140496

1761

Carbonate Deposits and Paleoclimatic Implications in the Northeast Pacific Ocean

Y. R. Nayudu*

Reprinted from Science, October 23, 1964, Vol. 146, No. 3643, pages 515-517

Carbonate Deposits and Paleoclimatic Implications in the Northeast Pacific Ocean

Abstract. *A narrow carbonate band consisting predominantly of* Globigerina-*rich sediments is present in the deep-sea deposits of the northeast Pacific Ocean extending almost parallel to the coasts of Oregon and Washington. Five radiocarbon dates in the cores from this area suggest that the greatest concentration of* Globigerina-*rich sediments occurred 27,000 to 12,000 years ago. This time interval corresponds roughly to the Vashon (late Wisconsin) glacial times in the Puget Lowland. The results suggest higher carbonate sedimentation in the northeast Pacific during glacial stages.*

It is generally believed that very fine clastic sediments occur in the deep-sea area off the coasts of Oregon and Washington (*1*). A more recent detailed study of cores collected in the area revealed a narrow carbonate band which consists predominantly of *Globigerina*-rich silts, clays, and other biogenic material (*2, 3*).

The submarine topography of the area is shown in Fig. 1. The area is characterized by a broad shelf, a steep irregular slope, the Cascadia Abyssal Plain (*4*) previously described as "Great Trough" (*5, 6*), a north-south trending hilly area, and the east-west Mendocino Escarpment including the hilly area south of the Cascadia Abyssal Plain in the west. A detailed description of the topography has already been presented by Menard (*5*), Gibson (*6*), and Hurley (*4*), and additional data is provided by Nayudu and Enbysk (*3*).

The *Globigerina*-rich sediments in cores 1, 2, 3, 4, 8, 9, 10, 16, and 17 form a narrow band, approximately 160 km wide and about 560 km long, almost parallel to the coasts of Oregon and Washington, 480 km offshore (Fig. 2). The concentration of Foraminifera, both planktonic and benthonic forms, results in a total carbonate content of approximately 30 to 70 percent. Because of variations in the concentration of Foraminifera, these sediments have been designated as *Globigerina*-rich rather than as ooze. In all these samples *Globigerina*-rich sediments extend from the surface to the bottom of the core, reaching a maximum depth of 144 cm in core 16. However, the upper 7 to 12 cm of all these cores shows about a 30 percent decrease in Foraminifera content and a concomitant increase in olive-brown silts and clays. There is also a great increase in number and variety of Radiolaria and diatoms in the northern part of the band. The upper section (of variable thickness) of *Globigerina*-rich silts and clays has been considered as a significant stratigraphic unit. In core 1 the upper 12 cm contain a large amount of olive-brown silts and clays, Radiolaria and diatoms; this core is low in Foraminifera. This section grades into *Globigerina*-rich sediment which in turn changes at about 115 cm into a sediment with very few Foraminifera and without Radiolaria or diatoms (Fig. 3). In core 16, located in the Tufts Abyssal Plain at a depth of 2244 meters, the upper section is 8 cm thick and grades downward into *Globigerina*-rich sediments. At 68 cm the *Globigerina*-rich sediments change with a break into a dark gray silty clay low in Foraminifera (about 30 percent) which extends to 90 cm. From 90 to 104 cm there is a gradual increase in the concentration of Foraminifera (30 to 45 percent) and at 104 cm the sediments are very rich in *Globigerina* (Fig. 4).

Two radiocarbon assays of core 1 have been done. The location of the core and the depth and age of the sample are shown in Fig. 3. The sample (15 to 25 cm) below the low carbonate upper layer is about 12,400 ± 375 years old. Radiocarbon dating of the sample (90 to 100 cm) above the section poor in *Globigerina* indicates that it originated 19,300 ± 950 years ago. Three additional radiocarbon assays were made from core 16 (Fig. 4), which indicate an age of 15,500 ± 600 years for the sample at 10 to 20 cm; 21,950 ± 700 years at 50 to 60 cm; and 26,950 ± 1,000 years at 130 to 140 cm (bottom of the core).

Crandell, Mullineaux, and Waldron (*7*) have shown that the youngest glaciation in the Puget Sound Lowland, the Vashon (late Wisconsin) appears to be generally correlative with the maximum of the Wisconsin stage (Tazewell) of the central United States. Radiocarbon dates on peat that postdates the Vashon drift in the Puget Lowland suggest that the glacier recession uncovered the southern Puget Lowland (south of Seattle) at some time before 14,000 years ago (*8*). Easterbrook (*9*), after a detailed study of Pleistocene deposits and the radiocarbon dates, suggested that the Vashon glaciation in the northern part of the Puget Lowland occurred between 26,500 and 11,600 years ago.

The five determinations of radiocarbon age made on cores 1 and 16 (Figs. 3 and 4) indicate that the greatest deposition of *Globigerina*-rich sediments took place during the Vashon (late Wisconsin) glacial times, suggesting a definite relationship between the rate of accumulation of planktonic Foraminifera and glacial times; that is, during a period of colder climate there is a greater accumulation of planktonic Foraminifera in the area.

An important feature is the approximate parallelism between the carbonate band and the surface current distribution. When the subarctic current approaches the American coast it splits into the northward deflected Alaskan gyral and the southward deflected California current (*10*) which nearly parallels the *Globigerina*-rich sediments. The study of plankton tows by Smith (*11*) in this area shows that a greater concentration of planktonic Foraminifera nearly coincides with the bottom distribution of *Globigerina*-rich sediments as shown in Fig. 2. Smith further stated that one of the dominant species is the *Orbulina universa* which is abundant between 100 and 150 meters. He concluded that there is no direct correlation between the temperature, salinity, dissolved oxygen, or inorganic phosphate concentration and the distribution of a foraminiferal population. *Orbulina universa* occurs in greater numbers in the *Globigerina*-rich sediments (*12*), and it is one of the most persistent forms in the entire length of the core.

The close conformity of the carbonate sediments on the bottom with the surface current path of the equatorial current system was first indicated by Murray and Renard (*13*). They explained the relationship by assuming a higher production of Foraminifera in the counter currents. Arrhenius (*14*) described a higher rate of accumulation of calcium carbonate (Foraminifera and coccoliths) below parts of the equatorial current system during the Ice Age in the tropical Pacific. He explained the observation as being due to the phenomenon of the high production rate of phytoplankton at the surface of the ocean. This high rate

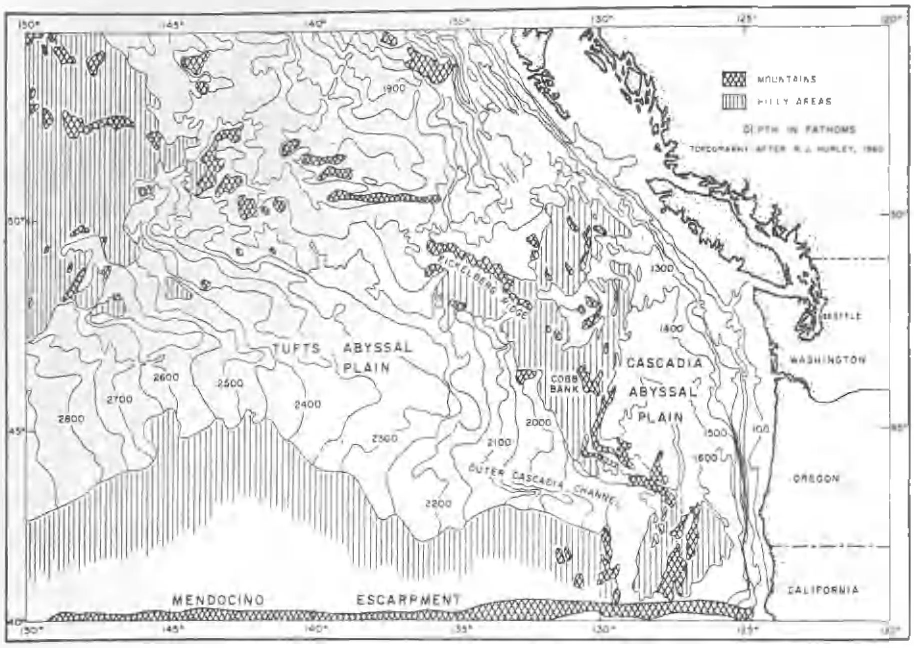
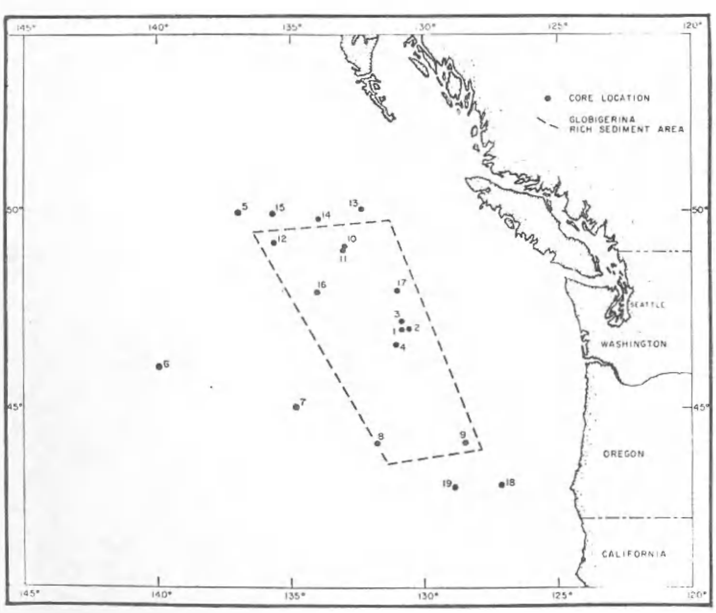
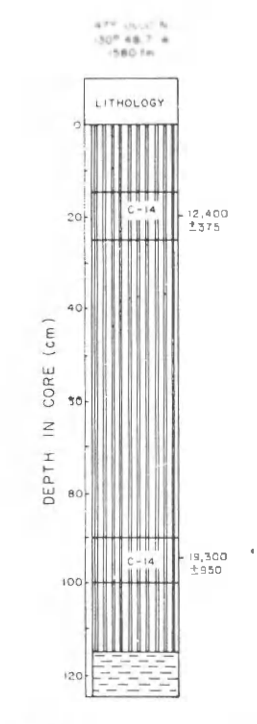


Fig. 1. Bathymetry of the area off the coasts of Oregon and Washington showing the major topographic features.

of production is believed to be due to an increased rate of upwelling in the divergence. He further postulated that the high rate of upwelling probably suggests greater intensity of atmospheric circulation in low and intermediate latitude during the Ice Age. From the isotopic measurements on Pleistocene planktonic Foraminifera, Emiliani (*15*) confirmed Arrhenius' interpretation of carbonate maxima as cold-water facies and the minima as warm-water facies. Nyberg (*16*) examined Arrhenius' theory of close association of the high rate of accumulation of calcium carbonate at the bottom of the sea and general atmospheric circulation and concluded that the existing meteorological facts do not contradict the theory. Schott (*17*), in discussing the carbonate deposits, suggested that in the Atlantic the sediments deposited during the glacial stages are low in calcium carbonate while those of interglacial or postglacial stages are high in calcium carbonate. He believed that during glacial stages the surface waters of the tropical Atlantic were cooled, and this resulted in a great reduction in the organic precipitation of calcium carbonate. At the same time the contribution of noncalcareous material from the continent to the sea floor greatly increased. On the other hand, Yalkovasky's study failed to reveal a direct correlation between temperature and carbonate concentration (*18*, *19*). Many aspects of this problem and the variety of controls of *Globigerina* accumulation were vigorously discussed by Wiseman, Emiliani, and Yalkovasky (*19*).

I believe that there were no significant changes either in topography or oceanographic conditions in the area of study during the deposition of *Globigerina*-rich sediments from approximately 27,000 to 11,000 (?) years ago. Hence, I conclude it is likely that the greater accumulation of *Globigerina*-rich sediments is due to increased production brought about by intensified atmospheric and oceanic circulation, which brought up nutrient-rich deep water to the surface during Vashon glacial times. Consequently there was





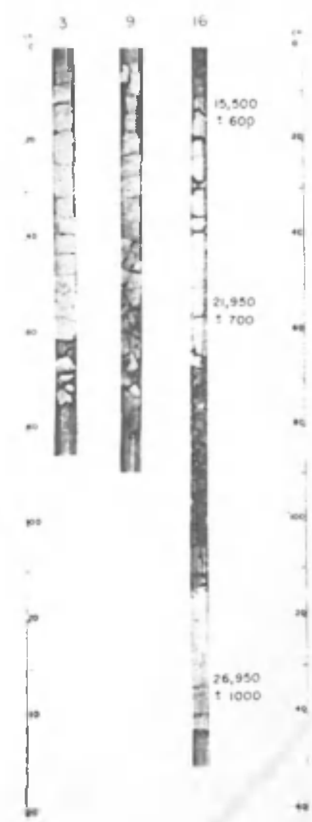


Fig. 2 (top left). Locations of cores and boundary of *Globigerina*-rich sediments. Fig. 3 (middle). Lithology of core 1 and carbon-14 dates. Fig. 4 (right). Cores showing the nature of *Globigerina*-rich sediments and carbon-14 dates for core 16.

greater production of Foraminifera. The lack of diluting terrigenous material may also have been a contributing factor. The results appear to confirm Arrhenius' hypothesis (*14*).

If we assume that the final withdrawal of the Vashon Ice in the Puget Lowland occurred between 14,000 and 11,600 years ago, then the radiocarbon dates of 12,400 ± 375 years for core 1 (15 to 25 cm) and 15,500 ± 600 years for core 16 (10 to 20 cm), taking into consideration the differences in the sample interval and possible margin of error and location, are in close agreement and can be correlated. These dates suggest that the upper section of variable thickness (7 to 12 cm) low in Foraminifera content, greater amounts of olive-gray silt and clay containing Radiolaria and diatoms (in the northern part of the band), may be due to the gradual return of present-day conditions and can be considered to represent postglacial times. The occurrence of sediments low in *Globigerina* at 115 cm in core 1 (Fig. 3) and from 68 to 104 cm in core 16 (Fig. 4) are correlated because radiocarbon dates of the samples taken above these intervals are nearly the same. These intervals may represent a short time of retreat or fluctuation and wasting of glaciers. It appears from the radiocarbon dates that section 68 to 104 cm in core 16 (Fig. 4) may be related to the "Farmdalian" (*20*).

From the five radiocarbon age determinations for cores 1 and 16 (Figs. 3 and 4) the inferred average rates of sedimentation for the *Globigerina*-rich sediments in this area are (i) less than 2 cm per 1000 years for the upper section in all cores representing postglacial times, and (ii) 10 cm per 1000 years for the section representing Vashon glacial times.

Y. R. NAYUDU*

Scripps Institution of Oceanography, University of California, San Diego, La Jolla

References and Notes

1. R. Revelle, *Carnegie Inst. Wash. Publ.* **556**, 1, 2 (1944); H. W. Menard, *Bull. Geol. Soc. Am.* **64**, 1279 (1953).
2. Y. R. Nayudu, *Bull. Geol. Soc. Am.* **69**, 1697 (abstract) (1958); *International Oceanographic Congress 1959, Preprints*, M. Sears, Ed. (AAAS, Washington, D.C., 1959), p. 477; thesis, Univ. of Washington (1959).
3. Y. R. Nayudu and B. J. Enbysk, *Sedimentology*, in press.
4. R. J. Hurley, *Scripps Inst. Oceanog. Marine Phys. Lab. Ref. 60-7* (1960), p. 105.
5. H. W. Menard, *Bull. Am. Assoc. Petrol. Geologists* **39**, 236 (1955).
6. W. M. Gibson, *Bull. Geol. Soc. Am.* **71**, 7, 1087 (1960).
7. D. R. Crandel, D. R. Mullineaux, H. H. Waldron, *Am. J. Sci.* **256**, 384 (1958).
8. G. B. Rigg and H. R. Gould, *ibid.* **255**, 341 (1957).
9. D. J. Easterbrook, paper presented to Geol. Soc. Am. Cordilleran Section, 58th Annual Meeting, Special Paper No. 73 (1962), p. 37.
10. R. H. Fleming, *Intern. North Pacific Fisheries Comm. Bull. No. 2* (1955).
11. A. B. Smith, *Contr. Cushman Found. Foram. Res.* **14** (pt. 1), 1 (1963).
12. T. B. Budinger and B. J. Enbysk, *Univ. of Washington, Dept. of Oceanog., Tech. Rept. No. 60* (1960).
13. J. Murray and A. F. Renard, *Rept. Challenger Exped.*, London (1891).
14. G. S. Arrhenius, *Swedish Deep-Sea Exped. Rept.* **5**, 1 (1952).
15. C. Emiliani, *J. Geol.* **63**, 538 (1955).
16. A. Nyberg, *Swedish Deep-Sea Exped. Rept.* **5** (fasc. II), 237 (1956).
17. W. Schott, *Soc. Econ. Paleontologists Mineralogists, Spec. Publ. No. 4* (1939), p. 409.
18. R. Yalkovasky, *J. Geol.* **65**, 480 (1957).
19. J. D. H. Wiseman, E. Emiliani, R. Yalkovasky, *ibid.* **67**, 572 (discussion) (1959).
20. J. C. Frye and H. B. Willman, *Illinois State Geol. Surv. Circ. No. 285* (1960).
21. I thank F. P. Shepard for valuable suggestions and critical reading of the manuscript. I also thank the Humble Oil Company Exploration Department and George S. Bien, Scripps Institution of Oceanography, for the radiocarbon assays, and D. R. Doyle for preparing the illustrations. This investigation was supported in part by ONR contract Nonr-477(10), project NR 083 012, and by NSF grants G-9407 and G-21518. Contribution No. 302 of the Department of Oceanography, University of Washington.
* Present address: Department of Oceanography, University of Washington, Seattle 5.

4 August 1964