial agreement with the soundings for six basins. For four other basins (San Clemente, Santa Cruz, Tanner, and Velero), the effective sill depths are 66, 105, 105, and 202 m shallower than the sounded sills, respectively. The reason for these differences is not known.

CHLORINITY

Titrations for chlorinity were done ashore with the ordinary silver nitrate method standardized against Copenhagen sea water. The method is considered accurate to about 0.02 ‰.

In general, the chlorinity increases from about 18.40 ‰ at the surface to 18.90 ‰ at a depth of about 300 m, below which it increases more gradually to values between 19.10 and 19.15 ‰ within most of the basins. Near the bottom, however, there appears to exist a slight decrease. Because this decrease may indicate an abnormal salinity-chlorinity ratio, the chlorinities are reported as such rather than as salinities.

The mean chlorinity of the water below the basin sills ranges from 18.96 ‰ for the basin having the shallowest sill to 19.14 ‰ for the one having the deepest sill. This range of 0.18 ‰ is only about nine times the limit of accuracy of the determination, in contrast to the temperature range of the bottom waters, which amounts to about 190 times the limit of accuracy of temperature determinations. Accordingly, the control of the water movement exerted by the sills is revealed more clearly from temperature observations than from chlorinity (Fig. 4).

OXYGEN

Oxygen determinations were obtained by the customary Winkler procedure. In general, the oxygen decreases rapidly from 5.5 to 6.0 ml/L near the surface to less than 0.5 ml/L at the oxygen minimum between 500 and 600 m. Below the oxygen minimum in the open sea the oxygen again increases to about 2.0 ml/L at 2,000 m. Wherever the water is trapped in a basin, the bulk of it retains the approximate oxygen content that occurs at the sill depth; thus, if the sill is near the depth of oxygen minimum the oxygen content is low; if the sill is well below the depth of oxygen minimum the oxygen content of the basin water is higher. Accordingly, the oxygen content of waters below basin sills ranges between 0.2 and 2.5 ml/L. Near the basin floors the oxygen content of the water may again decrease, owing to complex alteration of the water by the sediment and organisms living at the bottom.

SOURCES OF BASIN WATER

Pattern. In Fig. 4 it is obvious that the water near the bottom of San Nicolas Basin must have come from the mid-depths above San Clemente Basin rather than from Santa Cruz Basin, for there is no water in Santa Cruz Basin which is as cold as that in San Nicolas Basin. The deepest water of San Clemente Basin is so cold and dense that it cannot rise up to the level of the sill of San Nicolas Basin, and consequently it remains behind, marking the direction from which the water of San Nicolas Basin came. Similarly, the bottom water of San Nicolas Basin cannot rise to the level of the still shallower sill of Santa Cruz Basin, and it marks the direction from which Santa Cruz Basin was supplied.

The general path of the water is shown by isolated masses of trapped basin water of progressively higher temperature. Examined from this viewpoint, the temperature measurements show that the waters of the Santa Barbara, Tanner, and Long Basins have been supplied entirely or primarily from the open sea beyond the continental slope. Possibly some of the water in West Cortes Basin also came from the open sea. Velero Basin may have furnished some of the water in Long Basin and in the small unnamed basin just south of Sixtymile Bank. It appears probable that the waters in all of the remaining basins have funnelled through the unnamed and unexplored basin east of Velero Basin above its sill depth. From this unnamed basin two tongues extend northward. The left-hand one enters the small basin south of Sixtymile Bank and proceeds thence to East Cortes and finally to west Cortes Basin. The right-hand tongue enters San Clemente Basin, from whence it divides into three branches. One branch turns northwestward into San Nicolas and continues into Santa Cruz Basin. The middle branch continues northward into Catalina Basin, where it may partly leave that basin through the sill southeast of Santa Catalina Island to rejoin the third branch which left San Clemente Basin to proceed northward up the San Diego Trough. The two rejoined branches thereupon proceed northwestward into San Pedro and thence into Santa Monica Basins.

The sides of most of the basins extend upward to form islands or rise at least to depths that are much shallower than the sills; thus, the sides confine the movements of water at the depth of most down-current sills. Only the sills of the San Pedro Basin and Catalina Basin are sufficiently shallow with respect to the surrounding topography to permit water to enter by a number of routes. The current axes leading to these sills are shown as dashed lines in Fig. 6.

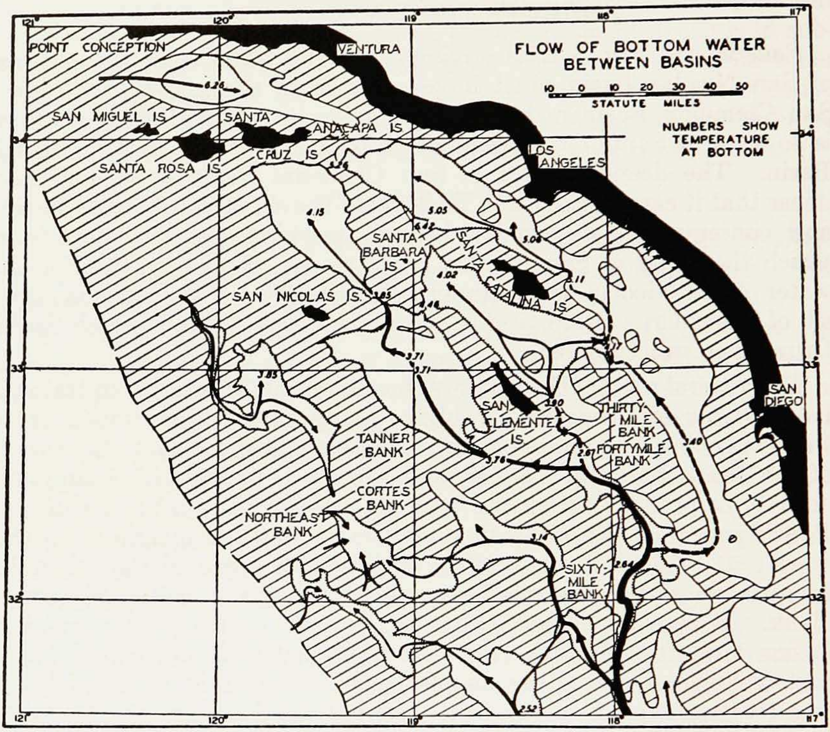

Figure 6. Pattern of water flow from basin to basin. Width of arrow serves as rough indicator of relative transport volume.

In its travels through the basins, the water appears to have followed a general northwesterly course that is opposed for the most part to the surface current, especially during winter. The latter is shown by the generalized map of surface isotherms (Fig. 5), if we assume that the current flows along the isotherms in a direction such that the warm water is on the right-hand side of the current. Because of the current which exists near the surface, there must be continual mixing across the interface between the water masses. As a result of this mixing, some of the water below the basin sills becomes less dense in the course of time, thus permitting the flow of additional water across the sills. Because of the slow mixing and replacement, the water within the basins does not become stagnant and devoid of oxygen.

The relationship of the water to topography off southern California is similar to that observed in basins of the East Indies (van Riel, 1934; van Riel, Hamaker, van Eyck, 1950) and in the West Indies (Parr, 1937). Thus, in a sense, the basins off southern California are small scale parallels of the basins of the East Indies and West Indies.

Velocity. The many surveys of temperature and salinity of the near-surface waters off southern California, when converted to dynamic topography, yield surface current speeds that locally range up to about 50 cm/sec and average between 10 and 15 cm/sec. Though such computations are subject to many errors, these computed currents show good agreement with the results of drift bottle experiments (Sverdrup and Fleming, 1941: 273).

Thus far indirect methods have not been applied to the problem of currents within the basins and below their sills, but brief measurements with current meters have been made just above the floors of Santa Cruz and San Pedro Basins (Shepard, 1948: 65). In Santa Cruz Basin, currents between 8 and 15 cm/sec were obtained, the speeds just above the bottom often being greater than those of currents slightly above them; thus the presence of turbulent motion is indicated. In San Pedro Basin the speeds ranged between 7 and 18 cm/sec. Since the measurements are not very complete, the origin of these currents is uncertain, but they may be related to seiches.

ACKNOWLEDGMENTS

Appreciation is due Captain Allan Hancock for making Velero iv available for the field work. Aid in the collection and analysis of samples was rendered by Messrs. B. L. Conrey, J. R. Grady, J. W. Marlette, and F. C. Ziesenhenne. John Lyman and Manley L. Natland kindly contributed unpublished data, part of which is listed in the Appendix.

REFERENCES

Crouch, R. W.
1952. Significance of temperature on Foraminifera from deep basins off southern California coast. Bull. Amer. Ass. Petrol. Geol., *36:* 807–843.

Emery, K. O. and S. C. Rittenberg
1952. Early diagenesis of California basin sediments in relation to origin of oil. Bull. Amer. Ass. Petrol. Geol., *36:* 735–806.

LaFond, E. C.

1951. Processing oceanographic data. Publ. Hydrographic Office, No. 614. 114 pp.

Leipper, D. F.

1947. Sea surface temperature variations influencing fog formation in southern California. Rep. Scripps Inst. Oceanogr., Oceanogr. *9:* 13 pp. (mimeo.).

Natland, M. L.

1953. The temperature and depth distribution of some recent and fossil Foraminifera in the southern California region. Bull. Scripps Inst. Oceanogr., *3:* 225–230.

Parr, A. E.

1937. A contribution to the hydrography of the Caribbean and Cayman seas based upon the observations made by the research ship "Atlantis," 1933–34. Bull. Bingham Oceanogr. Coll., *5* (4): 1–110.

Schott, G.

1928. Die Wasserbewegungen im Gebiete der Gibraltarstrasse. J. Cons. int. Explor. Mer, *3:* 139–175.

Shepard, F. P.

1948. Submarine Geology. Harper & Bros., New York. 348 pp.

Shepard, F. P. and K. O. Emery

1941. Submarine topography off the California coast: Canyons and tectonic interpretation. Spec. Pap. Geol. Soc. Amer., *31:* 171 pp.

Staff

1950. Physical and chemical data. Marine Life Research Program. Cruise 7, Sept. 5 to Sept. 18, 1949. Rep. Scripps Inst. Oceanogr., No. 7. (mimeo.)
1951. Physical and chemical data. Marine Life Research Program. Cruise 14, May 3 to May 18, 1950. Rep. Scripps Inst. Oceanogr., No. 14. (mimeo.)
1952. Physical and chemical data. Marine Life Research Program. Cruise 23, March 8 to March 23, 1951. Scripps Inst. Oceanogr., Ref. 52-9. (mimeo.)

Sverdrup, H. U. and R. H. Fleming

1941. The waters off the coast of southern California, March to July, 1937. Bull. Scripps Inst. Oceanogr., *4:* 261–378.

Sverdrup, H. U., M. W. Johnson, and R. H. Fleming

1942. The Oceans. Prentice-Hall, Inc., New York. 1087 pp.

Swainson, O. W., C. G. McIlwraith, and K. Dyk

1934. The velocity and ray paths of sound waves in deep sea water. U. S. Coast and Geodetic Survey, 37 pp. (mimeo.)

Van Riel, P. M.

1934. The bottom configuration in relation to the flow of the bottom water. The Snellius Expedition, *2* (2) ch. 2: 60 pp.

Van Riel, P. M., H. C. Hamaker, and L. Van Eyck

1950. Serial and bottom observations. Temperature, salinity, and density. The Snellius Expedition, *2* (6): 44 pp.

APPENDIX

Allen Hancock Foundation Stations made by VELERO IV, showing depth, temperature, and chlorinity.

AHF 2165

Oct. 11, 1952 Lat. 31°31.1′ Long. 118°27.0′ 2484 meters

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
0	18.5	18.43	1497	2.87	19.09
91	10.12		1679	2.65	19.11
186	10.70	18.91	1859	2.48	19.15
369	8.95	19.00	2042	2.50	19.14
552	6.76	19.00	2225	2.52	19.15
744	5.38	19.04	2289	2.47	19.13
926	4.38	19.03	2380	2.52	19.12
1109	3.78	19.04	2472	2.53	19.11
1314	3.30	19.08			

AHF 2178

Nov. 7, 1952 Lat. 33°32.7′ Long. 118°24.9′ 862 meters

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
0	17.75	18.41	679	5.31	18.93
183	8.63	18.70	752	5.11	18.98
365	7.52	18.92	828	5.09	
547	6.04	18.88			

AHF 2179

Nov. 7, 1952 Lat. 33°40.9′ Long. 118°53.0′ 893 meters

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
0	17.6	18.52	743	5.13	19.05
183	8.88	18.87	808	5.06	18.96
367	7.49	18.97	883	5.03	18.99
550	5.90	19.02			

AHF 2181

Nov. 8, 1952 Lat. 33°24.2′ Long. 118°51.0′ 1295 meters

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
0	18.0	18.52	821	4.52	19.04
184	8.44	18.85	1006	4.15	19.06
367	7.43	18.97	1112	4.11	19.06
550	5.99	18.99	1204	4.05	19.00
569	5.40	19.02	1286	4.00	18.99

AHF 2182

Nov. 8, 1952 Lat. 32°59.6′ Long. 118°58.3′ 1731 meters

Depth	*Temp.*	*Cl °/oo*	*Depth*	*Temp.*	*Cl °/oo*
0	17.3	18.52	1252	3.76	19.11
183	8.30	18.86	1402	3.74	19.11
366	7.30	18.96	1554	3.71	19.11
549	5.88	18.95	1692	3.71	19.06
732	4.99	19.03	1731		19.00*
914	4.35	19.06	1731	3.71	18.95†
1097	3.88	19.07			

*Clear: †Muddy.

AHF 2185

Nov. 9, 1952 Lat. 32°37.5′ Long. 118°08.0′ 2030 meters

Depth	*Temp.*	*Cl °/oo*	*Depth*	*Temp.*	*Cl °/oo*
0	16.1	17.88	1840	2.61	19.13
186	8.42	18.87	1950	2.60	19.13
370	6.89	18.93	1994	2.66	19.12
556	5.96	18.83	2025	2.60	19.13
921	4.34	19.08	2030	2.60	19.12*
1291	3.19	19.08	2030	2.61	19.11*
1660	2.65	19.10			

*Muddy

AHF 2198

Dec. 19, 1952 Lat. 33°40.5′ Long. 119°31.2′ 1893 meters

Depth	*Temp.*	*Cl °/oo*	*Depth*	*Temp.*	*Cl °/oo*
0	13.9	18.43	1138	4.15	19.12
361	7.65	18.98	1323	4.12	19.11
546	5.91	19.03	1509	4.15	19.09
729	4.85	19.06	1691	4.13	19.10
956	4.34	19.09	1874	4.17	19.09

AHF 2200

Dec. 20, 1952 Lat. 34°13.5′ Long. 120°02.5′ 589 meters

Depth	*Temp.*	*Cl °/oo*	*Depth*	*Temp.*	*Cl °/oo*
0	13.1	18.46	445	6.61	18.96
124	9.79	18.66	505	6.37	18.96
246	8.68	18.89	561	6.26	18.94
399	7.48	18.95			

AHF 2201

Dec. 20, 1952 Lat. 33°52.9′ Long. 119°24.3′ 677 meters

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
472	6.34	19.00	655	5.30	19.04
594	5.48	19.04			

AHF 2207

Jan. 28, 1953 Lat. 33°22.3′ Long. 118°10.7′ 722 meters

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
596	5.78	19.05	722		18.93†
722	5.20	19.00*			

*Muddy. †Clear.

AHF 2208

Jan. 28, 1953 Lat. 33°04.9′ Long. 117°59.1′ 935 meters

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
642	5.47	19.07	916	4.41	19.09
825		19.08			

AHF 2209

Jan. 29, 1953 Lat. 32°51.1′ Long. 118°17.9′ 939 meters

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
681	5.33	19.06	924	4.14	19.12
831		19.11			

AHF 2210

Jan. 29, 1953 Lat. 32°35.9′ Long. 118°35.5′ 1118 meters

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
0	15.4		1012	4.01	19.07
829	4.59	19.05	1103	3.77	19.12

AHF 2211

Jan. 30, 1953 Lat. 33°17.1′ Long. 118°56.0′ 845 meters

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
0	14.9		735	5.44	19.03
552	6.14	18.99	826	4.72	19.05

AHF 2213

Jan. 30, 1953 Lat. 33°18.6′ Long. 119°10.4′ 1051 meters

Depth	*Temp.*	*Cl* °/₀₀	*Depth*	*Temp.*	*Cl* °/₀₀
0	15.0	18.45	777	4.91	19.05
213	8.38	18.94	960	4.29	19.09
396	7.25	18.98	1051	3.93	19.05*
579	5.85	19.02			

*Muddy.

AHF 2215

Jan. 31, 1953 Lat. 32°58.8′ Long. 119°46.2′ 1490 meters

Depth	*Temp.*	*Cl* °/₀₀	*Depth*	*Temp.*	*Cl* °/₀₀
0	13.5	18.42	913	4.34	19.09
183	7.97	18.86	1097	3.90	19.11
366	6.62	19.01	1221	3.85	19.14
549	5.60	19.03	1405	3.90	19.13
732	4.86	19.06	1490	3.82	19.09*

*Muddy.

AHF 2216

Feb. 1, 1953 Lat. 33°36.4′ Long. 118°58.0′ 454 meters

Depth	*Temp.*	*Cl* °/₀₀	*Depth*	*Temp.*	*Cl* °/₀₀
0	14.2	18.40	350		18.87
166	8.55	18.83	442	6.80	18.92

Scripps Institution of Oceanography Stations. The Name of the Vessel Is Listed in Parentheses After the Station Number

SIO 80.55 (Horizon)

May 3, 1950 Lat. 34°21′ Long. 120°50′ 859 meters

Depth	*Temp.*	*Cl* °/₀₀	*Depth*	*Temp.*	*Cl* °/₀₀
0	12.26	18.67	300	7.57	18.92
50	9.93	18.71	400	7.05	18.95
100	8.84	18.81	500	6.32	18.97
150	8.48	18.88	600	5.64	18.97
200	8.13	18.88	700	5.05	19.02
250	7.82	18.90	800	(4.54)	(19.04)

SIO 90.70 (Black Douglas)

March 19, 1951 Lat. 32°04.5′ Long. 120°39′ 3743 meters

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
0	14.27	18.36	600	5.34	18.99
50	12.65	18.41	700	4.96	19.05
100	9.55	18.50	800	4.53	19.10
150	8.83	18.74	1000	3.87	
200	8.25	18.80	1200	3.37	
250	7.67	18.86	1500	2.77	
300	7.10	18.90	2000	2.07	
400	6.31	18.94	2500	1.79	
500	5.69	18.96			

SIO 904 (Crest)

Sept. 15, 1949 Lat. 31°46′ Long. 120°15′

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
0	18.30	18.49	600	5.62	19.01
50	16.05	18.47	700	5.11	19.04
100	11.07	18.51	800	4.69	19.06
150	9.24	18.71	1000	4.03	19.10
200	8.52	18.84	1200	3.51	19.13
250	7.96	18.89	1500	2.84	19.15
300	7.52	18.92	2000	2.12	19.17
400	6.85	18.96	2500	1.81	19.18
500	6.22	18.99	3000	1.70	19.18

SIO B-1 (E. W. Scripps)*

Sept. 4, 1940 Lat. 33°03′ Long. 119°00′ 1737 meters

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
0	18.04	18.67	618		19.03
26	14.87	18.61	824	4.77	19.04
77	9.84	18.71	1030	4.11	19.05
129		18.84	1236	3.91	19.09
206	8.39	18.89	1442		19.10
309	7.78	18.98	1648	3.71	19.10
412	7.15	18.98			

*John Lyman (personal communication)

SIO B-2 (E. W. Scripps)*

Sept. 5, 1940 Lat. 32°40′ Long. 117°35.5′ 1152 meters

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
0	20.22	18.54	298		18.94
26	16.04	18.50	398	7.83	18.96
77	10.88	18.46	410		18.96
128	10.28	18.78	497	6.87	18.97
140		18.84	696	5.45	19.01
199	9.54	18.90	895		19.04
249	9.13	18.92	1094	3.66	19.09

*John Lyman (personal communication).

SIO B-3 (E. W. Scripps)*

Sept. 28, 1940 Lat. 32°16′ Long. 118°23′ 1773–1847 meters

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
0		18.54	1600	3.14	19.12
1000		19.09	1610		19.11
1350	3.24		1640	3.15	19.11
1400	3.20	19.10	1740	3.14	19.11
1450	3.17	19.10	1780	3.13	19.15
1500	3.17		1790		19.10
1550	3.15	19.15			

*John Lyman (personal communication).

SIO B-4 (E. W. Scripps)*

Sept. 28, 1940 Lat. 32°08′ Long. 117°58′ 1929 meters

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
1625	2.74	19.17	1775		19.15
1675	2.70		1825		19.15
1725	2.64	19.19	1875		19.19
1735		19.13	1885		19.15

*John Lyman (personal communication).

SIO 13 (Bluefin)*

June 27, 1937 Lat. 34°10′ Long. 120°02′

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
0	15.21	18.61	250	7.90	18.92
50	9.56	18.68	300	7.65	18.94
100	8.85	18.82	400	7.03	18.95
150	8.50	18.87	500	6.40	18.96
200	8.20	18.91			

*Sverdrup and Fleming, 1941: 371.

SIO 15 (BLUEFIN)*

March 31, 1937 Lat. 33°34′ Long. 118°30′

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
0	13.80	18.49	300	7.43	18.96
50	10.54	18.61	400	6.70	18.98
100	9.34	18.75	500	6.16	18.99
150	8.85	18.83	600	5.67	19.02
200	8.38	18.89	800	5.08	19.02
250	8.06	18.94			

*Sverdrup and Fleming, 1941: 351.

OTHER OBSERVATIONS

SANTA CRUZ BASIN*

U. S. C. & G. S. (U. S. S. PIONEER) November, 1933

Depth	*Temp.*	*Cl °/₀₀*	*Depth*	*Temp.*	*Cl °/₀₀*
0	15.55	18.4	732	5.1	19.0
55	10.95	18.4	823	4.6	19.0
110	9.2	18.7	915	4.3	19.0
201	8.4	18.9	1006	4.2	19.1
292	7.9	18.9	1097	4.15	19.1
366	7.3	18.9	1280	4.15	19.1
457	6.7	18.9	1462	4.15	19.1
548	6.2	18.9	1700	4.15	19.0
640	5.6	18.9	1829	4.15	18.9

*Swainson, McIlwraith, and Dyk (1934: 20).

SAN PEDRO BASIN*

July 1931 to June 1932 Lat. 33°22.0′ to 33°45.8′ Long. 118°11.5′ to 18°20.5′

Depth	*Bottom Temp.*	*Depth*	*Bottom Temp.*
0	24.50	667	5.46
55	12.52	720	5.29
102	10.23	796	5.10
202	8.51	829	5.07
255	8.52	835	5.05
296	8.30	864	5.07
322	7.85	872	5.04
437	6.79	874	5.05

*Manley L. Natland (personal communication).