

A person is climbing a tall, textured rock face using a ladder. The rock is a mix of brown and tan colors with visible vertical fissures and shadows. The person is wearing a dark shirt and patterned pants. The ladder is made of wooden rungs and metal poles.

# nature geoscience

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**Surface rupture by great  
Himalayan earthquakes**

**VENUS'S ATMOSPHERE**  
More variable than expected

**PINE BEETLE OUTBREAK**  
Canadian climate warmed

**FIVE YEARS OF GEOSCIENCE**  
Nine shifts in perspective





**COVER IMAGE**

The recurrence times of great Himalayan earthquakes are difficult to assess because they rarely rupture the surface. Field mapping and <sup>14</sup>C dating of offset fluvial deposits are used to identify two great Himalayan quakes that ruptured the surface along the main plate boundary fault in AD 1255 and 1934. The image shows the Sir Khola river-cut cliff looking east. Thrust fault F4, outlined by a narrow band of thin dark gouge, is seen to cut obliquely deformed grey Siwalik siltstones. Shyam Bogati, from Cheru village in southeastern Nepal, is refreshing the cliff face. Article p71; News & Views p19

IMAGE: L. BOLLINGER

COVER DESIGN: DAVID SHAND

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**Venus's atmosphere**  
More variable than expected  
Letter p25; News & Views p20

**Pine beetle outbreak**  
Canadian climate warmed  
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**Five years of geoscience**  
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Sulphate concentrations in the ocean before 2.4 billion years ago were lower than today. The sulphur isotope systematics of 2.7-billion-year-old sulphide deposits suggests that these low concentrations were maintained by a balance between hydrothermal sources and microbial sulphate reduction.

Image: © Mark D. Hannington.  
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Every year, thousands of mesoscale storms (termed polar lows) cross the climatically sensitive subpolar North Atlantic Ocean. High-resolution numerical simulations of the ocean circulation, taking into account the effect of these storms on deep-water formation, suggest that polar lows significantly affect the global ocean circulation. Image: © NEODAAS Dundee Satellite Receiving Station.

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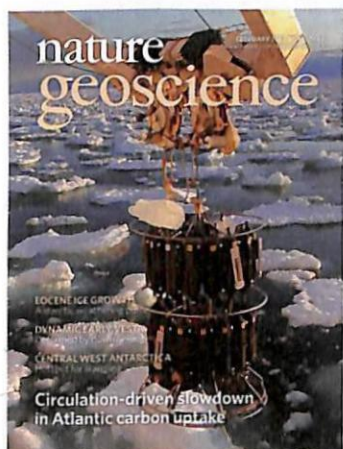
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**COVER IMAGE**

Uptake of atmospheric carbon dioxide in the subpolar North Atlantic Ocean declined rapidly between 1990 and 2006.

An analysis of oceanographic data suggests that the slowdown of the meridional overturning circulation was largely responsible.

The image shows sampling near the southeastern tip of Greenland aboard research vessel Thalassa, 18 June 2002. Article p146

IMAGE: IFREMER-OVIDE

COVER DESIGN: DAVID SHAND

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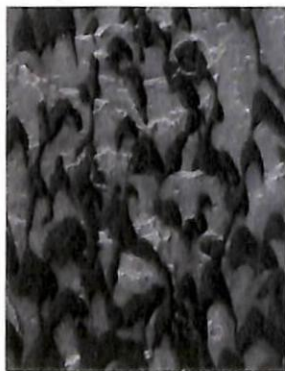






Deposits of highly vesicular pumice that blanket submarine volcanoes are often attributed to explosive eruptions. Density and textural analysis of clasts dredged from the submarine Macaulay Volcano in the southwest Pacific Ocean, however, reveal an eruptive style that is neither explosive nor effusive, with clasts instead forming from buoyant detachment of a magma foam.

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The subsurface of Mars could potentially have contained a vast microbial biosphere. An evaluation of the possibility of groundwater upwelling, which might provide clues to subsurface habitability, reveals evidence in the deep McLaughlin crater for clays and carbonates that probably formed in an alkaline, groundwater-fed lacustrine setting.

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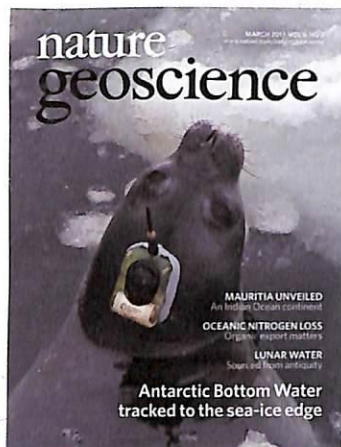
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**COVER IMAGE**

Antarctic Bottom Water fills much of the global abyssal ocean, and is known to form in three main sites in the Southern Ocean. Data from instrumented elephant seals and moorings suggest an additional source of bottom-water formation in the Cape Darnley polynya that is driven by sea-ice production. The image shows an instrumented Weddell seal, deployed together with the Southern elephant seals in the study.

Article p235; News & Views p166

COVER IMAGE: IAIN FIELD

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An Indian Ocean continent  
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**Oceanic nitrogen loss**

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Coccolithophores are a key component of the oceanic food web, and may be sensitive to environmental changes. Modern experiments and an assessment of the fossil record suggests that the response of individual species to a period of ocean acidification in the past may have affected the evolutionary success of these species' lineages.

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The fast flow of glaciers in Greenland during the summer season has been attributed to seasonal increases in subglacial melt water. Tracking the flow of subglacial water using geochemical tracers reveals the establishment of an increasingly efficient drainage network as the melt season progresses.

Image © Dave Chandler

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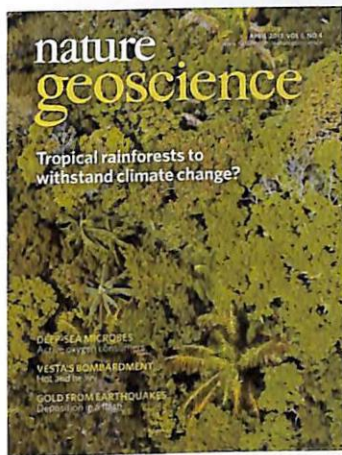
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## COVER IMAGE

Assessing potential future carbon loss from tropical forests is important for evaluating the efficacy of programmes for reducing emissions from deforestation and degradation (REDD). An exploration of results from 22 climate models in conjunction with a land surface scheme suggests that in the Americas, Africa and Asia, the resilience of tropical forests to climate change is higher than expected, although uncertainties are large. The image shows a tropical rainforest canopy.  
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IMAGE: THINKSTOCK/ PHOTODISC

COVER DESIGN: DAVID SHAND

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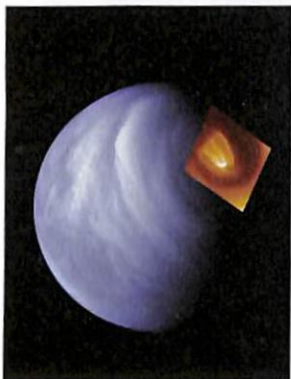
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A whirling vortex has been observed in the atmosphere at the south pole of Venus. Cloud motions tracked by the Venus Express spacecraft suggest that the south polar vortex is long-lived, erratic and baroclinic in character.  
Image © ESA/VIRTIS-Venus Express and VMC teams  
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The micronutrient iron is thought to limit primary production in large regions of the global ocean. Meltwater measurements suggest that the Greenland ice sheet serves as a significant source of potentially bioavailable iron to the surrounding coastal ocean.  
Image © Sarah Das  
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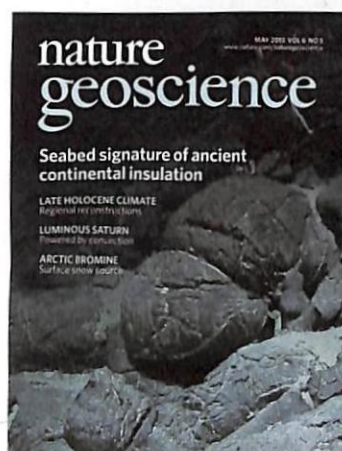
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## COVER IMAGE

The continents are thought to insulate and heat the underlying mantle. Geochemical analyses of lava samples formed at a mid-ocean ridge in the Atlantic Ocean immediately after continental break-up show that the mantle was up to 150 °C hotter than today and took about 70 million years to cool. The image shows pillow lavas — which record the chemical composition of the melts — at the southern Mid-Atlantic Ridge at 9°34'S. Letter p391; News & Views p332

IMAGE: © MARUM, UNIV. BREMEN, GERMANY

COVER DESIGN: DAVID SHAND

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The Antarctic Peninsula is one of the most rapidly warming regions on Earth. A reconstruction of ice melt over the past 2,000 years from an ice core taken near the northeastern tip of the peninsula shows that surface melt has accelerated during the twentieth century.  
Image © Nerilie Abram  
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Lavas erupted from individual volcanic centres often have one of two distinct compositions. High pressure and temperature experiments on lava samples collected from St Vincent Volcano in the Caribbean, combined with thermal modelling, show that this compositional bimodality is generated by volcanic systems with low heat and water content.  
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**COVER IMAGE**

Carbon is carried into the Earth at subduction zones. Geochemical analysis of subducted sediments now exhumed in Alpine Corsica, France, reveal the formation of graphite during shallow subduction, implying that carbonate transformation to graphite aids transport into the deeper Earth. This image shows a contact between hydrothermally altered mantle rocks and blueschist metasediments in Alpine Corsica, France.  
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IMAGE: ALBERTO VITALE BROVARONE  
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Hydrogen is commonly produced during the high-temperature hydration of mafic and ultramafic rocks. Laboratory experiments suggest that water-rock reactions also generate hydrogen at lower temperatures, potentially fuelling microbial life in ultramafic aquifers in oceanic and terrestrial crust. Article p478; News & Views p426

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**COVER IMAGE**

Flow in the deep mantle is thought to create textures in the high-pressure mineral post-perovskite. Laboratory simulations of the transformation between lower-pressure perovskite and post-perovskite show that post-perovskite can also inherit textures from the perovskite phase, and vice versa. This image shows an electron diffraction pattern with strong crystallographic alignment between perovskite and post-perovskite. Letter p575; News & Views p516

IMAGE: DOBSON ET AL.

COVER DESIGN: DAVID SHAND

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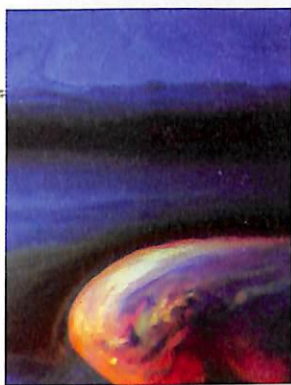
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A Great White Spot — a rare planet-encircling storm — raged on Saturn in 2010–2011. Analyses of high-resolution spacecraft imagery and numerical modelling reveal a dynamic storm head powered by sustained convection in the zonal flow of Saturn's atmosphere. Image: © NASA/JPL-Caltech/SSI and Universidad del País Vasco Letter p525



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## COVER IMAGE

The Lusi mud eruption in Indonesia has been ongoing since 2006. Numerical simulations show that a parabolic-shaped layer in the rock surrounding the site of the Lusi eruption could have amplified and focussed incoming seismic energy from an earthquake, which then triggered the mud eruption. The image shows mud oozing out of the Lapindo well in the district of Sidoarjo, Indonesia, on Monday, 18 September 2006. Letter p642; News & Views p592

IMAGE: BLOOMBERG, GETTY IMAGES

COVER DESIGN: DAVID SHAND

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Owing to the turbulent nature of the ocean, mesoscale eddies are omnipresent. An analysis of atmospheric conditions associated with several hundred thousand eddies in the Southern Ocean suggests that the transitory sea surface temperature fronts associated with these eddies alter near-surface winds, clouds and rainfall.

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The precise location of the mantle plume upwelling beneath Hawaii is debated. Seismic data reveal a thick layer of melt in the mantle beneath western Hawaii, implying that the upwelling plume may be deflected around an ancient, resistive root beneath the island.

Image: © Gabi Laske

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### COVER IMAGE

The remote detection of surface water indigenous to the Moon has proved difficult because of alternative sources, such as the solar wind. Spectroscopic observations of hydroxyl-bearing materials in Bullialdus Crater by the Chandrayaan-1 spacecraft are consistent with indigenous magmatic water that was excavated by impact from the lunar interior. The image shows an oblique view of Bullialdus Crater, taken from the west, about 74 km above the lunar surface, and looking east at the eastern crater wall (north is to the left). The central peak towers 1.1 km above the flat crater floor.

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IMAGE: NASA

COVER DESIGN: DAVID SHAND

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The thawing and decomposition of carbon stored in permafrost generates greenhouse gases that could further intensify global warming. However, the storage and burial of thawed carbon in long- and short-term reservoirs is likely to attenuate greenhouse gas emissions.

Image © Jorien E. Vonk  
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**COVER IMAGE**

During glacial periods, ice sheets covered continental margins through much of Arctic North America, Greenland and western Eurasia. Marine structures suggest that an ice sheet up to a kilometre in depth periodically covered the East Siberian continental shelf as well. The image shows the Korean icebreaker *Araon* conducting a swath bathymetric survey on the Arctic Ocean. Letter p842; News & Views p807

IMAGE: SEUNG PIL HAN

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The buoyancy of magma should cause it to rise into the crust, preventing it from ponding in the uppermost mantle. Magnetotelluric data from the Dabbahu rift segment, Ethiopia, identify a magma reservoir that extends well into the mantle beneath the rift, and is so large that it should persist for thousands of years. Image: Graham Dawes Letter p861; News & Views p811



Anthropogenic aerosols are highly spatially variable, whereas greenhouse gases are largely well-mixed at the global scale, but both affect climate. Nevertheless, climate simulations suggest that regional changes in sea surface temperature and precipitation in response to changes in greenhouse gas and aerosol forcings are similar.

Image: © Frontfoto.com

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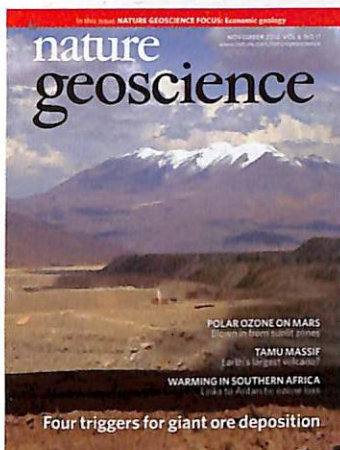
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**COVER IMAGE**

Porphyry ore deposits supply much of the copper, molybdenum, gold and silver used by humans. A review of the main processes that trigger porphyry ore formation suggests that sulphide saturation of the magmas that supply the metals could be the overriding mechanism that helps control the temporal and spatial distribution of the ore deposits. The image shows the view across the Ujina porphyry copper deposit, Collahuasi district, Chilean Andes, looking towards the Bolivian border.  
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IMAGE: JAMIE WILKINSON

COVER DESIGN: DAVID SHAND

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Palaeoclimate records indicate lower El Niño/Southern Oscillation (ENSO) variance during the middle Holocene compared with today, but the mechanisms leading to this muted variability are not clear.

A 175-year oxygen isotope record from a *Porites* coral microatoll in the NINO3.4 region records persistently reduced ENSO variance about 4,300 years ago, and season-specific analyses of the record suggest that insolation played an important role in this change.

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Subglacial meltwater channels beneath the Antarctic Ice Sheet have been reported, but the nature and distribution of these meltwater pathways are unclear. Remote sensing observations reveal persistent channelized features beneath the Filchner Ronne Ice Shelf in West Antarctica, suggesting widespread channelized flow driven by melting.

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William W. Sager, Jinchang Zhang, Jun Korenaga, Takashi Sano, Anthony A. P. Koppers, Mike Widdowson and John J. Mahoney

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**982 Helium in Earth's early core**

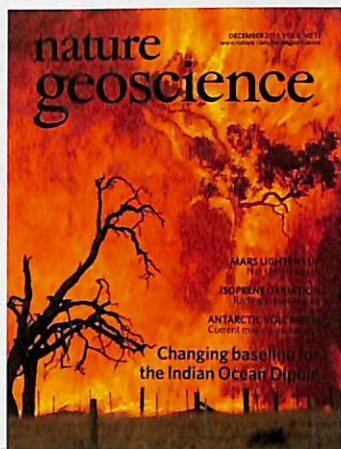
M. A. Bouhifd, Andrew P. Jephcoat, Veronika S. Heber and Simon P. Kelley



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**COVER IMAGE**

The Indian Ocean Dipole is a key mode of interannual climate variability influencing much of Asia and Australia. A Review suggests that in response to greenhouse warming, mean conditions of the Indian Ocean will shift towards a positive dipole state, but with no overall shift in the frequency of positive and negative events as defined relative to the mean climate state. The image shows a devastating bushfire in the small township of Tonimbuk, 90 km east of Melbourne, Australia, in February 2009, following severe austral spring rain deficits between 2006 and 2008, three consecutive years of positive Indian Ocean Dipole events.

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IMAGE: ANDREW BROWNBILL/AAP

COVER DESIGN: DAVID SHAND

**ON THE COVER****Mars lightens up**

Not strictly basalt

Letters p1008 and p1013;

News &amp; Views p991

**Isoprene oxidation**

Radicals regenerated

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**Antarctic volcanism**

Current magma movement

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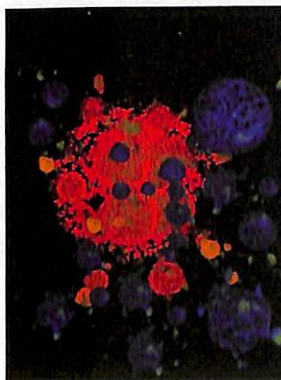
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Modern grasslands are dominated by grasses that use the C<sub>4</sub> photosynthetic pathway, and were established about 8 million years ago. A sediment record suggests that in southwestern Africa, the expansion of grasslands was associated with increasing aridity and fire activity, both of which favour grasses that use the C<sub>4</sub> pathway. Image © Paulus de Wilt Letter p1027



The pressures and temperatures experienced by material flung from craters following impact events are expected to preclude survival of organics. The preservation of biomarkers in impact glass from the Darwin crater in Tasmania suggests that organic matter can survive in the distal products of meteorite impact. Image © Kieren Howard and Deborah Berhanu Letter p1018; Editorial p987

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