oceanic basement off northwest Australia is some of the oldest yet found and approaches the age found in the western North Atlantic (*13*).

JAMES R. HEIRTZLER
Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543
JOHN V. VEEVERS
MacQuarie University, Sydney, Australia
HANS M. BOLLI
Eidgenössische Technische Hochschule, Zurich, Switzerland
ALAN N. CARTER
University of New South Wales, Sydney, Australia
PETER J. COOK
Bureau of Mineral Resources, Canberra, Australia
VALERI A. KRASHENINNIKOV
Academy of Sciences of the U.S.S.R., Moscow
BRIAN K. MCKNIGHT
University of Wisconsin, Oshkosh 54901
FRANCA PROTO-DECIMA
University of Padua, Padua, Italy
G. W. RENZ
Scripps Institution of Oceanography, La Jolla, California 92037
PAUL T. ROBINSON
University of California, Riverside 92502
KARL ROCKER, JR.
Naval Civil Engineering Laboratory, Port Hueneme, California 93041
PAUL A. THAYER
University of North Carolina, Wilmington 28401

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5. The Deep Sea Drilling Project is a joint project of five oceanographic institutions in the United States and is funded by the National Science Foundation. Its purpose is to drill deep holes in the sea floor for geological research.
6. R. S. Dietz and J. C. Holden, *Nature* **229**, 309 (1971). On leg 11 in the western North Atlantic the oceanic basement was found to be Oxfordian (Late Jurassic) [C. D. Hollister, J. I. Ewing, *et al.*, *Initial Reports of the Deep Sea Drilling Project* (Government Printing Office, Washington, D.C., 1972), vol. 11]. This Atlantic material, about 155 million years old, is the oldest found to date in the oceans.
7. J. J. Veevers *et al.*, *Geotimes*, in press; in leg 27 initial report, in preparation.
8. A fifth hole was drilled in the Timor Trough, which is underlain by continental crust.
9. C. von der Borch *et al.*, *Geotimes* (June 1972), p. 15; in leg 22 initial report, in preparation. On leg 26 holes were drilled in the eastern Indian Ocean, but the results have not yet been published.
10. The edge of the Australian continental block includes the Naturaliste Plateau [T. J. G. Francis and R. W. Raitt, *J. Geophys. Res.* **72**, 3015 (1967)], the Exmouth Plateau, and the Sahul Shelf [J. J. Veevers, *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **6**, 125 (1969)], which extends from Timor to the northwestern Australian coastline.
11. Australia was attached to Antarctica until about 55 million years ago, at which time it started moving north and away from Antarctica.
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13. Further preliminary examination of various microfossils by F. Proto-Decima (University of Padua), J. Remane (University of Neuchâtel), H. Thierstein (Eidgenössische Technische Hochschule, Zurich), V. Schreibnerova (New South Wales Geological Survey, Sydney), and J. Wiseman (West Australian Petroleum, Perth) shows the age of the oldest sediment to be about 115 to 120 million years at site 260, 150 million years at site 261, and 110 to 115 million years at site 263. These results do not alter the general conclusions of this report but indicate that the initial opening of the Indian Ocean was about 150 million instead of 140 million years ago.
14. We would like to thank Captain J. A. Clarke, Master of *Glomar Challenger*, and the ship's crew; J. A. Ruddell, Drilling Superintendent, and his crew; C. A. Morris, Operations Manager; T. B. Gustafson; all the Deep Sea Drilling technical staff; and Dr. N. T. Edgar, Chief Scientist of the Deep Sea Drilling Project for considerable assistance. We also wish to thank the Bureau of Mineral Resources (Australia), Lamont-Doherty Geological Observatory of Columbia University, and the University of New South Wales for supplying seismic data prior to drilling. Contribution No. 2966 of the Woods Hole Oceanographic Institution.

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Laser Transit-Time Measurements between the Earth and the Moon with a Transportable System

Abstract. *A high-radiance, pulsed laser system with a transportable transmitting unit was used at Agassiz Station, Harvard College Observatory, Harvard, Massachusetts, to measure the transit times of 25-nanosecond, 10-joule, 530-nanometer pulses from the earth to the Apollo 15 retroreflector on the moon and back.*

On 23 September 1972, the transit time of a laser pulse from the earth to the moon and back was measured six times at Agassiz Station, Harvard College Observatory, Harvard, Massachusetts. The laser pulse was directed to the Apollo 15 retroreflector on the moon by a transportable transmitting unit located 237 m from the 1.5-m telescope used to detect the returning pulse. All six transit times were measured with a combination of delay circuits and a fast oscilloscope. Three of these returns, which were stronger than the rest, were also measured more precisely with a time-interval counter.

Residuals for all the measured transit times were calculated from a special ephemeris at the University of Texas (*1*). These residuals (observed values minus the computed values) tended to increase with epoch (time of transmission of the laser pulse) over the period from $6^h\ 36^m$ to $8^h\ 12^m$ universal time during which they were obtained.

The best-fitting straight line through the residuals from the counter readings had a slope of $+0.35$ nsec/min with a standard deviation of 3.1 nsec. The best line through the residuals of the six oscilloscope readings had a slope of $+0.18$ nsec/min with a standard deviation of 2.5 nsec. The differences in the results from the two sets of data are not significant.

The slope of the straight line through the residuals is related to the error in the station's geocentric coordinates. If one assumes the error to be entirely in latitude, the local hour angle of these observations implies that a slope of 1 nsec/min corresponds to 1 arc sec, or 23 m at the station's 42.5° latitude. Hence, the slopes are consistent, with an error of about 15 m expected in the conversion of the station's coordinates from the North American Datum to a geocentric system.

The configuration of the transportable laser system, which can be used with other large telescopes, has been described elsewhere (*2*). The exceptionally high radiance of the system's neodymium-glass laser permits the use of a transmitting telescope, the diameter of whose aperture is only 0.2 m. It also increases the probability that each return generates at least one photoelectron. The system's pulse repetition rate is 0.2 per minute. A further report on its operation will be presented elsewhere (*3*).

C. G. LEHR
S. J. CRISWELL
J. P. OUELLETTE, P. W. SOZANSKI
Smithsonian Astrophysical Observatory, Cambridge, Massachusetts 02138
J. D. MULHOLLAND, P. J. SHELUS
Department of Astronomy, University of Texas, Austin 78712

References and Notes

1. This ephemeris, not yet described in the literature, is a numerical integration fitted to both optical and laser data. It was developed by J. D. Mulholland and P. L. Bender (Joint Institute for Laboratory Astrophysics) as a part of the Apollo Lunar-Laser Ranging Experiment.
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Inorganic Nitrogen Removal from Wastewater: Effect on Phytoplankton Growth in Coastal Marine Waters

Abstract. *Algal bioassays were used to demonstrate the high efficiency of a combined tertiary wastewater treatment and marine aquaculture system in removing inorganic nitrogen, and to show that the coastal waters off Woods Hole, Massachusetts, are limited in nitrogen for marine phytoplankton growth. When nutrients were removed from secondarily treated domestic wastewater through assimilation by phytoplankton in an outdoor growth pond, the pond effluent, in varying dilutions with seawater, could not support more phytoplankton growth than the seawater alone. However, when nitrogen was added back to the mixtures of pond effluent and seawater, the phytoplankton growth response was similar to that with a mixture of wastewater and seawater. This is similar to the findings of other researchers, and suggests that nitrogen may be the key growth-limiting nutrient in many coastal marine waters. The combined tertiary treatment–marine aquaculture system appears to be an effective means of removing nitrogen from secondarily treated wastewater and controlling eutrophication of coastal marine waters.*

There is increasing evidence that nitrogen is the phytoplankton growth-limiting nutrient in many coastal and estuarine waters (*1*, *2*). This is in contrast to the traditional view that phosphorus is often the growth-limiting nutrient in aquatic environments (*3*). As a result, considerable emphasis is curently being placed on finding ways to remove nitrogen from wastewaters in order to control and prevent further eutrophication of aquatic systems (*4*).

A novel approach to this problem, described by Ryther *et al.* (*5*), and one we are currently studying, involves combining a nutrient removal system with a marine aquaculture. In this combined system, nutrients (mainly nitrogen) are first removed from secondarily treated domestic wastewater (diluted with four parts of seawater) through assimilation by marine phytoplankton in an experimentally controlled outdoor growth pond. The phytoplankton, in turn, are removed from the system by filter-feeding herbivores such as oysters, clams, and mussels, all economically important shellfish. Any soluble inorganic nitrogen remaining in the wastewater, or regenerated by the herbivores, is removed by passage through a seaweed growth system. Details of the treatment process, and actual nitrogen removal efficiencies, will be reported elsewhere (*6*).

To demonstrate the high efficiency of the process in removing inorganic nitrogen, and to show that nitrogen was the growth-limiting nutrient in the coastal waters off Woods Hole, Massachusetts, at the time of our study, we have conducted a series of algal bioassays on samples from various components of the system.

In the bioassay reported here we compared the "algal growth potential" (*7*) of the influent and effluent samples from the phytoplankton growth system. Influent samples consisted of treated wastewater from the secondary wastewater treatment facility at Otis Air Force Base (Cape Cod, Massachusetts), diluted with four parts of seawater, and effluent samples consisted of the filtrate from the growth pond culture (Table 1). The pond influent and effluent samples were passed through Millipore filters (0.45 μm) and diluted with filtered seawater to simulate the actual dilutions that might occur when wastewaters are discharged in coastal waters. The dilutions used were 2 percent treated wastewater and 1 and 5 percent growth pond effluents. These samples (125 ml) and a seawater control sample were added to 250-ml flasks. We also enriched half of the 1 and 5 percent pond effluent samples with additional inorganic nitrogen as NH_4Cl. These samples then contained the same quantity of inorganic nitrogen that would be present if secondarily treated wastewater was used in place of the pond effluent at the designated dilutions with seawater. All samples (four replicates each) were inoculated with approximately 3500 cell/ml of a phytoplankton mixture (mainly the diatom *Chaetoceros simplex*) that had been taken the previous day from the growth pond. The flasks were incubated for 6 days at 22°C under fluorescent lighting ($\sim$ 5500 lumen/m^2), and in vivo chlorophyll measurements were made daily on a Turner model 111 fluorometer. The averaged results are reported as relative percentage values of the maximum seawater control value (Fig. 1).

The addition of filtered pond effluent to seawater had no effect over that of the seawater control in stimulating phytoplankton growth. The total inorganic nitrogen concentration ($\Sigma N = NH_4{}^+\text{-N} + NO_2{}^-\text{-N} + NO_3{}^-\text{-N}$) of the pond effluent was 5.13 μg-atom/liter. When the pond effluent was mixed with Woods Hole seawater ($\Sigma N = 2.38$ μg-atom/liter) at the designated dilutions, the nitrogen concentrations of the mixtures were virtually the same as that of the seawater alone.

Phosphate removal in the growth system was not nearly as complete as nitrogen removal because there was a gross excess of phosphorus over nitrogen in the secondarily treated wastewater used in this study, relative to that normally required by phytoplankton. This situation appears typical. For example, Ryther and Dunstan (*1*) pointed out that the nitrogen/phosphorus ratio in coastal marine waters, and in secondarily treated wastewater, is usually lower than in marine phytoplankton. Thus, more phosphorus is available in treated wastewater than can be utilized by the phytoplankton. In our study only 35 percent of the inorganic phosphorus was removed in the growth pond, so that the final phosphorus concentration in the pond effluent was 18.36 μg-atom/liter. Thus, the phosphate concentration of the samples increased significantly as more pond effluent was added to the seawater.