of 2.3 m/sec and a wavelength of 3200 km.

At one station Düing *et al.* noted that the disturbance occurred 3 to 4 days later at the surface than at a depth of 100 m. We also see this effect in comparing the electric field to the current meter data. Table 1 shows that the electric field, which represents the east-west transport averaged over the bottom 1000 m, lags the water current at meter 3, 10 m from the bottom, by 2.8 days and leads the current at meter 2 by 0.3 day, although the electric field recorder was located next to meter 3. However, the statistics of lag determinations are poor. Long observations from a larger array are needed to verify such a curious effect.

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References and Notes

1. W. H. Quinn, *J. Appl. Meteorol.* **13**, 825 (1974).
2. K. Wyrtki, E. Stroup, W. Patzert, R. Williams, W. Quinn, *Science* **191**, 343 (1976).
3. W. B. White and J. P. McCreary, *J. Phys. Oceanogr.* **4**, 295 (1974).
4. J. S. Godfrey, *ibid.* **5**, 399 (1975).
5. J. P. McCreary, *ibid.*, in press.
6. R. H. Hurburt, J. C. Kindle, J. J. O'Brien, *ibid.*, in press.
7. M. J. Lighthill, *Philos. Trans. R. Soc. Lond. Ser. A* **265**, 45 (1969).
8. The work of G. Philander and of J. Meinke is discussed in (*11*).
9. M. Sessions, *Exposure* **3**, 1 (1975).
10. R. R. Harvey, *J. Geophys. Res.* **79**, 4512 (1974).
11. W. Düing, P. Hisard, E. Katz, J. Meinke, L. Miller, K. V. Morashkin, G. Philander, A. A. Ribnikov, K. Voigt, R. Weisberg, *Nature (London)* **257**, 280 (1975).
12. We want to thank K. Wyrtki for his permission to make the measurements during the El Niño expedition and Admiral A. Arana and the scientists and workers of the Instituto del Mar del Peru, without whose aid the instruments could not have been recovered. This research was sponsored by the Office of Naval Research under contract ONR 0014-70-A-0016-0001-AA, the National Oceanic and Atmospheric Administration under contract NOAA 05-6-022-51022, and the North Pacific Experiment (NORPAX). Hawaii Institute of Geophysics contribution No. 774.

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Inositol Isomers: Occurrence in Marine Sediments

Abstract. *A combined gas chromatographic–mass spectrometric technique was used to identify and quantitate the occurrence of* myo-, chiro-, *and* scyllo-*inositol in marine sediments. The most abundant isomer was* myo-*inositol. These inositols were found in all the organic-rich sediment samples examined, and the amount of inositol decreased steadily with the age of the sample. A small fraction of the inositols occurred as hexaphosphate esters.*

The inositols, the isomers of hexahydroxycyclohexane, occur in all higher organisms and most microorganisms (*1*). Of the nine possible stereoisomers, *myo*-inositol is generally the most abundant although *scyllo*-inositol may be the most abundant in sharks (*2*) and a certain red alga (*3*). The hexaphosphates of inositol, known as phytic acids, are also abundant, and up to 90 percent of the phosphate in some seeds and grain is in the form of phytic acids (*4*). As far as we know, free inositols have not been looked for in soils; however, complex mixtures of penta- and hexaphosphates (the isomers of *myo*-, D-*chiro*-, L-*chiro*-, *scyllo*-, *muco*-, and *neo*-inositol) have been found in soils (*5*, *6*), and unspecified phytic acid isomers have been found in lake water (*7*), where up to 50 percent of the total phosphorus is in the form of inositol phosphates (*7*, *8*). We report here the presence of three inositol isomers in marine sediments and show that a small portion of the inositols is in the form of phosphate esters.

Our analysis is based on the stability of inositols to hot HCl hydrolysis; under this treatment most other organic compounds including carbohydrates give insoluble, ionic, or volatile compounds (*9*). After filtration or centrifugation, the inositols are separated from the ionic species by ion-exchange columns which do not retain the inositols (*10*). Thus, 1- to 2-g (wet weight) samples of sediment (*11*) were hydrolyzed with $6N$ hydrochloric acid at 110°C for 48 hours. The insoluble material was removed by centrifugation and washed twice with water. The combined extracts were evaporated to dryness, dissolved in a minimal volume of water, and then applied to a double bed column of Dowex 50WX8 (H^+) and Dowex 2X10 (OH^-). After drying, the desalted eluent was silylated by treatment with a mixture of pyridine, hexamethyldisilazane, and trimethylchlorosilane (9 : 3 : 1) for 24 hours at room temperature.

The resulting silylated mixture was then examined directly by gas chromatography–mass spectrometry (GC-MS) (*12*). The trimethylsilyl (TMS) ethers of the nine stereoisomers separated on the column to give eight peaks (the enantiomers of *chiro*-inositol give only one peak) (*13*). The TMS ethers are excellent derivatives for the identification of the isomers of inositol since each TMS isomer produces a unique mass spectrum. The isomers yield identical ions, but the fragment intensities vary remarkably for stereoisomers (*14*).

The marine sediments assayed (Table 1) yielded only three major GC peaks, *myo*-, *chiro*-, and *scyllo*-inositol. The identifications are based on the mass spectra and GC retention times and on the results of coinjection with known inositol isomers. The quantitation of the inositol isomers was based on the GC peak heights and is accurate to ± 10 percent for the *myo*-inositol.

Control experiments in which the same procedure was used were carried out on sediment samples to which authentic inositol isomers had been added. The added inositols were recovered quantitatively. No interconversion of the isomers could be detected on acid hydrolysis in the presence or absence of the sediment. No inositols were found in water blanks or ignited sediment samples.

No inositols were extracted from the sediment samples after three extractions

Table 1. Content of *myo*-, *chiro*-, and *scyllo*-inositols in marine sediments in parts per million (ppm). The figures in centimeters refer to the depth in the core.

Sample and reference	Lithologic description	Time of deposition (years)	Inositols (ppm, dry weight)		
			myo-	*scyllo-*	*chiro-*
1, Santa Barbara Basin (*17*) (34°11.80′N, 120°02.00′W)	Coastal basin sediment	10	87	4.2	2.8
2, Santa Barbara Basin (*17*) (34°11.80′N, 120°02.00′W)	Coastal basin sediment	80	37	3.2	2.1
3, SOT W7 P12*, 15 to 30 cm (*18*) (2°35.00′N, 85°1.80′W)	Calcareous clay	5×10^4	3.1	0.14	0.10
4, 15-148-16-3†, 90 to 105 cm (*19*) (13°25.12′N, 63°43.25′W)	Calcareous clay	2×10^6	1.7	0.13	0.14
5, 36-328-3-6†, 0 to 15 cm (*20*) (49°48.67′S, 36°39.53′W)	Diatom-bearing clay	6×10^6	0.12	0.03	0.04
6, 15-146-36R-2†, 138 cm (*21*) (15°06.99′N, 69°22.67′W)	Foraminiferal limestone	45×10^6	0.03	0.009	0.010

*Scripps Institution of Oceanography core sample designation. †The numbers refer to Deep Sea Drilling Project numbers for leg-hole-core-section.

with ten sample volumes of $6N$ HCl at room temperature or with a 3-hour benzene-methanol (1 : 1) reflux. These results indicate that the inositols are bound in the sediment, and that they are not associated with lipid-extractable material, for example, phosphatidyl inositol. Treatment of sediment sample 4 with $6N$ HCl at 100°C for only 60 minutes (instead of 48 hours) released approximately 90 percent of the bound *myo*-inositol as free inositol. Large amounts of free sugars were also released, which interfered with the detection of the other inositol isomers. Extraction of samples 1, 2, and 4 with $1M$ NaOH (60°C, 4 hours) followed by a 48-hour HCl hydrolysis of this extract released > 95 percent of the inositols. On acidification of the NaOH extract, the humic acids precipitated and about half of the inositol was found in the humic acid precipitate after acid hydrolysis.

The supernatant from the humic acid precipitate of samples 1 and 2 was treated with sodium hypobromite, which oxidizes the free inositols and fulvic acids but not the inositol hexaphosphates (*5, 15*). The inositol hexaphosphates were precipitated with ferric ion and then acid hydrolyzed and were found to contain about 5 percent of the total inositol in sediment samples 1 and 2. The ratio of inositol isomers in the hexaphosphate fraction was the same as in the whole sediment sample.

Because this inositol analysis is relatively simple and sensitive, the method may serve as a base line with which to compare other organic compounds in sediments instead of using total organic carbon as a base line. The steady decrease in the inositol concentration with age in the sediment samples examined could be due to bacterial attack, leaching of the sediments, or instability of the inositols. Since inositol is so stable to acid hydrolysis, the loss is probably due to the action of bacteria and leaching. The possible slow interconversion of inositol isomers that remain in the sediments could be the basis of a dating procedure.

The inositols in soils are probably bacterial in origin (*16*). We examined three different marine sediment bacteria from the Del Mar Lagoon and found the same relative proportion of inositol isomers in the bacteria as in the sediments. Other contributing sources of marine inositols would be oceanic detritus and terrestrial sources.

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References and Notes

1. T. Posternak, *The Cyclitols* (Holden-Day, San Francisco, 1965).
2. G. Staedeler and F. T. Frerichs, *J. Prakt. Chem.* **73**, 48 (1858).
3. B. Lindberg, *Acta Chem. Scand.* **9**, 1097 (1955).
4. S. Posternak, *C. R. Acad. Sci.* **137**, 439 (1903).
5. D. J. Cosgrove, *Nature (London)* **194**, 1265 (1962).
6. D. H. Smith and F. E. Clark, *Soil Sci.* **72**, 353 (1951); M. F. L'Annunziata, W. H. Fuller, D. S. Brantley, *Soil Sci. Soc. Am. Proc.* **36**, 183 (1972); M. F. L'Annunziata and W. H. Fuller, *ibid.* **35**, 587 (1971).
7. S. E. Herbes, H. E. Allen, K. H. Mancy, *Science* **187**, 432 (1975).
8. G. Anderson, in *Soil Biochemistry*, A. D. McLaren and G. H. Peterson, Eds. (Dekker, New York, 1967), p. 78.
9. J. W. Halliday and L. Anderson, *J. Biol. Chem.* **217**, 797 (1955).
10. Y. Kojima and H. Kusakabe, *J. Sci. Res. Inst. Tokyo* **48**, 121 (1954).
11. Core samples (from which sediment samples were taken) were immediately frozen to −20°C and kept at this temperature up to the time of analysis. To reduce possible contamination, only material from the inside of the core samples was used. Dry weights were determined by drying samples at 110°C to constant weight.
12. In the GC-MS analysis we used a LKB-9000 fitted with a glass column (1.8 m long by 0.32 cm in inside diameter) containing 3 percent OV-17 on Gas-Chrom Q. The column was programmed from 150° to 300° at 10°C per minute. Helium was used as the carrier gas at a flow rate of 26.4 ml per minute. All spectra were recorded at 70 ev. Under these conditions the inositol isomers had the following retention times (in minutes): *neo*-, 5.0; D-*chiro*-, 5.9; *scyllo*-, 7.0; and *myo*-, 7.5.
13. W. R. Sherman, S. L. Goodwin, K. D. Gunnell, *Biochemistry* **10**, 3491 (1971).
14. W. R. Sherman, N. C. Eilers, S. L. Goodwin, *Org. Mass Spectrom.* **3**, 829 (1970).
15. C. L. Wrenshall and W. J. Dyer, *Soil Sci.* **51**, 235 (1941).
16. A. G. Caldwell and C. A. Black, *Soil Sci. Soc. Am. Proc.* **22**, 293 (1958).
17. A. Soutar and J. D. Isaacs, *Fish. Bull.* **72**, 257 (1974).
18. The age assigned to this sample was based on the racemization of isoleucine [J. L. Bada and R. A. Schroeder, *Earth Planet. Sci. Lett.* **15**, 1 (1972)].
19. N. T. Edgar, J. B. Saunders, H. M. Bolli, T. W. Donnelly, W. W. Hay, F. Maurrasse, I. P. Silva, W. R. Riedel, N. Schneidermann, in *Initial Reports of the Deep Sea Drilling Project* (Government Printing Office, Washington, D.C., 1973), vol. 15, pp. 17–168.
20. P. F. Barker, I. W. D. Dalziel, D. H. Elliott, C. C. von der Borch, R. W. Thompson, G. Plafker, R. C. Tjalsma, S. W. Wise, Jr., M. G. Dinkelman, A. M. Gombos, Jr., A. Lonardi, J. Tarney, *Geotimes* **19**, 16 (1974).
21. N. T. Edgar, J. B. Saunders, H. M. Bolli, T. W. Donnelly, W. W. Hay, F. Maurrasse, H. P. Nieto, I. P. Silva, W. R. Riedel, N. Schneidermann, in *Initial Reports of the Deep Sea Drilling Project* (Government Printing Office, Washington, D.C., 1973), vol. 15, pp. 217–276.
22. We thank Andrew Soutar for supplying the samples from the Santa Barbara Basin and Jeffrey L. Bada for sample SOT W7 P12. The samples from the various Deep Sea Drilling Project sites were supplied (to J. L. Bada) through the assistance of the National Science Foundation. Samples of known inositol isomers were supplied by William R. Sherman. Bacteria cultures isolated from sediment samples were supplied by Kenneth H. Nelson. This work was supported by NSF grant MPS 72-05043. The gas chromatography–mass spectrometry was obtained in part with NSF grant GP 18245.

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Yearly Seismic Energy Release: World Totals Versus Ridge System Totals

Abstract. *Yearly seismic energy totals for many different regions of the earth show highs in 1965 and lows in 1967. Correlations found between totals for ridge systems and for the world are attributed to ambient stresses, which are close to those needed for failure in the lithosphere underlying those ridge systems. Energy highs for many different plate edges are thought to be the result of triggering by the large Alaskan earthquake of 1964. Other suggestions of triggering by major earthquakes are found in 1969 and 1971.*

Evidence has recently been presented which suggests that similarities in the seismic activity of widely differing tectonic environments may be related to worldwide fluctuating stress fields (*1*). This evidence is in the form of time series of counts per unit time of earthquakes with magnitudes greater than a chosen threshold. Many of the time series from widely separated regions were found to have activity highs in 1965 and lows in 1966 and 1967. Similar observations have previously been made using yearly seismic energy totals for differing tectonic regions (*2, 3*), as well as cumulative strain release totals (*4*). In one of these investigations (*3*), yearly totals for ten of 15 regions studied were found to have high values in 1965, while totals for eight regions were found to have low values in 1967. Regions having highs in 1965 or lows in 1967, or both, included oceanic ridge systems contributing as little as 0.5 percent to the yearly seismic energy totals for the world, as well as major earthquake zones. It was concluded that such relations, displayed over relatively short time intervals (1 year), required the existence of an efficient worldwide mechanism of energy distribution, which produced both major earthquakes throughout the world and minor activity along individual rising plate edges. In this report additional information is provided concerning these suggested relations, and the possible significance of this information is discussed in view of the hypothesis proposed by Chinnery and Landers [worldwide fluctuating stress fields (*1*)] and the hypothesis proposed by Anderson [accelerated plate tectonics (*5, 6*)].

Yearly seismic energy totals for most of the seismically active regions of the earth are shown in Fig. 1. National Earthquake Information Service (NEIS) list-