

This Week's Citation Classic®

Shackleton N J & Opdyke N D. Oxygen isotope and palaeomagnetic stratigraphy of Equatorial Pacific core V28-238: oxygen isotope temperatures and ice volumes on a 10^5 year and 10^6 year scale. *Quaternary Res.* 3:39-55, 1973.

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Core Vema 28-238 yielded an excellent oxygen isotope and magnetic record of the past 870,000 years. Detailed correlation with sequences described by C. Emiliani in the Caribbean and the Atlantic Ocean is demonstrated. The boundaries of 22 stages representing alternating times of high and low Northern Hemisphere ice volume are recognized and dated. [The *SCI*® and *SSCI*® indicate that this paper has been cited in over 730 publications, making it this journal's most-cited paper.]

Rosetta Stone for Quaternary Ice Ages

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It was Cesare Emiliani who seized the opportunity to apply oxygen isotope analysis to the Quaternary, and his classic 1955¹ and subsequent papers were so remarkable that even two decades later people would ask why I would want to enter a research area that had already been cleaned up by Emiliani. My success was largely due to good fortune in meeting Jim Hays and John Imbrie at the time that the CLIMAP project was starting. When I learned that the major problem that they faced in attempting to reconstruct the climate of the Ice Age world was basic stratigraphy, I confidently asserted that I could easily solve it. I had shown that the continental glaciation gives rise to oxygen isotopic changes that should be easily detected in any deep-sea core containing carbonate microfossils, implying that oxygen isotope data should enable one to pinpoint the level of the last glacial maximum in any core. I had also claimed that the method would reveal the longer history of Quaternary glaciation.

In core V28-238 I was able to convincingly show that the oxygen isotope fluctuations affected the whole global ocean, by analysing both organisms that floated at the ocean surface and those inhabiting the sea floor in the West Pacific almost antipodal to Emiliani's records. I was also able to extend Emiliani's sequence and, thanks to Neil Opdyke's palaeomagnetic stratigraphy, to tie down the chronology. I kept this to myself until I could show it to Emiliani privately before announcing it at the 1972 American Quaternary Association meeting in Miami. His immediate reaction was that, contrary to his previous belief, the major glacial cycles were related to changing eccentricity of the earth's orbit rather than to obliquity of the rotational axis, as Hays, Imbrie, and I later demonstrated more formally.²

I was able to do this work using a primitive mass spectrometer with some rather bizarre personal modifications, but on the other hand I was surprised to find Emiliani was himself still working with a machine from the 1950s. My work stimulated design of a new generation of stable isotope mass spectrometers and a huge growth in their application in the earth sciences. By early 1973 I had a new instrument and within the year was analysing cores from all over the oceans, as well as exploring long Deep Sea Drilling Project records with Jim Kennett.

This paper has had enormous use because in it I argued the importance of the record of V28-238 in global terms, both for the oceans and for the continents, rather than focussing on its relevance for the West Pacific. It is still regarded as the Rosetta stone (Imbrie's expression) for the Quaternary Ice Ages by a very motley, interdisciplinary, and international crowd of geologists and archaeologists. The chronology of glaciation became an order of magnitude more secure with this publication and has scarcely changed, although the detailed interpretation of the oxygen isotope record remains controversial,³ as does the stratigraphic correlation of many specific continental glacial and interglacial deposits with V28-238. It is regrettable that the address from which the raw data were supposed to have been available on microfiche seems to have been fictitious (the data are, of course, available from me).

1. Emiliani C. Pleistocene temperatures. *J. Geology* 63:538-78, 1955. (Cited 500 times.)

2. Hays J D, Imbrie J & Shackleton N J. Earth orbital variations: pacemaker of the ice ages. *Science* 194:1121-32, 1976. (Cited 465 times.)

3. Shackleton N J. Oxygen isotopes, ice volume and sea level. *Quaternary Sci. Rev.* 6:183-90, 1987.

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