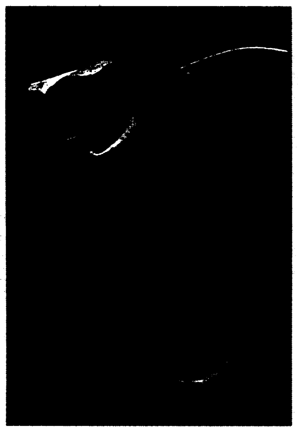
BROWSINGS



Archipelago: The Islands of Indonesia. From the Nineteenth-Century Discoveries of Alfred Russel Wallace to the Fate of Forests and Reefs in the Twenty-First Century. ***Gavan Daws and Marty Fujita.*** **University of California Press, Berkeley, CA, 1999. 271 pp. $45, £27.50. ISBN 0-520-21576-1.**

Eight years of travel and observation in the Malay Archipelago led Wallace to his independent development of the theory of evolution by natural selection. Daws and Fujita use their account of Wallace's explorations to frame a dicussion of the exploitation of the islands' rich biodiversity and current attempts to conserve it. Their text is accompanied by striking photographs of the regions' landscapes and life forms, such as the colorful pitcher plant from Borneo shown here.

cognitive mechanisms will reflect the specific functions for which they were originally selected. Recent studies have supported this expectation with evidence that when we apply reason to evolutionarily novel domains, our thinking is often shaped by specific evolved mechanisms drafted for the new purpose (akin to the process of exaptation discussed by Stephen Jay Gould and others). The domains that Calne covers in depth provide examples: different religious beliefs about the behavior of spirits and gods follow from our folk psychology of humans and animals (*4*); the production and dissemination of art follows reasoning matched to the domain of courtship and mate attraction (*5*); and moral indignation toward deviant social behaviors appears as an extension of food-related disgust (*6*). Thus to understand what forms of thinking fall within reason, and how best to apply these to modern problems, we must be cognizant of the specific past domains whose evolutionary traces suggest themselves for present use.

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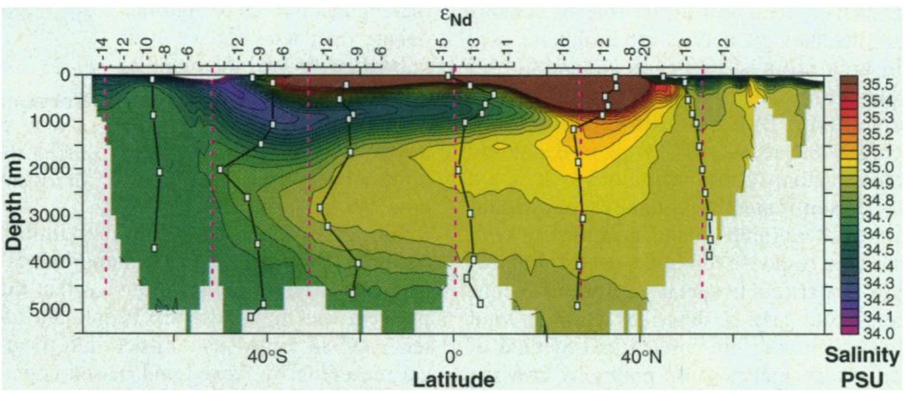
PERSPECTIVES: PALEOCEANOGRAPHY

Tracing Past Ocean Circulation?

Friedhelm von Blanckenburg

Interest in global ocean circulation has increased since coupled ocean-atmosphere models have suggested that the current mode of circulation is fragile. Natural changes have occurred in the past, for example, in conjunction with glaciations, but the models suggest that ocean circulation may also be heavily perturbed by anthropogenic greenhouse emissions, with dramatic consequences for global climate. However, to understand how ocean circulation and climate may change in the future, we must first understand how the system operated in the past, without man's influence. New isotopic tracers are now helping to elucidate past ocean circulation patterns, but controversies remain regarding the relative influence of ocean circulation and weathering on the isotopic signals.

Analyses of the salinity and temperature of water masses are used by oceanographers to reconstruct the present-day ocean circulation. For example, the salt content of Atlantic seawater differs depending on where the water originated (see the figure on this page). To determine the distribution of former water masses, paleoceanographers rely on isotopic measurements of marine sediments, which reflect the distinct isotope composition of the water masses from which they formed. For the past 20 years, the stable isotope ratios of carbon have been used as a tracer for labeling present-day water masses (*1*). They are also preserved in the shells of marine organisms, but the carbon isotope ratios in planktonic foraminifera, for example, are modified from those of the water masses in which they live by temperature (*1*), the availability of nutrients (*1*), and carbonate (*2*). Similarly, Cd/Ca elemental ratios in foraminifera are prone to thermodynamic effects (*3*). In addition, information from ^{14}C is limited by its short half-life of 5700 years (*1*). Therefore, there is demand for a supplementary set of tracers.



Two different water mass tracers. Present-day salinity distribution, integrated over the western Atlantic Ocean. A long tongue of water with high salinity (NADW, marked in yellow) carries about 18 x 10^6 m^3 of water per second southward. This is compensated for by two water masses flowing north with lower salinities [Antarctic Bottom Water (AABW), in green, and Antarctic Intermediated Water (AAIW), in blue]. Superimposed are measured sections of the isotopic composition of Nd dissolved in seawater, presented as ε_{Nd} ($^{143}Nd/^{144}Nd$ normalized and presented in parts of 10^4) (*14*, *15*). ε_{Nd} in NADW is dominated by Nd originating from the old continents surrounding the North Atlantic and has a uniform value of −13.5. This value is outlined by the dashed red line in each section. Water at 60°S has an ε_{Nd} of −9, because it is derived from erosion of much younger mountain belts. PSU, practical salinity units.

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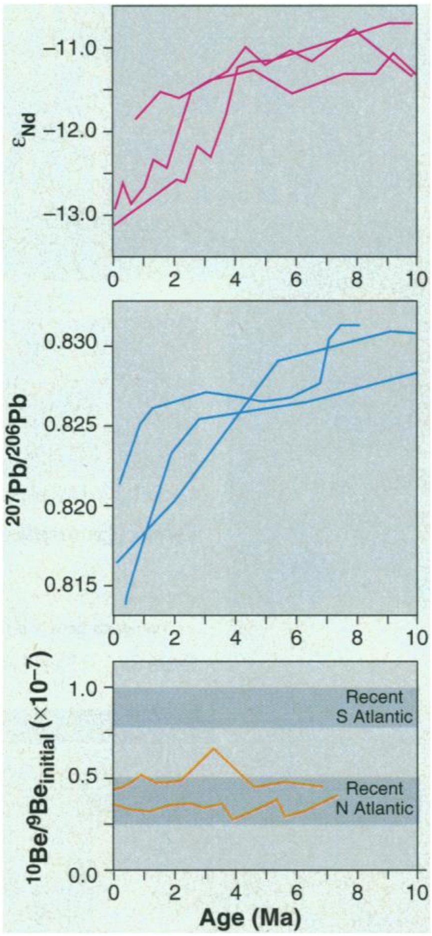
One approach makes use of inorganic trace elements such as neodymium (Nd) and lead (Pb), whose isotope compositions are not subject to the modifications upon uptake described above and are only controlled by slow radioactive decay within their continental sources, from which they enter the oceans through erosion. Unlike the isotopes of Sr, which has a long ocean residence time, the isotopic differences of these trace elements are preserved in different water masses because their residence time is limited to a few hundred years, preventing them from being homogenized by the global thermohaline circulation (*4*). For example, the neodymium isotope ^{143}Nd is produced by radioactive decay of ^{147}Sm in the continental crust. The ratio of ^{143}Nd to the stable isotope ^{144}Nd in water samples, commonly presented in a normalized way as ε_{Nd}, is primarily a function of the age of its continental source. ε_{Nd} is -13.5 in North Atlantic Deep Water (NADW) (see the figure on previous page) but is much higher in the southern circumpolar water ($\varepsilon_{Nd} \sim -9$). The Atlantic water masses between these two end-members have intermediate signatures that correlate well with salinity (see the figure on the previous page).

The isotopic compositions of North Atlantic ferromanganese crusts that have grown from NADW have now been analyzed, yielding the isotopic composition of NADW back to more than 10 million years ago (Ma) (see the figure on this page). The results are quite spectacular. At 2 to 3 Ma, during the onset of Northern Hemisphere glaciation, the Nd isotope ratios dropped from a value characteristic of that of South Atlantic water ($\varepsilon_{Nd} = -11$) to the canonical value of -13.5 measured in NADW today. Over the same period, another isotope ocean tracer with a short residence time, ^{207}Pb/^{206}Pb, also dropped from a ratio more typical of southern Atlantic Water masses to that of NADW.

One interpretation of these patterns is that they record climate-linked changes in the nature and intensity of the thermohaline circulation, supporting the theory that the circulation changed in direct response to the closure of the Panama Gateway (*5*). There are some open questions, however. Unlike the Nd and Pb tracers, the ratio of the extremely rare cosmogenic seawater tracer ^{10}Be (with a half-life of 1.5 million years) to the continent-supplied ^{9}Be is not dependent on a particular continental provenance. ^{10}Be/^{9}Be ratios from two North Atlantic Fe-Mn crusts do not show isotope shifts concomitant with Nd and Pb, which would be expected if the latter had varied as a consequence of changes in water mass distribution because ^{10}Be/^{9}Be has distinct water mass signatures too (see the figure on this page) (*6*).



Isotopic tracers in North Atlantic Fe-Mn crusts. Over the past 10 million years, both ε_{Nd} (**top**) and ^{207}Pb/^{206}Pb (**middle**) decrease from values more typical of South Atlantic water to those with a strong component of tracers eroded from ancient continents, as observed in NADW today. Over the same period, ^{10}Be/^{9}Be ratios (**bottom**) are almost constantly within the range of present-day NADW, despite the fact that today's North and South Atlantic water masses have different Be isotope signatures. [Data from (*6*, *16*–*19*).]

An alternative interpretation is that the Nd and Pb isotope variations result from changes in the amount and style of weathering (*5*–*8*). The Labrador Sea, which represents a major source for NADW, receives Nd and Pb with unique compositions from sources in the ancient continents of Greenland and the Canadian shield. The buildup of large ice sheets during the Northern Hemisphere glaciation caused an enormous increase in the delivery of mechanically eroded detritus into the Labrador Sea, which probably shifted NADW radiogenic isotope tracer compositions. It is important to remember that geochemists measuring ocean tracers with longer residence times, such as Os and Sr, have long been accustomed to the concept that variations of isotope composition with time result from changes in weathering, because the long residence time would have erased all individual water mass labels (*9*–*11*).

So where do we stand with our exciting set of new tracers? We need to resolve to what extent weathering versus ocean circulation is responsible for the observed variations. Most likely the answer will differ from case to case. More importantly, a much higher time resolution than can be obtained from studying Fe-Mn crusts must be achieved for climate change studies. It has been suggested that planktonic foraminifera incorporate and record an accurate seawater Nd isotope signal, if cleaned from diagenetic oxide coatings with the most stringent methods (*12*). Their study could allow higher time resolution. However, planktonic foraminifera will pick up a surface water signal. Measurement of the chemically precipitated component of marine sediments offers to provide the isotope composition of deep water. In one such study, deep-water variations relating to glacial-interglacial variations in NADW strength have been observed in the South Atlantic (*13*). Such variations have been hotly debated among paleoceanographers over the last decade. If it is confirmed that isotope compositions obtained from marine sediments are a robust tool to achieve reliable information on paleocirculation, our new rare isotope tracers have a long and golden future before them.

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