Whales in the Desert

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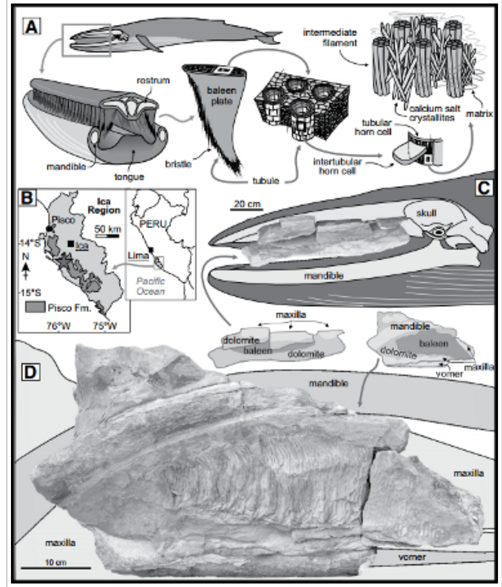
Boulder, Colo., USA - In Cerro Colorado, located in the Ica Desert of Peru, sedimentary sequences dating back nine million years have been found to host the fossil skeletons of hundreds of marine vertebrates. In 2008, remains of a giant raptorial sperm whale, *Livyatan melvillei*, were discovered at this site. In September 2014, the same international team of researchers, guided by Giovanni Bianucci from Pisa University (Italy), found a partial skeleton of a mysticete whale in a rock boulder.

Besides fossil bones of the skull and mandibles, the rock containing the skeleton showed perfect casts of the whale baleen. The exceptionality of the finding is that the casts provide details at the submillimetric scale, revealing under the microscope the subtle structure of the baleen bristles. Indeed, fossilized baleen bristles have been studied for the first time by chemical and mineralogical analyses. The data obtained allow researchers to compare the Miocene whale feeding habits to those of the extant sea whale, and strengthen the preservation potential of the Ica desert for the marine vertebrate fossil record.



Part of figure 1. from highlighted article by Gioncada et al. A: Main baleen features of an extant rorqual, at different scales; tubule diameter ~0.5 mm (modified and redrawn from Szewciw et al., 2010). B: Location of Cerro Colorado, Peru. C: Left baleen rack of the balaenopteroid specimen M1 as found in the field, with drawing showing the original position in the whale skull. D: Right baleen rack of specimen M1. Dolomite concretion is indicated. Click on the image for a somewhat larger figure; higher-resolution images are available from the authors.

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FEATURED ARTICLE
Inside baleen: Exceptional microstructure preservation in a late Miocene whale skeleton from Peru
Anna Gioncada et al., Dipartimento di Scienze della Terra, Università di Pisa, via S. Maria 53, 56126 Pisa, Italy. This article is online at http://geology.gsapubs.org/content/early/2016/08/23/G38216.1.abstract.

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Extensive Noachian fluvial systems in Arabia Terra: Implications for early Martian climate
J.M. Davis et al., Department of Earth Sciences, University College London, London WC1E 6BT, UK. This article is OPEN ACCESS online at http://geology.gsapubs.org/content/early/2016/08/23/G38247.1.abstract.

Extensive systems of fossilized riverbeds have been discovered in an ancient region of the Martian surface called "Arabia Terra," supporting the idea that the now cold and dry Red Planet had a warm and wet climate about 4 billion years ago. This study examined images from NASA's Mars Reconnaissance Orbiter spacecraft at a much higher resolution than was previously possible – 6 meters per pixel compared to 100 meters per pixel. The data reveal the existence of over 17,000 km of fossilized riverbeds which are visible as inverted channels spread across the Arabia Terra plains. Their geological relations with previously mapped areas of Mars suggests that these river systems were active about 3.9-3.7 billion years ago, during Mars' ancient "Noachian" period. Their presence in Arabia Terra is more consistent with "warm and wet" climate models of early Mars than "cold and dry" scenarios.

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Abyssal origin for the early Holocene pulse of unradiogenic neodymium isotopes in Atlantic seawater
Jacob N.W. Howe et al., Department of Earth Sciences, University of Cambridge, Cambridge CB2 3EQ, UK. This article is OPEN ACCESS online at http://geology.gsapubs.org/content/early/2016/08/23/G38155.1.abstract.

Studying how deep ocean circulation changed in the recent geological past helps improve our understanding of the relationship between Earth's ocean and climate. However, as we cannot directly observe the ocean in the past we must rely on indirect information inferred from proxies. The isotopes of the element neodymium are one such proxy that are measured on specific phases on deep sea sediment cores to try and trace where water masses in the deep ocean originated from in the past. In this work we present three new records of neodymium isotopes, measured on sediment cores retrieved from the North Atlantic Ocean, spanning the last ~25,000 years. These records did not show the extreme neodymium isotope changes that have been observed previously in records from cores retrieved from the abyssal Northwest Atlantic during recent warm periods. This finding improves the constraints upon how the neodymium isotope composition of water from the North Atlantic changed during past warm periods. These improved constraints, in turn, allow greater confidence in the interpretation of neodymium isotopes as a tracer of water mass sourcing, thereby enhancing our understating of deep ocean circulation in the past.

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The influence of vegetation on debris-flow initiation during extreme rainfall in the northern Colorado Front Range
Francis K. Rengers et al., U.S. Geological Survey, Denver Federal Center, MS 966, Denver, Colorado 80225, USA. This article is online at http://geology.gsapubs.org/content/early/2016/08/23/G38096.1.abstract.

A week of rain in September 2013 caused regional flooding and more than 1100 debris flows in the Colorado Front Range. The flooding and debris flows combined resulted in eight fatalities, the destruction of 125 houses, and damage to more than 3773 additional houses. After the storm it was noted that 78% of the debris flows originated on south-facing hillslopes, and in the Colorado Front Range it is well known that south-facing slopes have sparse forests with low tree densities. This study focuses on exploring the influence of slope direction and tree density on debris flows. Using remotely sensed image analyses, Francis Rengers and colleagues found that despite the large concentration of debris flows on south-facing slopes, the debris flow density (number of debris flows per square kilometer) was nearly identical on all hillslopes with a similar tree density. Therefore, sparse tree density appears to have a strong influence on debris flow initiation, and as forest density decreases as a result of climate change the risk of debris flows will likely increase.

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Zipper junctions: A new approach to the intersections of conjugate strike-slip faults
John P. Platt, Department of Earth Sciences, University of Southern California, Los Angeles, California 90089-0742, USA; and Cees W. Passchier, Department of Earth Sciences (Institut für Geowissenschaften), Johannes Gutenberg Universität, Becherweg 21, 55128 Mainz, Germany. This article is online at http://geology.gsapubs.org/content/early/2016/08/17/G38058.1.abstract.

Strike-slip faults such as the San Andreas fault in California, USA, are an important type of plate boundary, and are liable to produce damaging earthquakes. In many places around the world, a strike-slip fault with one sense of slip intersects another with the opposite sense of slip at a high angle. An example is the San Andreas fault, which slips to the right, and intersects the Garlock fault, which slips to the left, north of Los Angeles. These intersections present a problem -- if one fault cuts and offsets the other, it should deactivate it, yet in many cases both faults are known to be active. The faults commonly appear to merge without offset, even if they have displacements of tens or hundreds of kilometers. This requires considerable distortion and rotation of the surrounding crust. In this paper, John Platt and Cees Passchier propose that the two faults may zipper up, merging into one fault, so that crust from one side of one of the faults is juxtaposed against crust from the opposite side of the other fault. In some cases the merged fault may un-zip. This idea may help resolve many unanswered questions about how these important faults operate.

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Control of lithospheric inheritance on neotectonic activity in northwestern Canada?

Pascal Audet et al., Department of Earth and Environmental Sciences, University of Ottawa, Ottawa, Ontario K1N 6N5, Canada. This article is online at http://geology.gsapubs.org/content/early/2016/08/17/G38118.1.abstract.

Tectonic inheritance refers to old tectonic boundaries that are more easily reactivated in subsequent reorganization of tectonic plates. However, a precise link between inherited tectonic structures and current earthquake activity is elusive. In this work, Pascal Audet and colleagues use seismic anisotropy data to show that a former tectonic boundary in the northern Canadian Cordillera (northwestern Canada) is preserved in the texture of upper mantle rocks, and coincides with a change in seismicity. Their results indicate that neotectonic activity in modern Cordilleras is controlled in part by inherited upper mantle structures.

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Kimberlites and the start of plate tectonics

R.J. Stern et al., Department of Geoscience, University of Texas at Dallas, Richardson, Texas 75080, USA. This article is online at http://geology.gsapubs.org/content/early/2016/08/17/G38024.1.abstract.

Earth is the only planet we know that has plate tectonics and continental drift. One of the most important unanswered questions in Earth history is when did plate tectonics begin? An international geoscientific team considered kimberlites as a line of evidence in this investigation. Kimberlites are unusual igneous rocks that form when magmas with high concentrations of water and carbon dioxide blast 150 kilometers (~100 miles) or more up through a continent to the surface. Kimberlites are of special interest to geoscientists because they bring the deepest samples of Earth's interior and diamonds to the surface. This study shows that kimberlites rarely erupted before about 1 billion years ago and concluded that the greatly increased abundance of these eruptions in recent Earth history was due to massive increases in the delivery of water deep into the mantle as a result of subduction. Subduction and plate tectonics are intimately related (as shown by animation at https://www.youtube.com/watch?v=6wJBOk9xjto), so the results of this study in conjunction with what is known about other important geological indicators of plate tectonics discussed in the article compel the conclusion that that plate tectonics and continental drift began in earnest no earlier than one billion years ago.

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First terrestrial occurrence of tistarite (Ti_2O_3): Ultra-low oxygen fugacity in the upper mantle beneath Mount Carmel, Israel

W.L. Griffin et al., ARC Centre of Excellence for Core to Crust Fluid Systems and GEMOC, Macquarie University, NSW 2109, Australia. This article is online at http://geology.gsapubs.org/content/early/2016/08/17/G37910.1.abstract.

The oxidation state of a rock can be defined by the state of its iron (ranging from metal to rust); it controls many aspects of fluid fluxes in Earth's upper mantle, including volcanism. In general, iron occurs as an oxide in the upper 250 km of the mantle, but may be present as the metal in the deeper mantle, and this is accepted as the mantle's minimum oxidation state. However, minerals brought up in some volcanic rocks suggest that local volumes of the mantle may have much lower oxidation states -- places where there is very little oxygen at all. This paper describes pockets of molten rock, trapped in aggregates of sapphire ejected ca 100 m.y. ago from volcanoes the Mount Carmel area of Israel. These melts have crystallized a range of unusual minerals that require an environment dominated by methane and hydrogen. Some of these are previously known only from the most primitive meteorites, and they condensed from the solar nebula when it was dominated by hydrogen. The authors propose that fluxes of methane and hydrogen rising from the deep Earth may be a common, but previously unrecognized, phenomenon in volcanic systems related to major plate boundaries.

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Widespread dispersal and aging of organic carbon in shallow marginal seas

Rui Bao et al., Geological Institute, ETH Zürich, Zurich 8092, Switzerland. This article is online at http://geology.gsapubs.org/content/early/2016/08/17/G37948.1.abstract.

Organic carbon with old radiocarbon (14C) ages is a commonly observed phenomenon for many continental shelf settings. However, the nature, causes, and abundance of occurrence of the organic carbon in continental margin surface sediments remain largely undetermined. In this study, we present the results of an extensive survey of the abundance and 14C ages of OC in surface sediments from the Chinese marginal seas. Our findings show that the OC with old 14C ages can be associated with different grain size fraction sediments. We also found that organic matter in the sortable silt fraction has older 14C age than that of other grain size fractions. We propose organic matter associated with this sortable silt fraction as an example and conclude the organic matter associated with the finer sediments is subject to protracted entrainment in resuspension-deposition loops above the seafloor. During the transport in the water volume, the organic matter became aging. This finding sheds new light on the 14C ages of organic matter accumulating in continental shelf sediments, with implications for our understanding of carbon cycling on continental shelves and interpretation of sedimentary records.

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Recycling in debris-filled volcanic vents

A.H. Graettinger et al., Geology Department, University at Buffalo, 126 Cooke Hall, Buffalo, New York 14226, USA. This article is online at http://geology.gsapubs.org/content/early/2016/08/17/G38081.1.abstract.

Explosive eruptions produce deposits that contain newly formed fragments of cooled magma, pieces of surrounding rock, and fragments of both that have been recycled by returning to, or staying in, the vent during the eruption. Recycled clasts are important because they may look similar to fresh magmatic fragments but do contribute to the thermal budget of an eruption. Such clasts have been observed in natural settings, but the use of meter-scale explosion experiments have revealed that many, if not most, of clasts that end up in the deposits of eruptions through debris-filled vents have experienced some form of recycling. These experiments used buried chemical explosives to simulate explosions in volcanic vents full of debris such as maar-diatremes, Strombolian explosions, and eruptions through hydrothermal systems using various tracer materials, like ping pong balls and colored sand, to track the recycling process. Recycling includes falling back into the vent after an explosion, collapse of the deposits surrounding the vent, and/or subsurface mixing by explosions at depth within the vent. Previous interpretations of deposits that assume clasts were deposited directly by the explosion that transported them must be revisited and estimates of thermal budgets require additional consideration in light of these results.

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Tectonic settings of continental crust formation: Insights from Pb isotopes in feldspar inclusions in zircon

Hélène Delavault et al., Department of Earth Sciences, University of St Andrews, North Street, St Andrews KY16 9AL, UK. This article is online at http://geology.gsapubs.org/content/early/2016/08/17/G38117.1.abstract.

For billions of years the continental crust has evolved to form the environment we live in and the resources we depend on, and yet its tectonic settings of formation remain a great matter of debate. At present ~80% of the continental crust is generated along subduction zones, but there is increasing evidence that earlier in Earth's history continents were formed in environments that were either away from plate margins or in an environment which pre-dates plate tectonics. This paper brings new insights into how continents formed, based on ion probe analysis of Pb isotopes in feldspar inclusions within well-dated zircons. Pb isotope data are used to calculate the U/Pb ratios of the juvenile crust as it was extracted from the mantle. Magmas generated in subduction or intraplate settings have markedly different Pb isotopes and U/Pb ratios, and the analysis of Pb isotopes in feldspar inclusions within zircons with a range of crust formation ages should ultimately open new avenues to our understanding of the formation and the evolution of the continental crust through time.

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Nanoscale deformation twinning in xenotime, a new shocked mineral, from the Santa Fe impact structure (New Mexico, USA)

Aaron J. Cavosie et al., TIGeR (The Institute for Geoscience Research), Department of Applied Geology, Curtin University, Perth, WA 6102, Australia. This article is online at http://geology.gsapubs.org/content/early/2016/08/23/G38179.1.abstract.

Shocked minerals are important for studying Earth's the impact history because they provide unique evidence of hypervelocity deformation that is used to confirm an impact origin for suspect craters. High-pressure shock waves generated during meteorite impact produce microscopic deformation features in so-called "shocked" minerals. A new study at the Santa Fe impact structure in New Mexico (USA) by Cavosie et al. reports the first discovery of shock features in the rare-earth orthophosphate mineral xenotime (YPO_4), a mineral not previously known to record shock deformation. The authors used electron backscatter diffraction to analyze xenotime grains from a shocked-quartz-bearing shatter cone in shocked granite. Several of the xenotime grains were found to contain nano-scale deformation twins and other evidence of crystal-plastic deformation attributed to impact. Impact-deformation twins are known to form in other shocked minerals that have a similar structure, such as zircon, but have not previously been reported in xenotime, and were attributed by the authors to have formed at shock conditions from 5-20 GPa based on the conditions required to form shocked quartz and shatter cones. These results highlight the use of xenotime for studying shock deformation.

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Development of cutoff-related knickpoints during early evolution of submarine channels

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Sinuous submarine channels and their deposits are common on the modern seafloor and in the subsurface; they are conduits through which sediment and organic matter are transported to deep-sea basins by sediment gravity flows. Many submarine channels seem to initiate as relatively straight depressions that gradually develop markedly curved bends, due preferential erosion along one side, and the formation of oxbow-like cutoffs is unavoidable at high sinuosities. Using a seismic example from the shallow subsurface of offshore Angola and numerical modeling inspired by a model developed for river meandering, we have investigated cutoff formation in submarine channels and have found that this process results in steep channel segments or knickpoints. The steeper the continental slope where the channel is located, the larger and steeper the knickpoints will be. These knickpoints are likely locations of erosion in the channel and must have a significant impact on the structure of the preserved channel deposits. Although we focus here on incising, overall erosive channels, this process is present in aggradational systems as well and it results in along-channel slope variability without any external influence such as tectonic deformation, sea-level changes, or major avulsions.

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Modeling the oxygen isotope composition of the Antarctic ice sheet and its significance to Pliocene sea level

Edward Gasson et al., Department of Geosciences, University of Massachusetts, Amherst, Massachusetts 01003, USA. This article is online at http://geology.gsapubs.org/content/early/2016/08/23/G38104.1.abstract.

Recent estimates of global mean sea level based on the oxygen isotope composition of mid-Pliocene benthic foraminifera vary from 9 to 21 m above present, which has differing implications for the past stability of the Antarctic ice sheet during an interval with atmospheric CO2 comparable to present. Here we simulate the oxygen isotope composition of the Antarctic ice sheet for a range of configurations using isotope-enabled climate and ice sheet models. We identify which ice sheet configurations are consistent with the oxygen isotope record and suggest a maximum contribution from Antarctica to the mid-Pliocene sea-level highstand of ~13 m. We also highlight that the relationship between the oxygen isotope record and sea level is not constant when ice is lost from deep marine basins, which has important implications for the use of oxygen isotopes as a sea-level proxy.

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How to make a transverse triple junction -- New evidence for the assemblage of Gondwana along the Kaoko-Damara belts, Namibia

Cees Passchier et al., Department of Earth Sciences, Johannes Gutenberg University, 55122 Mainz, Germany. This article is online at http://geology.gsapubs.org/content/early/2016/08/23/G38015.1.abstract.

Earth's continents consist of a mosaic of crustal fragments of different age and origin known as cratons, separated by bands of strongly deformed rocks known as mobile belts. Mobile belts are ancient, eroded mountain belts that formed when oceans between the cratons closed. Triple junctions of mobile belts between cratons can form when an ocean opens oblique to an older mobile belt, and later closes again to form a new mobile belt oblique to the remains of the older, transected one. Such a triple junction therefore has mobile belts of different age. We found an alternative mechanism to form triple junctions in Namibia, where the Congo Craton collided with the Rio de la Plata (RDLP) Craton in the west and with the Kalahari Craton in the south to form the E-W Damara and N-S Kaoko mobile belts. Subsequently, the RDLP Craton slid southward along faults in the Kaoko belt to cover the western end of the Damara mobile belt as a "transverse triple junction." This took place between 590-530 Ma during amalgamation of the supercontinent of Gondwana. The transverse triple junction was later split by the Atlantic ocean, and now lies partly in Africa and South America.

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