NEWSLETTER GEOBRASIL
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- **NATURE**

Increased seasonality in Middle East temperatures during the last interglacial period 164
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Correspondence and requests for materials should be addressed to T.F. (tfelis@allgeo.uni-bremen.de). The data that we report here can be accessed at the World Data Centers for Marine Environmental Sciences (http://www.wdc-mare.org/PangaVista?query=@Ref25611) or Paleoclimatology (http://www.ngdc.noaa.gov/paleo/pubs/felis2004/felis2004.html).
The last interglacial period (about 125,000 years ago) is thought to have been at least as warm as the present climate. Owing to changes in the Earth's orbit around the Sun, it is thought that insolation in the Northern Hemisphere varied more strongly than today on seasonal timescales, which would have led to corresponding changes in the seasonal temperature cycle. Here we present seasonally resolved proxy records using corals from the northernmost Red Sea, which record climate during the last interglacial period, the late Holocene epoch and the present. We find an increased seasonality in the temperature recorded in the last interglacial coral. Today, climate in the northern Red Sea is sensitive to the North Atlantic Oscillation, a climate oscillation that strongly influences winter temperatures and precipitation in the North Atlantic region. From our coral records and simulations with a coupled atmosphere–ocean circulation model, we conclude that a tendency towards the high-index state of the North Atlantic Oscillation during the last interglacial period, which is consistent with European proxy records, contributed to the larger amplitude of the seasonal cycle in the Middle East.

- **SCIENCE**

Molecular evidence links cryptic diversification in polar planktonic protists to Quaternary climate dynamics Kate F. Darling, Michal Kucera, Carol J. Pudsey, and Christopher M. Wade Proc. Natl. Acad. Sci. USA published 10 May 2004, 10.1073/pnas.0402401101 http://www.pnas.org/cgi/content/abstract/0402401101v1?ct

Impact of Genetically Modified Crops and Their Management on Soil Microbially Mediated Plant Nutrient Transformations P. P. Motavalli, R. J. Kremer, M. Fang, and N. E. Means J. Environ. Qual. 1 May 2004; 33(3): p. 816-824 http://jeq.scijournals.org/cgi/content/abstract/33/3/816?ct

Dissolution of Trace Element Contaminants from Two Coastal Plain Soils as Affected by pH JiSu Bang and Dean Hesterberg J. Environ. Qual. 1 May 2004; 33(3): p. 891-901 http://jeq.scijournals.org/cgi/content/abstract/33/3/891?ct

Use of Stream Chemistry for Monitoring Acidic Deposition Effects in the Adirondack Region of New York Gregory B. Lawrence, Bahram Momen, and Karen M. Roy J. Environ. Qual. 1 May 2004; 33(3): p. 1002-1009 http://jeq.scijournals.org/cgi/content/abstract/33/3/1002?ct

Enhanced Desorption of Herbicides Sorbed on Soils by Addition of Triton X-100 M. S. Rodriguez-Cruz, M. J. Sanchez-Martin, and M. Sanchez-Camazano J. Environ. Qual. 1 May 2004; 33(3): p. 920-929 http://jeq.scijournals.org/cgi/content/abstract/33/3/920?ct

Reducing Phosphorus Runoff from Swine Manure with Dietary Phytase and Aluminum Chloride D. R. Smith, P. A. Moore, Jr., C. V. Maxwell, B. E. Haggard, and T. C. Daniel J. Environ. Qual. 1 May 2004; 33(3): p. 1048-1054 http://jeq.scijournals.org/cgi/content/abstract/33/3/1048?ct

Assessment of the Use of Industrial By-Products to Remediate a Copper- and Arsenic-Contaminated Soil Enzo Lombi, Rebecca E. Hamon, Gerlinde Wieshammer, Mike J. McLaughlin, and Steve P. McGrath J. Environ. Qual. 1 May 2004; 33(3): p. 902-910 http://jeq.scijournals.org/cgi/content/abstract/33/3/902?ct

Life's Chemical Kitchen Barbara Sherwood Lollar Science 14 May 2004; 304(5673): p. 972-973 http://www.sciencemag.org/cgi/content/summary/304/5673/972?ct

This Week's Letters Science 14 May 2004; 304(5673): p. 959a http://www.sciencemag.org/cgi/content/abstract/304/5673/959a?ct

Hydrocarbons in Hydrothermal Vent Fluids: The Role of Chromium-Bearing Catalysts Dionysis I. Foustoukos and William E. Seyfried, Jr. Science 14 May 2004; 304(5673): p. 1002-1005 http://www.sciencemag.org/cgi/content/abstract/304/5673/1002?ct

Enhanced Open Ocean Storage of CO2 from Shelf Sea Pumping Helmuth Thomas, Yann Bozec, Khalid Elkalay, and Hein J. W. de Baar Science 14 May 2004; 304(5673): p. 1005-1008 http://www.sciencemag.org/cgi/content/abstract/304/5673/1005?ct

Asphalt Volcanism and Chemosynthetic Life in the Campeche Knolls, Gulf of Mexico I. R. MacDonald, G. Bohrmann, E. Escobar, F. Abegg, P. Blanchon, V. Blinova, W. Bruckmann, M. Drews, A. Eisenhauer, X. Han, K. Heeschen, F. Meier, C. Mortera, T. Naehr, B. Orcutt, B. Bernard, J. Brooks, and M. de Farago Science 14 May 2004; 304(5673): p. 999-1002 http://www.sciencemag.org/cgi/content/abstract/304/5673/999?ct

Evidence of Huge, Deadly Impact Found Off Australian Coast? Richard A. Kerr Science 14 May 2004; 304(5673): p. 941a http://www.sciencemag.org/cgi/content/summary/304/5673/941a?ct

- **EARTH PAGES**

Web resources

Impacts' effects

Algorithms that model the physical effects of extraterrestrial impacts from the Lunar and Planetary Laboratory of the University of Arizona, headed by Jay Melosh, have been assembled into a handy on-line calculator, with notes on the processes involved. If you want to find out if you will be fried, buried or blown to smithereens (probably all three if our luck is really out), and the chances of being harmed by alien lumps of rock or ice, you can find the calculator at http://www.lpl.arizona.edu/impacteffects/. It is not recommended for estate agents, because, unlike many other disastrous events, impacts can be anticipated anywhere.

Anthropology and geoarchaeology

Early humans of Beijing

One of the most remarkable achievements of early humans (*Homo ergaster* aka *H. erectus*) was not their tools, but their migration out of Africa around 1.8 Ma, to reach as far as Indonesia and China. There is no evidence for that feat having occurred again until fully modern humans arrived in east Asia about 70 ka ago. The toolkit of Asian "Action Man" is unimpressive, in the sense that it resembles the slightly reshaped broken pebbles of the Oldowan culture, that first appears in the African archaeological record about 2.4 Ma ago. Development in Africa of the enigmatic and beautiful bi-face or Acheulean axe was after the first Asians had departed, around 1.5 Ma. So what were these early wanderers like; what did they want? The decade-long work in China by Noel Boaz, an anatomist from the Ross School of Medicine in New Jersey and anthropologist Russell Ciochon of the University of Iowa will soon appear in their book *Dragon Bone Hill, an Ice-Age Saga of Homo Erectus* (Oxford University Press), which they preview in the 17 April 2004 issue of *New Scientist* (p. 32-35). Boaz and Ciochon have worked mainly in Zhoukoudian near Beijing, a major resource for human remains whose different levels extend back to about 800 thousand years. Another site in China, Longouppo, contains disputed remains as old as 1.8 Ma, as are Dubois' famous discoveries of the type specimens of *H. erectus* by the Solo River in Java. From the time when Zhoukoudian became famous among Chinese apothecaries as a source of "dragon's bones" (a mixture of human and other animal remains) there has always been an air of myth about the findings there – a permanent dwelling for hundreds of thousand years, protected from glacial temperature falls by the consistent use of fire. In essence, the publicised view is that "Peking Man" led a cosy hearthside existence for a very long time indeed. Boaz and Ciochon tell a different, and more mundane story. Most bones in the deposit are those of a great variety of other animals, with disproportionately few of human origin, and those are highly fragmented. The dominant species is a giant hyena, and many of the bones, including humans, are well gnawed, which is what hyenas do especially well. There are occasional signs of human occupation and use of fire. The human remains are encased in layered carbonate flowstone,. Records of fluctuating $d^{18}O$ from that matrix, matched against the global time series of climate change, show that occupation was only during interglacials - the site was abandoned or unvisited during the depth of glacial periods. Some animal bones show cut marks made by stone tools, and it is more likely that *H. erectus* raided to get remnants of other beasts' kills, perhaps using fire, rather than being top of the predatory order. The great surprise throughout Asia is the complete lack of development of stone tools from the primitive culture that arrived there, until as late as 20 to 30 thousand years ago, when Asian *H. erectus* vanished. Apart from the stunning breakthrough to the bi-face axe, African erects also had a million-year long cultural stasis – resting on laurels with a vengeance. Finally, from a number of skulls at Zhoukodian, Boaz and Ciochon have shown signs of trauma. These are depression fractures, probably not necessarily fatal, but indicate sharp blows to the head with blunt instruments. Their interpretation is that the Chinese erects settled disputes by bashing heads; so that aspect of culture has not changed a lot since. Their story is not "politically correct", but with publication of their book, other palaeoanthropologists can judge it on the basis of the evidence from Dragon Bone Hill.

<u>Faster development of Neanderthals</u>

Go to any horse sale and you will see bidders closely studying the teeth of their prospective purchases; the origin of the saying, "Never look a gift horse in the mouth". Teeth show growth ridges, and in grazing animals they are prominent, so that it is possible to judge the age of a horse easily and accurately. Human teeth are different only in the less obvious signs of growth. Microscopic examination reveals such records, down to the daily level, although the most prominent features are curious disturbances in their deposition that form approximately weekly. They appear as ridges on the crowns of teeth. The variable spacing of these *perikymata* provides a record of the pace at which adult teeth develop. In modern humans the spacing becomes very much closer in the later growth history (towards the tooth's cutting edge) than in its early stages, and reflects the slow development to full adult dentition. In a painstaking study of hundreds of teeth from Cro Magnon and Neanderthal teeth, Fernando Rozzi of the University of Paris and José Bermudez de Castro of the Spanish National Museum of Natural Sciences have discovered an odd difference in the development rates of Neanderthals (Rozzi, F.V.R & Bermudez de Castro, J.M. 2004. Surprisingly rapid growth in Neanderthals. *Nature*, v. 428, p. 936-939). The late *perikymata* of Neanderthals are more widely spaced than in Cro Magnon and modern humans, strongly suggesting that Neanderthals developed to adulthood by about the age of 15, three to five years earlier than us and our immediate ancestors. As well as confirming that they are a separate species, the results suggest that Neanderthals, while acquiring brains as large, and in some cases even larger than ours, had evolved more rapid maturation and probably a genetically determined shorter adult life. This would have had some effect on transfer of culture, which in human societies is often the most important value of elderly folk. The fewer samples of teeth of earlier human species (*H. heidelbergensis* and *H. antecessor*) reveal an even greater surprise. They are more like modern human teeth (albeit with signs of somewhat faster growth), which suggests that evolution of the Neanderthals involved a regression. The authors suggest that the combination of a backward step to faster development with rapid brain growth to large size might reflect a very-high calorie diet together with adverse environmental conditions.

Geobiology, palaeontology, and evolution

<u>Devonian broad-shouldered fish</u>

How, when and under what circumstances vertebrates got limbs to take them charging across the forested land of the late Palaeozoic form a central issue in our own evolution, as well as that of the other four-footed land animals. By negative analogy with the functional though rather rudimentary enlarged fins of various modern fish that flop from pond to pond during dry seasons, many vertebrate palaeontologists have considered limbs as evolutionary adaptations in air-breathing fish once they made this a habit. As so often, the fossil record has not given up enough evidence for that to be certain. Well, an upper foreleg bone (*humerus*) has turned up in Late Devonian rocks from Pennsylvania at a time and in a context that strongly suggests it was carried by a fish (Shubin, N.H. *et al*. 2004. The early evolution of the tetrapod humerus. *Science*, v. 304, p. 90-93). While not able to ride a bicycle, the advanced fish probably used what became limbs to hold itself motionless while lying in ambush for its prey. That would provide a plausible point of departure from which walking might develop.

<u>Early biomarkers in South African pillow lavas</u>

It is now established that various kinds of bacteria infest rocks down to depths of 2 km or more, one particularly favourable habitat being in sea-floor basalts though which hydrothermal fluids travel. Although the majority probably inhabits cracks and joints, some seem to work actively to corrode rock, especially volcanic glass, thereby obtaining mineral nutrients. Signs of this microbial corrosion in modern volcanic glasses are radiating tubes on a scale of a few micrometres, that show up in micrographs, and many may have been overlooked by petrographers in all kinds of rock. That they are definitely formed by organic activity is demonstrated by the presence of nucleic acids, carbon and nitrogen in the tubules. Carbon isotopes from them show the strong depletion in ^{13}C that is the hallmark of organic fractionation of natural carbon. A team of geoscientists, from Norway, Canada and the USA, who have steadily accumulated evidence for biological rotting in modern oceanic basalts, turned their focus to the oldest, well- preserved pillow lavas in the 3.5 billion-year old Barberton greenstone belt of north-eastern South Africa (Furnes, H. *et al*. 2004. Early life recorded in Archean pillow lavas. *Science*, v. 304, p. 578-581). Virtually identical microtubules seem common in them too, particularly in hydrated glasses that are now tinged with the low-grade metamorphic mineral chlorite. Indeed, chlorite seems to have grown preferentially from clusters of the holes, which suggests that they formed before metamorphism of the basalts. Micro-geochemical studies confirm the presence of hydrocarbons with low $d^{13}C$. The bulk of the tubules occur in the inter-pillow debris, that probably formed as glassy rinds as magma protruded on the Archaean sea floor. As well as adding to evidence for ancient terrestrial life, the find has inevitably opened up the search for such signs in meteorites reckoned to have come from Mars. In two, olivine grains show similar structures, although why the olivine hadn't broken down in the presence of water that is essential for life makes such

observations worth taking with a pinch of salt. A number of studies have stymied claims for early bacterial fossils (see *Artificial Archaean "fossils"* and *Doubt cast on earliest bacterial fossils*, April 2002 and December 2003 issues of *EPN*) and inorganic processes conceivably might create structures that can be mistaken for ones formed by biological action. The Fischer- Tropsch process is capable of producing hydrocarbons, and produces depletion in ^{13}C abiogenically. In the on-line April edition of Science Express (http://www.sciencexpress.org) experiments are reported that highlight the possible influence of chromium-bearing mineral catalysts in hydrothermal generation of hydrocarbons from inorganic carbon dioxide(Foustoukos, D.I. & Seyfried, W.E. 2004. Hydrocarbons in hydrothermal vent fluids: the role of chrome-bearing catalysts. *Science Express*, April 2004). The Barberton greenstone belt is well known for ultramafic lavas rich in chromium, as are most early volcanic sequences.
See also: Kerr, R.A. 2004. New biomarker proposed for earliest life on Earth. *Science*, v. 304, p. 503.

Geochemistry, mineralogy, petrology and volcanology

<u>And now….molybdenum isotopes! Ocean anoxia in the Proterozoic</u>

"Everyone knows" that free atmospheric oxygen appeared about 2300 million years ago, thanks to the waste products of blue-green bacterial photosynthesis. At least the land surface became an oxidising environment and a progressively redder place, as Fe-2 was oxidised to Fe-3 which forms insoluble oxides and hydroxides. Paradoxically, the shallow sea floor of earlier times was redder than anything since, because of exactly the same oxygen-containing, ferric minerals. It hosted the largest build-up of any metal concentration in Earth's history; the banded iron formations (BIFs) that have for a century or more been the source of industrial iron. A simple, and probably accurate explanation for BIFs is that iron dissolved in ocean water that lacked oxygen as Fe-2, and was supplied by sea-floor volcanism. Once blue-green bacteria began pumping out oxygen, an oxidising reaction dumped both elements as slimy red sediment where the two met. Dissolved iron consumed oxygen – just as well, because to most prokaryote life it is a poison – yet as oxygen productivity rose (and perhaps sea-floor spreading slowed) dissolved iron was increasingly removed by oxyidation from sea water. The tipping point, when air contained oxygen and sea water became starved of iron (a vital micronutrient for phytoplankton) is difficult to address since the two chemical environments are so different and interact in complicated ways. BIFs continued to form for about half a billion years after the first sign of atmospheric oxygen, then they disappear from the geological record at 1800 Ma ago. There were minor reappearences in the Neoproterozoic, at the time of "Snowball Earth" events, and that is a fascinating topic in its own right. Clearly, there was a long period of transition to what we can regard as a thoroughly modern world. Studies that use sulphur isotopes suggest that in the Mesoproterozoic the upper ocean was oxygenated while bottom waters were perpetually akin to those of the Black Sea today. Conditions in them may have been highly conducive to burial of dead organic matter – rapid drawdown of atmospheric $CO---_2$, but allowing the massive production of methane by anaerobic bacteria. Methane is a far more potent greenhouse gas than carbon dioxide, so controls over climate may have been very different from today's. Molybdenum offers an independent and potentially useful means of testing hypotheses about ocean chemistry. It enters the sea in river water, which in post 2300 Ma times would have been oxygenated, allowing the formation of the soluble and very stable molybdate ion. In anoxic ocean floor conditions, bacteria that generate hydrogen sulphide remove molybdenum as the sulphide, which is why modern Mo concentrations remain stable – it ends up in a very small percentage of ocean floor sediments. The stable isotopes of molybdenum (^{97}Mo and ^{95}Mo) fractionate during precipitation of the element, the heavier one being preferentially removed during sulphide precipitation, to give high $^{97}Mo/^{95}Mo$ ratios in sediments. The opposite seems to occur if precipitation is in the oxide form, as in sea-floor manganese nodules. Geochemists from the Universities of Rochester and Missouri, USA have compared Mo isotopes from apparently anoxic Mesoproterozoic sediments with those in modern euxinic basins (Arnold, G.L. *et al*. 2004. Molybdenum isotope evidence for widespread anoxia in mid-Proterozoic oceans. *Science*

v. 304, p. 87-90). The Precambrian results are isotopically much lighter than modern ones, suggesting that ^{97}Mo did not become enriched in seawater as a result of oxide precipitation in the equivalent of modern manganese nodules. They estimate that 10 times more of the ocean floor was anoxic than today or since about 1300 Ma ago. So far no comparable work has been done of the extremely abundant black shales and schists of the Neoproterozoic, that link with “Snowball Earth” events. Whether or not “modern” redox conditions emerged 1300 Ma ago, with probably a big impact on climate controls, the oddest time climatically was between about 750 and 600 Ma ago. Not only were there several dramatic coolings and warmings, but the main indicator of organic carbon burial, $d^{13}C$, went haywire. As did the BIFs, did ocean anoxic conditions once more get footholds. Molybdenum isotope data seem likely to shed some light on those strange times.

Geomorphology

River incision and anticlines

In many areas of active deformation, landforms that suggest that uplift and river down-cutting keep pace are very common. Stream courses cross zones of uplift, rather than being diverted or ponded up to form lakes. Traditionally, geomorphologists have described such drainages as “antecedent”, i.e. rivers that were present before uplift began. They can be seen on all scales up to examples such as the Indus and Brahmaputra rivers that carve their way across the actively rising Himalaya. The most common are anticlines through which streams flow in canyons perpendicular to the fold axes. A curious and common feature is that the canyons are not haphazard, but often cut the fold where its amplitude is greatest and its axis plunges away from the site of incision. The stupendous rates at which crustal rocks are eroded and transported away in the courses of the Indus and Brahmaputra, and in lesser drainages on the flanks of major extensional orogens, such as the Red Sea, clearly removes load from the crust. Consequently there is an isostatic component to the uplift involved in the two cases at a grand scale. Peter Molnar and Phillip England suggested an erosional role in large-scale uplift over a decade ago. Intervening ridges rise higher than they would if erosion was slower or non-existent. In major rift systems, the highest peaks are often within the escarpments rather than at the lip of uplift, sometimes more than 500 m higher. Bearing this well-known process in mind, Guy Simpson of ETH Zurich, has sought evidence that it functions on much smaller scales (Simpson, G. 2004. Role of river incision in enhancing deformation. *Geology*, v. 32, p. 341-344). That comes from the surprising symmetry of doubly plunging anticlines that are cut by rivers at their highest point. His modelling suggests that the phenomenon can occur when the crust deforms plastically, allowing isostatic response to erosion on even minor scales during compression. When deformation is by brittle means, any uplift of rigid crust is flexural and has long wavelengths, so that rivers bear no relation to local structures

Planetary, extraterrestrial geology, and meteoritics

Water on Mars; almost official

Two lines of evidence from the current robotic explorations of Mars add to less tenuous ones that the planet is really wet – icy to be precise. One is mineralogical. Spectroscopy of the surface being slowly trundled across by a NASA rover, shows abundant signs of the hydrated, iron-potassium sulphate jarosite, which probably can only form under wet conditions. When it was precipitated is not known with certainty, but it occurs in layered sediments that contain structures that clearly point to transport in and deposition from surface water. The time when liquid water could exist at the surface probably goes back to the earliest events on Mars, tied to the famous canyons and more recently discovered dendritic drainage patterns. The other evidence stems from even more remote sensing, that captures short-wavelength infrared radiation emitted by the Sun and reflected from the Martian surface. Ices of water and carbon dioxide have distinct and unique reflected spectra, because of the different ways in which they absorb a small proportion of solar radiation. Results from the OMEGA instrument aboard the European Space Agency’s Mars Express satellite show that the south polar region contains as much as 15% water ice mixed with solid CO_2 (Bibring, J-P *et al*. 2004. Perennial water ice identified in the south polar cap of Mars. *Nature*, v. 428, p. 627-630).

Sedimentology and stratigraphy

Magnetic polarity reversals

The Earth's magnetic field is changing all the time, in its intensity, direction and, now and again, its polarity. It's the last that proved the key to sea-floor spreading and plate tectonics, though ocean-floor magnetic "stripes", and which has become a key stratigraphic tool for correlation and approximate dating. Along with palaeomagnetic pole determinations, that are vital to continental reconstructions, the whole field still remains largely empirical. Although widely agreed to be connected to changes in motions in the core, exactly what happens during reversals of geomagnetic polarity remains enigmatic, despite 40 years having passed since they were first recognised. There is no doubt that they are quick events, but to judge their pace and what happens to field strength and direction during a "flip" requires high quality data that is well-calibrated to time. Most early work focussed on magnetisation in igneous rocks, where the signal is strong. Minerals such as igneous magnetite acquire a permanent magnetisation once they cool below their Curie temperature, but since accurate radiometric dating gives an age, not a range of ages, it might seem that all that is possible with lavas and intrusions is to obtain a series of points. Fine for a time series, but useless for the details of reversals. However, by modelling the cooling history of an igneous body, it is possible to calibrate different levels within it to time. With careful choice, it has proved possible to find flows in flood basalt sequences that include the brief progress of a reversal. The results seem very odd, the pole itself seeming to migrate rather than jump from north to south, and gross changes in intensity over a short time. Improved instrumentation allows a shift from strongly magnetic basalts, to sediments that preserve much weaker signals. These are due to the alignment with the field of magnetic grains as they slowly settle. Marine sediment cores can now be magnetically characterised – the principle behind magneto-stratigraphy. For geomagnetists the most recent reversals have proved especially instructive, when the sedimentary record is analysed (Clement, B.M. 2004. Dependence of the duration of geomagnetic polarity reversals on site latitude. *Nature*, v. 428, p. 637-640). On average, the last four "flips" took about 7000 years to complete by migration of the magnetic poles. Yet there is an oddity in the detail. Sites at low latitude show significantly shorter periods (down to 2000 years) than those at high latitude (as much as 10000 years). Clement's explanation for the difference is the persistence of the lower intensity non-dipole field, which might suggest different core processes or a single process with several components that evolve at different rates.

Sulphur cycling and sea-level change

Sulphur is one the major prerequisites for life after carbon, hydrogen, oxygen and nitrogen, and the bulk of it is supplied by sulphate ions. After chlorine, the SO_4^{2-} ion is the most abundant anion in the oceans. Not very much is added annually by river drainage, and although anaerobic bacteria remove some by reducing it to hydrogen sulphide so that it is removed from solution as a result of precipitation of insoluble iron sulphide, the sulphur cycle has been considered to be the most sluggish of all the major geochemical rhythms at the Earth's surface. Because iron sulphide is highly reactive in oxidising conditions, should marine sulphide-rich sediments become exposed at the surface their oxidation to sulphuric acid and iron hydroxide would rapidly add sulphate ions to seawater. Studies of sulphur isotopes seem to suggest that this is not very important however. Through sulphate-sulphide reducing bacteria, sulphur is implicated in the carbon cycle because of its sheer abundance, not so much from the encouragement and burial of the bacteria, but because they induce the highly reducing conditions that help a larger proportion of dead organic matter to remain unoxidised and become buried. In a roundabout way, sulphur has a role in climate controls. In fact, two roles. Sulphate ions affect the alkalinity of seawater, and on that depends the oceans' ability to dissolve $CO\text{-}_2$ from the atmosphere. The big question is, "Does the sulphate content of seawater ever change fast enough to have some impact on climate in the short term?". Most studies of the S-cycle have focused on sulphur isotopes, so a new twist is bound to be interesting. Alexandra Turchyn and Daniel Schrag of Harvard University looked instead at the isotopes of oxygen within barium sulphate contained within seafloor sediments since the Late Miocene (about 10 Ma ago) (Turchyn, A.V. & Schrag, D.P. 2004. Oxygen isotope constraints on the sulfur cycle over the past 10 million years. *Science*, v. 303, p. 2004-2007). Up until 6 Ma, the barite $d^{18}O$ (measured against mean ocean water values) stayed constant at about 9.5 ‰ , and then rose to around 12.5 ‰ by 3.5 Ma. Through the Late Pliocene and Pleistocene, the period of repeated glacial-interglacial cycles, it fell dramatically to its present level of 7.9 ‰ . In that later period, the average $d^{16}O$ of deep water foraminifera rose significantly. The decline in "heavy" oxygen in marine sulphates can be linked to increased exposure of pyrite-bearing marine sediments during glacial sea-level falls when "light" atmospheric oxygen enters the sulphate ions that are produced. Modelling suggests sulphate ions in seawater increased by as much as 20% during the Great Ice Age. Whether that had an influence on the oceans' take-up of carbon dioxide from the atmosphere in the last 3 Ma is yet to be evaluated. However, Turchyn and Schrag's detection of a short term shift in the sulphur cycle, and attributing it to falling sea level, may allow a new approach to global sea-level change, which has mainly been deduced from features in stratigraphy.

See also: Derry, L.A. & Murray, R.W. 2004. Continental margins and the sulfur cycle. *Science*, v. 303, p. 1981-1982

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