aluminum coatings are in good condition.

High-speed Polaroid Polascope 410 and Polaroid Land type 57 film were chosen for the experiment because of their sensitivity, convenience, and speed of development. Polascope 410 film required about 200 times longer exposure than the same film used with the help of ZnS intensifier.

Figure 2 shows typical autoradiographs obtained with standard NTA or NTB film as compared with autoradiographs of the same material using amplification and photographic film. The specimen was obtained from a rat injected intravenously with $^{239}Pu$. Sections of femur 10 microns thick were attached to glass slides with double-coated cellophane tape, and the phosphor (13 mg/cm$^2$) on aluminum-coated Mylar film was sandwiched between the photographic film and the sections for exposure. The quality of the high-speed gross autoradiographs produced with the aide of ZnS is close to that obtained with standard emulsion, and the exposure time needed is sharply reduced.

Using the same intensifier technique to locate a sliver of plutonium in excised human skin required an exposure time of less than a minute. Even a trace of plutonium rubbed off as a sliver penetrates would be adequate to identify location if deeper penetration occurred. The very short time required for exposure and the ease of development suggest that this technique might have application during surgical probing to remove imbedded slivers of Pu or other alpha emitters. Likewise, this technique has shown some promise in examining plates of $^{239}Pu$ prepared from urine samples and used in routine bioassay. Because of its speed and convenience, this new technique of autoradiography may find other areas of application.

JACK J. C. HSIEH
F. P. HUNGATE
S. A. WILSON
*Biology Department, Pacific Northwest Laboratory, Battelle Memorial Institute, Richland, Washington*

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18 November 1965

## Ice-Rafted Detritus as a Climatic Indicator in Antarctic Deep-Sea Cores

Abstract. *Ice-rafted detritus is readily identified in sediment cores raised from the deep ocean floor around Antarctica. A few cores have reached a depth below which no ice-rafted material is found. This depth is interpreted as indicating the establishment of earliest Pleistocene glaciation in the Southern Hemisphere. It is just below a depth where there is a change in assemblages of Radiolaria which Hays associates with the Pliocene-Pleistocene boundary. The presence of ice-rafted material throughout the upper zone in cores taken south of the Polar Front indicates continuity of glaciation in Antarctica. Further north, near 45°S in the Argentine Basin, zonation of the ice-rafted detritus can be used to delineate glacial stages of the Pleistocene.*

It is well known that there is a wide zone (320 to 960 km wide) of ice-rafted or glacial marine sediments on the sea floor surrounding Antarctica (*1*). Lizitzin's description (*2*) of the sediments that cover the continental shelf and slope and extend into the adjacent oceanic areas around Antarctica indicates that most ice-borne sediment is released south of 40° to 50°S. The glacial marine sediments intergrade with a zone of diatom ooze (up to 1300 km wide) whose northern boundary is slightly north of the Antarctic Polar Front. North of the zone of diatom ooze the pelagic sediments are generally calcareous ooze in depths less than 4100 to 4700 m and red clays in greater depths. Hays has summarized the literature on these sediments (*3*); the zones shown in Fig. 1 are based on his work (*4*).

Hays studied cores raised in a program of sediment-coring in high southern latitudes that was undertaken by Lamont Geological Observatory in 1956. The purpose of the program was to compare the history of Pleistocene glaciation in the Southern and Northern Hemispheres.

Several sediment cores from south of the Polar Front show a marked depositional change from red clay to overlying diatom ooze. Hays showed (*3*) that this change correlates with a horizon marking the extinction of Tertiary Radiolaria and that it is related to the transition in Foraminifera and *Discoaster* which has been studied in other deep-sea cores in connection with the problem of the Pliocene-Pleistocene boundary (*4*, *5*).

The sand fraction from five of the cores used by Hays (Fig. 1, Table 1) has been examined at intervals of 20 to 30 cm down the cores, and the occurrence and abundance of ice-rafted detritus have been estimated (Fig. 2*A*). Three of the cores (V16-59, V16-116, and V16-132) consist of 5 to 9 m of diatom ooze which overlies red clay. The fourth, V17-88, was taken north of the Polar Front near Tierra del Fuego; it has gray lutite overlying red clay. In three of these cores the boundary between ooze and red clay is gradational, but in the remaining core of diatom ooze (V16-116) this boundary is sharp (Fig. 2*A*). The fifth core consists of 11 m of foraminiferal ooze and foraminiferal clay. It also was raised from north of the Polar Front.

The diatom oozes contain 2 to 10 percent sand but the red clay generally contains less than 1 percent. The percentage of sand-size material in the core of foraminiferal ooze decreases from 50 percent at the top to 20 percent at the bottom of the core. The sand-size sediment in the oozes consists mainly of tests of radiolarians or foraminiferans mixed with ice-rafted and volcanic detritus. The ice-rafted detritus is easily identified, being poorly sorted, angular, and consisting of quartz, feldspar, garnet, and fragments of granitic, sedimentary, and metamorphic rocks of all sizes, from very fine sand to pebbles as large as the diameter of the coring tube (64 mm). The ice-rafted material is mixed with pumice, lapilli, glass shards, fresh plagioclase, and volcanic rock fragments that presumably are derived from local volcanoes (*2*).

The amount of ice-rafted sand and pebbles varies from just a few grains per gram of sediment to 50 percent of the total sand fraction. Thin sections of the sand fraction from core V16-132 consist essentially of 20 to 40 percent quartz, 20 to 30 percent potassic feldspar, plagioclase, granitic

and gneissic rock fragments, and a mixture of other metamorphic, sedimentary, and volcanic rocks.

Ice-rafted detritus is present in the diatom and foraminiferal ooze and gray lutite in all five cores but is far less abundant, or absent, within the red clay zone. The sand fraction in the red clay zone consists mostly of micronodules of manganese, with some radiolarians, sponge spicules, fish teeth, and minor amounts of fine-grained mineral and rock fragments.

In the cores from south of the Polar Front, the Pliocene-Pleistocene boundary, to judge from the radiolarians (*3*), occurs at the junction of diatom ooze and the top of the transition zone between diatom ooze and red clay. Ice-rafted detritus first occurs close to the base or at the base of this transition zone (Fig. 2*A*). The transition zone can be recognized easily, for there are a gradual decrease in the number of manganese micronodules and a gradual increase in the number of diatoms and radiolarians from the base to the top of the zone.

In core V16-116, diatom ooze directly overlies red clay that is barren of ice-rafted detritus but contains radiolarians which indicate that sediment of upper Pliocene age is missing (*4*). Hence, in core V16-116 the boundary between diatom ooze and red clay is unconformable and does not include the transition as it occurs in the other three cores of diatom ooze and gray silt.

In core V16-66, taken north of the Polar Front, the Pliocene-Pleistocene boundary was originally placed at a depth of 270 cm on the basis of foraminifers and discoasters by Ericson *et al.* (*5*) but described as very transitional. However, Ericson *et al.* noted that ice-rafted detritus first occurred at a depth of 850 cm and that the frequency curve of *Globigerina pachyderma* indicated a gradual cooling from 800 cm. Hays (*3*, *4*) found that the change in Radiolaria which was associated with the red clay-diatomite contact in cores taken south of the Polar Front occurred at 720 cm in core V16-66. Ice-rafted detritus was identified in our study of this core in all samples from above 900 cm (Fig. 2*A*). Glacial surface textures on ice-rafted quartz grains in this core have been described by Krinsley and Newman (*6*).

Cores raised from the oceanic rise in the Argentine Basin contain pollen and diatom assemblages that can be grouped in zones that delineate cold and warm climatic phases in the Pleistocene (*7*). Three of these cores (Fig. 1) were selected for our study, and the abundance of grains with a probable ice-rafted origin was estimated for the sand fraction at intervals down the cores (Fig. 2*B*). The cores consist of 20 to 40 cm of brownish-gray, silty clay overlying about 10 m of olive-gray and grayish-olive, silty clays and clayey silts.

Table 1. Location and depth of deep-sea cores.

| Core No. | Latitude and longitude | Water depth (m) |
|---|---|---|
| | *Antarctic* | |
| V17-88 | 57°01.5′S,74°29′W | 4064 |
| V16-59 | 50°03′S,35°11′E | 4868 |
| V16-66 | 42°39′S,45°40′E | 2985 |
| V16-116 | 55°05.5′S,147°29′E | 3296 |
| V16-132 | 60°44.5′S,107°29′W | 4898 |
| | *Oceanic rise, Argentine Basin* | |
| V17-121 | 43°58′S,52°09′W | 5786 |
| V15-142 | 44°53.7′S,51°32′W | 5885 |
| V17-126 | 47°35′S,43°21′W | 5497 |

The sand-size fraction generally comprises less than 5 percent of the core; most of the sand is very fine-grained and angular, consisting mainly of plagioclase, quartz, glass shards, and volcanic rock fragments with varying amounts of radiolarians and diatoms. In zones down the cores, angular grains, ranging in size from 200 to 1000 $\mu$, of quartz, orthoclase, microcline, perthite, garnet, and granitic, sedimentary, and metamorphic rock fragments make up less than 5 percent of the sand fraction. Their composition and their occurrence in pelagic or hemipelagic sediment far from land suggest that they were probably dropped from melting icebergs derived from Antarctica or South America. Ice-rafted rocks of similar petrological affinities were trawled from the Atlantic Ocean off the Cape of Good Hope and described by Needham (*8*) as probably originating in Antarctica or South America. Grains of probable ice-rafted origin are missing from some sections of the cores, whereas they are quite abundant in other sections (Fig. 2*B*) and occur in zones in the cores. Using pollen and diatom assemblages, Groot

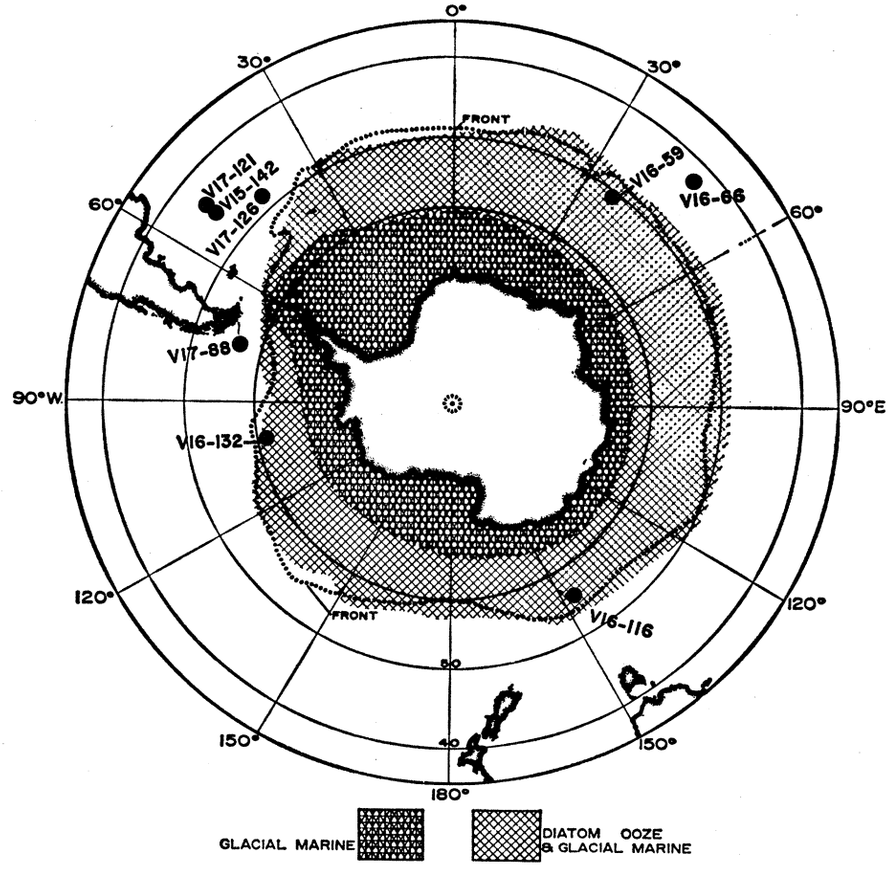


Fig. 1. Location of cores taken in the deep-sea floor off Antarctica and in the oceanic rise in the Argentine Basin. The Polar Front and the principal sedimentary zones are also shown.

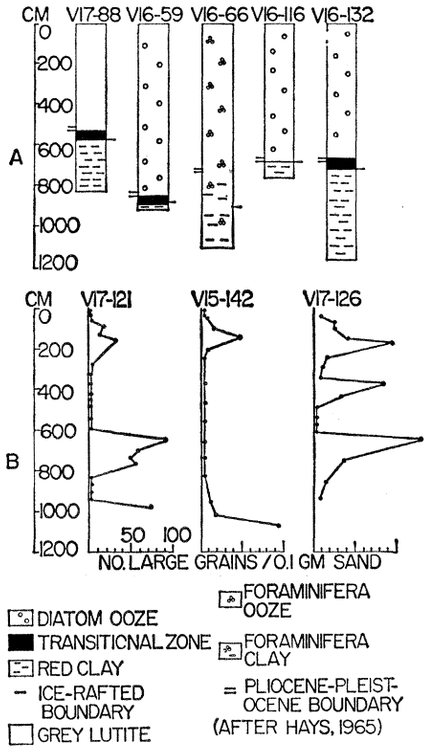


Fig. 2. *A*, Lithology of five cores from the deep-sea floor off Antarctica showing the position of the Pliocene-Pleistocene boundary, based on studies of radiolarians (*4*) and on the first appearance of ice-rafted grains. *B*, Variation of the number of large ice-rafted grains with depth in three cores from the oceanic rise in the Argentine Basin.

*et al.* (*7*) show that the uppermost brownish-gray zone was probably deposited during the Holocene and that the cores penetrate two to three major cold climatic periods in the Pleistocene, with a probable sedimentation rate of 2 to 5 cm per 1000 years. The zones containing assemblages associated by Groot *et al.* with glacial stages correspond very closely to the zones containing ice-rafted grains shown in Fig. 2*B*.

The results suggest that the distribution of easily recognizable, ice-rafted grains in deep-sea cores from areas around 40° to 50°S latitude can be effectively used to subdivide the Pleistocene into glacial and interglacial climatic phases, as was shown for comparable latitudes in the North Atlantic (*9*), and that the initiation of ice-rafting as evidenced in deep-sea sediments in high temperate latitudes probably is a good indicator of the initiation of the Pleistocene glaciation. Cores from south of the Polar Front contain ice-rafted material continuously after first appearance, indicating continuity of glacial conditions on Antarctica. This indicator of glacial conditions provides an independent check on the climatic interpretation of fossil fauna and flora, as demonstrated in the North Atlantic, where excellent correlation has been established by us (*10*) between zones assigned to glacial stages on the faunal evidence of Ericson *et al.* (*11*) and zones containing high concentrations of ice-rafted particles.

JOHN R. CONOLLY
MAURICE EWING
*Lamont Geological Observatory,*
*Columbia University,*
*Palisades, New York*

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28 September 1965

## Electrophoresis of Hemoglobin in Single Erythrocytes

Abstract. *A technique for electrophoretic analysis of the hemoglobin mixtures from single erythrocytes has been developed. Hemoglobin mixtures were separated into their constituents, $A_2$, A, C, S, and J, at least qualitatively.*

Attempts have been made to isolate and fractionate genetically different hemoglobin mixtures from single cells. By the use of microspectrophotometric techniques, hemoglobin F can be separated from hemoglobin A, and these two fractions can be accurately determined (*1*). Unfortunately other hemoglobins, including $A_2$, S, C, and J, which are present in single cells in normal or pathologic conditions cannot be detected by these methods. The problem of measuring the products of single-gene activity in single cells has become more important as a way of answering questions related to genetic expressions in various phases of cell differentiation and of solving problems concerning the mechanism of the transformation from hemoglobin F to hemoglobin A during the passage from fetal to adult life. Since the heterogeneity of cell preparations so far obtainable forbids this analysis on a large scale, the analysis on single cells is mandatory.

Since electrophoresis is widely used for fractionation of various hemoglobin fractions, mainly because of differences in electric charge, the customary techniques of electrophoresis have been adapted for use with very small (picogram, $10^{-12}$ g) quantities in order to analyze hemoglobin mixtures. An electrophoresis method for picogram quantities has been developed by Edström (*2*) for the analysis of RNA–DNA bases of single cells. Our attempts to use Edström's technique for the hemoglobin separation, however, failed because of difficulty in placing single cells on the cellulose fiber, which he used as a supporting medium, and because hemoglobin $A_2$ was undistinguishable from hemoglobin A in those few occasions where an electrophoretic run was obtained. We now describe an apparatus and results for electrophoretic analysis of the hemoglobin from single erythrocytes with polyacrylamide gel as a supporting medium. The degree of separation of various hemoglobin fractions compares favorably with the separation obtained by polyacrylamide electrophoresis on a large scale.

The electrophoresis was conducted under direct microscopic observation in a special chamber. This chamber was made from a normal glass slide with glass tubes (2.5 cm in length, 0.9 cm inside diameter, 1.2 cm outside diameter) glued on its surface, 5.5 cm apart. There was at the base of each tube a semicircular opening which faced the middle of the slide. The tubes were filled to one-fourth of their volume with 1 percent agarose (Calbiochem) solution in a buffer (0.03*M*, *p*H 8.5) composed of glycine (ammonia free) and HCl-tris. The agarose was connected through the semi-circular openings with a layer (1.5 mm thick) of 1 percent agarose solution, in the same buffer, which covers the slide surface between the tubes. After complete gelation of the agarose a slot (0.7 cm wide) was cut perpendicularly