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- **AMAZINGS**

PERIODICIDAD SISMOLOGICA EN LA FALLA DE SAN ANDRES

Mientras los expertos siguen esperando la llegada de un verdadero "gran terremoto" relacionado con la Falla de San Andrés, en California, algunos de ellos han detectado que los movimientos sísmicos moderados a grandes que se producen a lo largo de la zona central de la falla parecen agruparse alrededor de intervalos regulares de tres años.

Este ciclo, hasta ahora ignorado, nos proporciona elementos para predecir la aparición de terremotos más potentes.

El estudio, realizado por sismólogos de la University of California, en Berkeley, muestra una mayor probabilidad de que se produzcan terremotos moderados (magnitud 4 a 6) cuando la frecuencia de otros más pequeños (microterremotos) empieza a elevarse a lo largo de la mitad norte del segmento de casi 200 km de largo de la zona central de la Falla de San Andrés. La frecuencia de estos microterremotos que se repiten se eleva y desciende a lo largo de un período de tres años. Los terremotos moderados a grandes tienen entre seis y siete veces más probabilidades de ocurrir en el punto álgido de este ciclo.

Según Robert Nadeau, geofísico, los terremotos de magnitud superior a 3,5 tienden a ocurrir dentro de los 12 meses posteriores al inicio del pulso. Examinando la historia, y suponiendo que el ciclo de tres años siga vigente, el próximo pico de microterremotos se producirá a finales de 2004.

El estudio ha utilizado datos procedentes de 16 años de observaciones, entre 1984 y 2000. El fenómeno sugiere que algo ocurre bajo la zona sismogénica, algo que la carga e incita a la aparición de terremotos. La zona sismogénica es la quebradiza corteza superior donde suceden los movimientos sísmicos.

Sin embargo, aún no está claro si los grandes terremotos, como el de San Francisco en 1906 (magnitud 8,0), están asociados con los pulsos casi periódicos de los microseísmos. Estos últimos son terremotos que no se sienten (magnitud inferior a 3,5), pero que los instrumentos sí pueden registrar. Durante el estudio, se han analizado hasta 2.594 terremotos que se suceden en 515 puntos diferentes a lo largo del segmento central de casi 200 km de la falla, midiéndose su periodicidad.

Los científicos instalan sismómetros en agujeros a decenas o cientos de metros de profundidad, donde pueden vigilar la actividad sísmica con una alta precisión.
Información adicional en: http://www.amazings.com/ciencia/noticias/130104b.html

- **SCIENCE**

Geochemistry of ground water and the incidence of acute myocardial infarction in Finland
A Kousa, E Moltchanova, M Viik-Kajander, M Rytkonen, J Tuomilehto, T Tarvainen, and M Karvonen
J. Epidemiol. Community Health 2004 February 1; 58(2): p. 136-139
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Satellite Measurements Reveal Persistent Small-Scale Features in Ocean Winds
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Dissolved Phosphorus Retention and Release from a Coastal Plain In-Stream Wetland
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J. Environ. Qual. 2004 January 1; 33(1): p. 394-401
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Assessment of a {delta}15N Isotopic Method to Indicate Anthropogenic Eutrophication in Aquatic Ecosystems
Marci L. Cole, Ivan Valiela, Kevin D. Kroeger, Gabrielle L. Tomasky, Just Cebrian, Cathleen Wigand, Richard A. McKinney, Sara P. Grady, and
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Leaching of Dissolved Organic Carbon and Carbon Dioxide Emission after Compost Application to Six Nutrient-Depleted Forest Soils

Werner Borken, Yi-Jun Xu, and Friedrich Beese
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Selenospheres
Brooks Hanson
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Inferences on Flow at the Base of Earth's Mantle Based on Seismic Anisotropy
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Finite-Frequency Tomography Reveals a Variety of Plumes in the Mantle
Raffaella Montelli, Guust Nolet, F. A. Dahlen, Guy Masters, E. Robert Engdahl, and Shu-Huei Hung
Science 2004 January 16; 303(5656): p. 338-343
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Keeping God Out of the Canyon
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AMERICAN GEOPHYSICAL UNION MEETING: Vicissitudes of Ancient Climate
Richard A. Kerr
Science 2004 January 16; 303(5656): p. 307
http://www.sciencemag.org/cgi/content/summary/303/5656/307?ct

AMERICAN GEOPHYSICAL UNION MEETING: An Ill-Mannered San Andreas?
Richard A. Kerr
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AMERICAN GEOPHYSICAL UNION MEETING: An Early Start for Greenhouse Warming?
Richard A. Kerr
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EARTH SCIENCE: Panel Urges Shakeup of NOAA Research
David Malakoff
Science 2004 January 16; 303(5656): p. 297a
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Analysis of Dissimilatory Sulfite Reductase and 16S rRNA Gene Fragments from Deep-Sea Hydrothermal Sites of the Suiyo Seamount, Izu-Bonin Arc, Western Pacific
Tatsunori Nakagawa, Jun-Ichiro Ishibashi, Akihiko Maruyama, Toshiro Yamanaka, Yusuke Morimoto, Hiroyuki Kimura, Tetsuro Urabe, and Manabu Fukui
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Sabine Fiedler and Michael Sommer
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Composition, Fabric, and Porosity of an Arenic Haplustalf of Northeast Thailand: Relation to Penetration Resistance
Ary Bruand, Christian Hartmann, Santi Ratana-Anupap, Pramuanpong Sindhusen, Roland Poss, and Michel Hardy
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Evaluation of Adsorbed Arsenic and Potential Contribution to Shallow Groundwater in Tulare Lake Bed Area, Tulare Basin, California
S. Gao, R. Fujii, A. T. Chalmers, and K. K. Tanji
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Edouard Bard, Frauke Rostek, and Guillemette Menot-Combes
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Robert M. Nadeau and Thomas V. McEvilly
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14C Activity and Global Carbon Cycle Changes over the Past 50,000 Years
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Enhanced: Weak Faults--Rotten Cores
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- **EARTH PAGES**

Happy and rewarding 2004 to all readers
Seasonal advice to graduate students
Protecting your intellectual property
Long ago, most students entered research by thinking up their own project, albeit with advice from potential supervisors. That is rarely possible today, for many reasons. Instead, gifted students are recruited to research topics proposed to funding agencies by established scientists. More often than

not, such projects slot into an overall strategy centred on an academic's career or the ambitions of a research group. There are advantages in having the sometimes undivided attention of a "boss", a structured approach to work within a broader framework, access to a group's equipment and funding, and support from several co-thinkers. With the old style, there were risks in "ploughing a lone furrow", such as abandonment by a disenchanted supervisor (the enchanted ones could be even more worrying). The single most important advantage of designing your own project, hard and risky as that might be, was one of possession from the outset. Such responsibility develops qualities that are otherwise not easy to get: independence of thought and action, time-management, resourcefulness, an ability to argue your case, and self-discipline – if you can really "hack" it. Except for the indolent and irrecoverably stupid, most people can, given some knowledge of where their subject is going and the *sine qua non* of curiosity. In those "old days", the risks were more than offset by the advantage of ownership, and it was rare for postgraduates not to be successful, and the majority gained their doctorates within three years. Today, up to a third of enrolled graduate students withdraw or fail their degrees, and hardly any complete inside this reasonable period.

Funding agencies now demand guarantees that their outlay bears fruit. They increasingly direct lines of research, so that studentships follow previous funding. The funders are more accountable, and by the iron logic of the marketplace so too must be the recipients. The upshot is continual assessment of research performance by departments, the creation of "centres of excellence", and the crushing of departments that do not measure up to an amoebic growth of criteria and guidelines. So, for anyone keen on testing their abilities to the limit and following their curiosity, the options are increasingly limited. Even if you have independent means, it is now a very rare department that encourages self-motivated research by students, or even by its established staff. In truth, most academics find it hard to be independent, because they no longer have the security that once guaranteed freedom of thought, action and expression. In Britain, if an academic began their career or earned promotion after 20 November 1987, they can be dismissed solely on grounds of redundancy, rather than "with good cause", which was the rock on which tenure used to be based. "Gross moral turpitude" was, I believe, the operative and infinitely more expressive phrase in US institutions. So for your average supervisor the world has turned upside down. Now it's a case of "publish or perish", larded with citation and impact records, and bringing cash into your institution to boost its research assessment. There are very few academics with the energy, imagination, brass neck and wit to jump through all these hoops and remain sanely independent. So we see a growth of hidden but nonetheless unwholesome vices adopted by some to survive and prosper in this deranged environment. There are many victims, but the new researcher is most at risk. During the festive season it is customary to give and receive advice, as well as greetings. Here is some that concerns the vice that dare not speak its name –plagiarism - in the form of a bestiary to help you memorise potentially risky people.

1. **Chameleons** Check out potential supervisors. The Science Citation Index will reveal their record of sole or senior authorship of papers (<u>not</u> reviews). If they are what they claim to be, that will dominate. Relative to that, how many times does their name appear within multi-author papers, of which they are not senior author? If the latter dominates, their reputation probably rests on offering technical facilities that they control, or the research talents of other people. You may find individuals who have a short publication list of either kind. They are either at the start of their career, or beyond all human help (except perhaps your own).

2. **Beavers** Never let anyone else do any work for you, unless they are a kindly technician (who then deserves at least an acknowledgement). Where possible, keep your research materials under your personal control – in some institutions burial is a useful tactic.

3. **Curlews** Be suspicious of a supervisor who shares your findings with the rest of a team; either you do that yourself or not at all.

4. **Moles** Although communication with others is an essential aspect of research, until you are ready to submit a paper for peer review, do not reveal all in seminars and conferences. Pay particular attention to your posters. At every conference you will see people photographing them, whom you can safely assume are after your ideas.

5. **Hamsters** Beware the friendly soul offering, without being asked, to read your first draft of a paper. Instead, plead with the most curmudgeonly academic around, the one who hammers your every utterance, for he or she will probably be honest.

6. **Tapeworms** Do not allow your supervisor to routinely add their name or others in a research team to your papers. Authorship is not based on advice, basic training in research techniques or discussion of your work. That is your supervisor's duty of care, and a good one should give far more than they take. Acknowledgements are the place to express gratitude for such assistance. Authors have to do real work, both analytical and intellectual, to deserve a place in the list.

7. **Squirrels** Insist that your supervisor lets you read all drafts of their papers that bear on your own field, to check that your findings are not included, as well as to learn. If your work appears, you have a right to authorship.

8. **Weasels** Be aware of the relationships among academics and post-docs in your department, and theirs with others in outside institutions. Keep an eye on "networking", which often involves mutual sharing of information as well as gossip, particularly if joint bids for funding are in the offing.
9. **Ravens** It is easy to be pressured overtly and subtly, particularly in a large research group. That may be beneficial, but can be to get you to toe the "party line".
10. **Wolverines** Never tolerate anything that seems like plagiarism, manipulation, obstruction, exploitation, bullying or harassment. Best to confront politely yet firmly the person responsible, but that is not easy. Finding someone who can help is not easy either. Your institution may well have a policy of pastoral care based on designated individuals, who are deemed to be disinterested and trustworthy. In the real world there is a culture of protecting long-term colleagues, which extends throughout a university; you are transitory... In case of difficulty, ask to change your pastoral advisor. Other students of longer standing may know who is straight, or have similar experiences. Whatever, it is essential that you get honest support to resolve such problems. One useful tactic is to air your grievances as accurately as possible in writing, with a copy to someone that you can trust.
11. **Diverse enchanted beasts** The most difficult obstacle to ownership can be, oddly, the genuinely honest, kindly and enthusiastic supervisor. Because of their greater experience and breadth of knowledge, your work can easily become their obsession, usually because of their frustration with your progress. They will not steal your thunder consciously, but can easily end up driving you rather than the other way round. If you want to become their creature, fine. If not, then you have battles ahead, but they will serve both of you well!

Economic and applied geology

Supergiant hydrocarbon field just leaked away

The largest producing hydrocarbon field, which is unlikely to be bettered, is the Gharwar oil field of Saudi Arabia. It extends for about 3500 km^2 and still contains 80 billion barrels of oil. Anything comparable in size, or bigger, would have been tripped over decades ago, because of the sheer size of the geological trap structures. That is one of the reasons to believe that hydrocarbon resources are unlikely to last until the 22nd century, unless other kinds of accumulation can be exploited economically. There are vast onshore reserves of tar sands from which the more volatile hydrocarbons have leaked away, but for them to become generally useable requires very large rises in oil price. The same conditions will have to prevail before oil shales, the source rocks for conventional hydrocarbons, become viable.. Had tectonics not induced the Colorado Plateau to rise and be eroded, oil would be far cheaper and more secure, and the USA would have even more economic and political clout than it already has. The recognition of unroofed hydrocarbon fields in that region of western North America may therefore come as a relief to many people (Beitler, B., Chan, M.A. & Parry, W.T. 2003. Bleaching of Jurassic Navajo Sandstone on Colorado Plateau Laramide highs: Evidence of exhumed hydrocarbon supergiants. *Geology*, v. **31**, p. 1041-1044).

The desert dune sandstones of the North American Jurassic form some of the world's most spectacular scenery, because of their vast outcrops in Utah national parks, such as Monument Valley. Their attraction lies in the colours of the sandstones as well their deep incision. Discovery of what was once a series of supergiant hydrocarbon fields lies in variations of that coloration. When laid down, the sandstones were reddened by precipitation of ferric (Fe^{3+}) oxides from water that seeped through them during diagenesis under oxidising conditions. However, large tracts now show signs of variable bleaching, which gives the variegation that tourists flock to see. Iron has been removed in places, and for that to happen, the insoluble Fe^{3+} has been reduced to the more soluble Fe^{2+}, or ferrous form. That can occur when conditions in the rock change to highly reducing, as in the case of hydrocarbons migrating in along with water. Most wind-blown sands have good porosity and their uniform grain size induces excellent permeability as well, so they are near-ideal reservoirs. However, for them to become permeated by hydrocarbons that migrated from source rocks (usually shales) requires pathways and structures in which the hydrocarbons can be trapped. The Jurassic of the western USA has alternations of these sandstones with less permeable rocks, and was deformed into huge open anticlines during the Laramide orogeny, that originally might have created such traps on a regional scale. Brenda Beitler and her colleagues from the University of Utah have mapped the zones of bleaching using Landsat-7 Enhanced Thematic Mapper data. Sure enough, the most bleached areas coincide with the crests of the large upfolds, and with reverse faults that link them to basins with source rocks and may have acted as fluid migration pathways. The pore volume that could have been available for hydrocarbon trapping would have been 2200 km^3, equivalent to 18.5 trillion barrels, about 6 times larger than estimates of the modern world's recoverable oil. Since the Cretaceous, the Colorado Plateau has undergone more than 2 km of uplift and every single upfold has been breached and deeply incised. Sorry George, the oil leaked out long ago! The inevitable leakage of the gas fraction, perhaps as much as 2 billion tonnes, could have warmed the Tertiary climate, if a significant fraction were released quickly. The main incision of the Colorado Plateau was probably in the late Miocene (around 6 Ma), when ocean-floor data suggest global warming of the order of 0.5 to 1ºC.

Background to globalisation of water resources

"The second provision of any civilised society after a system of laws, is that of a safe water supply" is anonymously attributed in the repeated warnings about the parlous state of water provision for about two thirds of the world's population. Many of the private companies that took over the public water authorities in Britain now stride the planet organising that provision. In South Africa, the resulting increases in water pricing are the main source of anger throughout the poorer sections of its population, especially in the townships. In Cochabamba, Bolivia there have been mass protests about similar price hikes that came years ahead of any improvement in supplies. A consortium of national and transnational companies needed the extra cash to finance a major dam project, instead of looking to global investors in the project. *Science* carried a lengthy article that provides a context for this new trend in globalisation (Gleick, P.H. 2003. Global freshwater resources: soft-path solutions for the 21st century. *Science*, v. **302**, p. 1524-1528)

Environmental geology and geohazards

Deep-sea drilling project financed Liberian carnage

Despite the common knowledge of rapidly deteriorating conditions for civilians in Liberia for the last 10 years or so, the Joint Oceanographic Institutions' drilling vessel *Resolution* and its predecessors continues to this day to be registered under a Liberian flag of convenience. Shipping registrations form a major part of Liberia's foreign earnings, and have been used for purchase of arms that have been used on its population, and quite possibly on that of Sierra Leone. Flags of convenience allow ship owners to avoid taxation and internationally agreed regulations for the safety and working conditions of its crew. So, the International Ocean Drilling Program and NSF which funds it are in an awkward position. The whole venture is privatised, NSF funding JOI, which in turn co-owns the famous vessel with Transocean, the world's largest offshore drilling company. ODP, which directs operations claims to have been too busy with that to consider the implications of ship registry….

Source: Dalton, R. 2003. Ship row flags up funding of war in Africa. *Nature*, v. **426**, p. 485.

Wildfires and uplift chronology

The "next big thing" in geomorphological studies has been said to be precisely dating crustal exhumation during erosion and uplift. Fission tracks produced in some minerals by particles emitted by radioactive isotopes within them are preserved only when temperature is below that at which annealing can take place. That temperature varies from mineral to mineral. By counting the tracks it is possible to estimate the time since the containing mineral cooled below its annealing temperature during its rise to the surface. Analysing surface samples from different topographic elevations in an area can therefore build up a history of uplift, those lowest in the section being the last to pass through the temperature, and vice versa. Similarly, radiogenic gases only accumulate in a mineral once it cools below a temperature at which the molecular structure blocks diffusion of the gas from the mineral. One example is radiogenic argon produced by decay of ^{40}K. Ages of potassium minerals, such as micas and feldspars, determined by the Ar-Ar technique relate to the time when the containing samples rose through the blocking temperature. There are numerous problems with fission track dating, although most users assume that the ages that they get are real. For Ar-Ar "thermochronology" the blocking temperatures are above 150ºC, which is also problematic, because for a normal continental geothermal gradient of 30ºC km^{-1} a sample would have to rise 5 km to reach the surface before yielding an age relevant to uplift and erosion history. Unless a study area has much higher geothermal heat flow, or has undergone enormous rapid uplift, most ages obtained by such studies are much older than the event of interest. In the case of helium, the blocking temperatures are lower, about 70ºC in the case of apatite. So dating the accumulation of helium produced by decay of uranium and thorium in apatite offers a tool that seems near-ideal for studying rapid exhumation of the order of a couple of kilometres, and that seems likely for many mountain belts and continental margins. It is the apatite U-Th/He dating method that has spurred a flurry of new studies, now that mass spectrometry is capable of precisely measuring the tiny amounts of helium in single apatite grains. But that has its drawbacks too. On that is pretty obvious is the effect of heating of the surface in recent times. Sara Mitchell and Peter Reiners of the universities of Washington and Yale studied the effects of biomass burning on the method (Mitchell, S.G & Reiners, P.W. 2003. Influence of wildfires on apatite and zircon (U-Th)/He ages. *Geology*, v. **31**, p. 1025-1028) because modelling suggests that fires can reset apatite ages. They found that resetting and scrambling of ages does indeed occur, down to depths of 3 cm in surface samples. That casts doubt on this dating not only on detrital apatites found in soils and sediment, but also in rocks, unless the exposed surfaces are ground away before separating mineral grains. Fires are not the only means of heating rock surfaces, and high temperatures are experienced daily by many rocks due simply to solar heating at low latitudes. This affects depths down to as much as 30 cm, especially in rocks with a dark surface. It <u>is</u> possible to fry eggs on exposed rock in some parts of the world, though they are not very appetizing.

Geobiology, palaeontology, and evolution

Fossil hamster's food cache

It is uncommon to find fossilised nuts, so imagine the fervour that has greeted an actual cache of them, clearly secreted by some hoarding animal. The Garzweiler lignite pit near Cologne in Germany has long been a treasure house for Miocene terrestrial fossils, thanks largely to the keen eyes of miners who work there. In 1992 they came across 1800 nuts in one of the sand horizons that divides the lignite deposit. They were in a burrow through probable dune sands. Its dimensions give a clue to the hoarder, which was about 25 cm long and weighed in at 225 grams (Gee, C.T., Sander, P.M & Petzelberger, B.E.M. 2003. A Miocene rodent nut cache in coastal dunes of the Lower Rhine Embayment, Germany. *Palaeontology*, v. **46**, p. 1133-1149). This is about the size of an extinct hamster, remains of which have been found at a similar level in the lignites. Evidently, hamsters have always worried about their future, especially when food is likely to be scarce, but are also dim-wittedly forgetful. The hazel-like nuts are the earliest-known example of a lost food cache (about 17 Ma), and have been suggested to represent the onset of seasonality in Europe during the late Early Miocene.

The selectivity of mass extinctions

Every mass extinction, whatever its magnitude, was selective; there always were surviving organisms, otherwise we wouldn't be here. However, selectivity according to the lifestyles of animals that became extinct can give important clues to the causes of extinctions. Die-off across the ecological board strongly suggests a cause that was all encompassing, such as a major impact or geochemical stress that reached into every corner, as might occur with massive flood-basalt volcanism. At the end of the Pliensbachian Epoch of the Early Jurassic there was a significant mass extinction. Its victims were mainly marine organisms, especially molluscs. Study of the disappearances of bivalve species shows that those which lived in burrows suffered more than ones inhabiting open sea floor (Aberhan, M. & Baumiller, T.K. 2003. selective extinction among Early Jurassic bivalves: A consequence of anoxia. *Geology*, v. **31**, p. 1077-1080). A likely cause is loss of oxygen from the upper layer of sea-floor sediments, but a less reducing environment immediately above the sediment surface

Planetary, extraterrestrial geology, and meteoritics

Recent snowfall on Mars

Evidence from the neutron detector on Mars Odyssey suggested the possible existence of subsurface water on Mars (*Water on Mars*, August 2002 *Earth Pages News*). I reluctantly succumbed to all the hype about what is implied by that, the more so when reports came in of dendritic drainages revealed by high-resolution elevation data (*Case for Martian rainfall strengthens* in October 2003 issue of *EPN*). In planetary exploration, including remote sensing of the Earth's surface features, progressive improvement in resolution generally reveals novelty. The Mars Orbiter Camera, deployed by the Mars Global Surveyor mission has a resolution from 15 down to 2 metres. For the Earth, you can get 15 m images freely from the ASTER programme, but to match the 2 m images would be very costly. Given a broadband or better connection you can download the lot for Mars (http://pds-imaging.jpl.nasa.gov/atlas/). It is this resource that scientists from Brown and Boston Universities in the USA and the Kharkov National University of the Ukraine have used to reveal the latest paradigm buster from the Red Planet (Head, J.W. *et al*. 2003. Recent ice ages on Mars. *Nature*, v. **426**, p. 797-802).

James Head and his colleagues focused on the smooth terrains, or mantles, which drape over older deposits above 30º latitude on both Martian hemispheres, especially where water had been indicated by the Mars Odyssey neutron detector. They were looking for signs of what on Earth would be regarded as periglacial features, formed by the growth and melting of subsurface ice. They found lots, including signs of flowing ice-bound debris, but they do not show them in the Article, which deals with the implications of their findings. An important conclusion is that at least some of the mantle may have formed by what could be described as very dirty snow – a mixture of ice and wind blown dust. Judging the age of the deposits directly depends on the standard stratigraphic method for all planets other than the Earth and Moon, their relationship to signs of impacts. There are very few fresh craters in the mantle, but many that have been "blurred" by it. Head *et al*. suggest that the mantle dates to at most 10 Ma. They resort to modelling climate shifts on Mars from its orbital and rotational history. Its rotational axis undergoes the greatest obliquity shifts of any planet, from about 15 to 35º over a 124,000-year cycle (unlike Earth's tilt, which slowly rocks through a range of only 4 degrees thanks to the stabilising tuggings of our large Moon). At high obliquity, the polar caps probably evaporate. loading the atmosphere with water vapour, so unlike the Earth it is global warming that induces low-latitude ice accumulation. It is this modelling that encouraged the authors to suggest an ice age between 2 million and 400 thousand years ago.

Journals News

Change of Geology Today's editor

Those of you who subscribe to *Geology Today* will have noticed that its Editor is no longer Peter J. Smith. He was the founding editor of this, the leading digest of news, comment and articles for "lay" geoscientists. *Geology Today* arose out of Peter's determination to develop a truly independent forum in the Earth sciences, which appeared as *Open Earth* back in the 1970s. One of the original five members of the Open University's Department of Earth Sciences in 1969, Peter took early retirement in March 2003. His replacement at *Geology Today* is Peter Doyle.

Tectonics

Geoscience consensus challenged

The history of science shows that what is widely agreed is generally wrong. Yet, there is more than the temptation of cosiness, and the ease of publication that goes with it, that induces even the most imaginative scientists rarely to stick their necks out. In their overthrow of the geocentric view of the cosmos, both Copernicus and Kepler felt ideological pressures that we can only guess at. Colleagues of Copernicus had been burnt at the stake, so he hid himself for the 40 years of his life and only dared publish his ideas so late that the galleys arrived at his deathbed. Kepler, a Protestant in the Holy Roman Empire, kept one step ahead of trouble by networking that would done many a modern scientist proud, and a sort of Bowdlerisation of his ideas so that they merged almost seamlessly with the prevailing ideology of both sides of European Christianity. Even the bravest, most honest and gifted scientists generally agree with their peers, simply because they rarely know any better. If they do, they either keep or are kept quiet. There is very little, if any objectivity in the science of any age… because it is scientists who do it! Kepler cuddled up to Tycho de Brahe, he of the gold and silver nose (fitted after student duelling), in order to gain access to Tycho's observational data when the old feller died. He got them alright, and began to turn the universe back on its feet, thereby opening an avenue for Newton. Neither Kepler, an unstable hypochondiac who was good at geometry, but not much else, nor Tycho, an anal retentive maker of revolutionising instruments and the founder of empirical science, but devoid of ideas, would have been celebrated for four centuries if the one had not worked with the other. The evolution of science has been marked by the influence of non-conformists, but few worked in isolation against the mainstream.

One modern geoscientist who seems rarely to conform is Warren Hamilton of the Colorado School of Mines, and now he has gone for it big time (Hamilton, W.B. 2003. An alternative Earth. *GSA Today*, v. **13**(11), p. 4-12). His starting point is to challenge the consensus among geophysicists and geochemists that the mantle has a still-unfractionated lower part beneath depleted upper mantle which has sourced oceanic and continental lithosphere progressively over time. Linked to that is the notion of easy circulation of material from top to bottom through descending, subducted slabs and plumes rising from the core-mantle boundary. Hamilton says that neither exists, and that upper and lower mantle are decoupled. His challenge stems from the certainty that the Earth accreted "hot, fast and violently", and the strong likelihood that its Moon originated after a titanic collision of Earth with a Mars-sized planet less than 100 Ma after accretion. Chances are it became wholly molten and suffered massive loss of volatiles. Such a body would have fractionated rapidly, to produce a lower mantle very unlike that imagined by most geochemists and geophysicists. Moreover, it would have remained so, partly due to its likely perovskite mineralogy, highly fractionated nature and phase-change barriers to transfer of matter – the 630, 1000 and 2000 km discontinuities. Such an early scenario would have transferred most potassium, uranium and thorium into the outermost Earth, where the generation of radiogenic heat would have concentrated. This is very similar to models proposed in the 1960s and early 70's by J.V. Smith and others, when lunar geochemistry, particularly that of the anorthositic highlands, set in motion ideas about a planet-wide magma ocean and global fractionation as it cooled. Like Smith and others, Hamilton considers continental crust to have formed rapidly, sequestering a large proportion of the elements that make mantle rocks "fertile". But only traces remain in the form of a small pinch of pre-4 Ga zircons, that could easily be lost in a single sneeze. Much of this early sial returned swiftly to the upper mantle to make it increasingly heterogeneous – fertile parts and some not so petrogenetically prone.

The current consensus has its roots, according to Hamilton, in much older ideas about the early phases of Earth's evolution. Harold Urey and others in the 1950s and early 60s considered the planet to have formed by slow, cold accretion of the most primitive meteoritic materials, chondrites, particularly those containing carbonaceous materials. They are petrogenetically highly fertile, and the radioactive heating of a chondritic Earth, plus that from core formation, would involve a continual, slow fractionation of the mantle that would probably still be going on today. That this fundamental set of assumptions still dominates, though is rarely mentioned, is down to the rapidly increasing number of mantle profiles based on seismic tomography, that are claimed to have imaged seismic-speed anomalies that could be explained by both slabs and plumes extending to the core-mantle boundary. Hamilton makes the reasonable point that the very irregular distribution of earthquakes in the top 600 km of the Earth leaves large volumes of the mantle in blind spots, and that the majority that are used are subduction related. That, he suggests, predestines tomograph images to create artifacts that just "look" like deep penetration of descending slabs. Moreover, stunning as they look in publications, there is much graphic sleight of

hand that assigns primary colours to lower mantle anomalies that have an order of magnitude lower amplitude than those at shallower depths, as well as filling unimaged areas with average or interpolated values, placement of sections to look most plausible, and a great deal of data filtering. There is a "fudge factor" that hypes the hoped-for, and avoids alternative data analysis – you can't do this kind of thing on a PC. The plume hypothesis is falsified exactly where it ought not to be – in the Emperor-Hawaiian seamount chain (see *Wandering hot spots* in the September issue of *EPN*). There the great bend dated at 45 Ma is not matched by any known change in the direction of Pacific sea-floor spreading. The magma source for the chain might well be a restricted volume of mantle, but it didn't stay still as a plume must. Seismic tomography, at the time Hamilton's essay went to press, had not verified a single plume sourced in the lower mantle – there are many cases of volcanic hotspots without any plume, and tomographically inferred hot mantle doesn't always have a volcanic expression.
Hamilton's essay is worth reading in its entirety, as it reviews the whole of Earth's tectonic and magmatic evolution. I have just tried to pick out the critical aspects here.

More, or less plumes

In view of Warren Hamilton's questioning the existence of mantle plumes (*Geoscience consensus challenged*), in the same month as his essay appeared a team of seismologists from the universities of Princeton, California, Colorado and the National Taiwan University used a new approach to seismic tomography to seek evidence for plumes (Montelli, R. *et al*, 2003. Finite-frequency tomography reveals a variety of plumes in the mantle. *Science Express* www.sciencexpress.org, 4 December 2003, p, 1-10). They present evidence for 32 suspected plumes. Some have a seismic expression at shallower depths than 650 km in the mantle, such as beneath Iceland and the Galapagos. Others seem to reach as deep as the core-mantle boundary, as beneath Hawaii and the Kerguelen Plateau. In fact most of the classic volcanic hotspots that have associated chains appear to have plumes beneath them, with the exception of Yellowstone. An apparent duality of shallow and deep plumes suggests to the authors a two-tier division in vertically moving mantle, above and below the 660 km discontinuity. The long-suspected major plumes beneath Africaand the Pacific also appear to spawn lesser plumes, that in turn sometimes split

- **IAPC**

Contents

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