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Aguja Saint Exupery, one of seven peaks of the Fitz Roy massif in Argentina

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Deception Island in Antarctica

Deception Island Volcano in Antarctica

Sunlight shines through China's Great Arch of Getu He, Guizhou Province

Kruger National Park, South Africa

FAITHFUL REHABILITATION

History, culture, religion, and engineering all intertwined in a recent project in Jerusalem to rehabilitate and strengthen the site believed to be the tomb of Jesus of Nazareth. Modern methods, including 3-D laser scanning, nondestructive testing techniques, and ground-penetrating radar, combined with careful documentation, revealed the secrets of how to help preserve and sustain the ancient site for future generations.

BY THE NATIONAL TECHNICAL UNIVERSITY OF ATHENS INTERDISCIPLINARY TEAM FOR THE PROTECTIONOF MONUMENTS AND CONTRIBUTING AUTHORS

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Before the recent rehabilitation project, the structure known as the Holy Aedicule, believed to house the tomb in which Jesus of Nazareth was placed after crucifixion, was supported by an iron frame installed in 1947. That frame was removed during the rehabilitation.

For centuries, the site believed by Christians to be the tomb in which Jesus of Nazareth was placed following crucifixion has intrigued religious pilgrims, historians, and scientists. Hewn from the rock at the area known as Golgotha, outside the old city of Jerusalem, the Holy Tomb of Christ, as it is known, has evolved from a burial chamber to a complex aedicule structure surrounding and embedding remnants of the original monolithic tomb.

Known as the Holy Aedicule, the structure is a small, stone-clad masonry building that is located within another building—in this case, the Church of the Resurrection, also known as the Church of the Holy Sepulchre, which was constructed in Jerusalem in AD 326. The Roman emperor Constantine the Great, working with his mother, now known as Saint Helena, is credited with excavating much of the tomb and constructing the original aedicule as well as the church building around it. Over the centuries, the aedicule was expanded and altered in form.

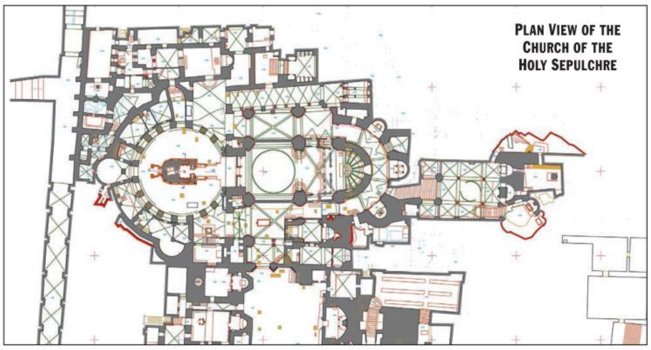
Today, the Holy Aedicule and the Holy Tomb of Christ are not only a mystery to historians and a focal point to the faithful, but also represent important historical and cultural monuments that modern science was called upon to protect and preserve despite considerable engineering challenges. The engineering community was not called upon to resolve issues of faith, of course, but to provide solutions based on scientific methodologies, facts, and sound practices. Their efforts were intended to ensure the structural integrity and sustainability of the Holy Aedicule and to preserve and reveal the historical, cultural, and religious significance the structure represents.

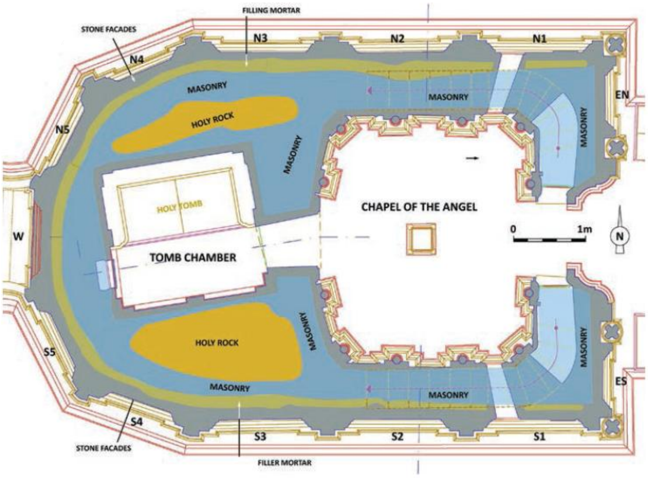
Over the centuries, the Holy Aedicule has sustained considerable damage and deformation. It has also undergone many attempts at reconstruction and interventions designed to restore the site's structural integrity. The most recent attempt at restoration was completed in 1810 by the architect known as Komnenos. Since that effort, however, this unique monument has experienced significant additional damage and deformation, which demanded immediate interventions to reinstate its structural integrity and ensure its sustainable preservation. The deformations of the Holy Aedicule, for example, had reached a dangerous-enough point during the first half of the 20th century that an iron frame was installed around the structure in 1947 to help prevent a collapse. This was during the period of the British Mandate when Great Britain administered the region from 1922 to 1948. The frame represented only a temporary solution, and since then the situation had grown worse, as evidenced by the additional buckling of the aedicule's stone facade and the structure's generally poor state of preservation.

The Holy Tomb of Christ is controlled by three distinct Christian groups—the Greek Orthodox Patriarchate of Jerusalem; the Franciscan Order of the Roman Catholic Church known as the Custody of the Holy Land; and the Armenian Patriarchate of Jerusalem. Together, these groups are designated the three Christian communities, and though they have sometimes sparred—a physical altercation broke out inside the Church of the Resurrection in 2008—they managed to put aside their differences during a recent project designed to rehabilitate the site. This rehabilitation effort began when the National Technical University of Athens (NTUA) was invited to implement an integrated diagnostic research project and strategic planning effort to determine the materials and interventions that would be necessary for the conservation and rehabilitation of the Holy Aedicule.

Because of the complexity of the structure and the lack of appropriate engineering information, the study was conducted through an interdisciplinary approach with innovative technologies and an emphasis on nondestructive testing and integrated documentation.

Specifically, the NTUA team used infrared thermography and portable digital microscopy to assess the state of the exterior and interior stone facings. In parallel, the team also used analytical testing of core samples to characterize the building materials—the mortars and stones—and to detect any evidence of decay. This work combined optical and digital microscopy, scanning electron microscopy coupled with microanalysis, thermal analysis, x-ray diffraction, mercury intrusion porosimetry, total soluble salts tests, and mechanical tests. The results of these tests identified the mortars that support the site's masonry as the critical material and the deterioration of these mortars as the main factor causing the deformations of the aedicule.





PlanView of the Holy Aedicule

The historical mortars used in the aedicule were characterized as slightly hydraulic lime mortars and mixed lime-gypsum mortars and presented high percentages of soluble salts; indeed, the soluble salt levels were found to be extremely high, which indicated that the masonry was in danger of experiencing swelling and salt-induced degradation. Using a reverse-engineering approach, the NTUA team analyzed the historical mortars—in combination with the characteristics of the masonry stones and the prevailing decay factors—and determined that the damaged mortars had to be replaced with a compatible and "performing" restoration mortar; the term "performing" refers to the structural performance of the mortar and its mechanical properties and/or physicochemical performance and durability.

The properties of the restoration mortar that the team selected were assessed by a finite element model of the structure to verify the new material's structural performance before its application. Furthermore, because the aedicule features different layers of material that could not be completely dismantled, the team also determined that it was necessary to apply compatible and performing grouts, along with the new mortars, to strengthen and homogenize the various layers from different construction phases of the monument. The volume of the mortars and grouts necessary to rehabilitate the aedicule was estimated through the volumetric information extracted from a 3-D geometric model.

Cross Sectionof the Holy Aedicule

This 3-D model of the Holy Aedicule was created using image-based techniques and terrestrial laser scanning. The production of the high-resolution model enabled the team to extract the necessary conventional 2-D information. For example, highly accurate specific geodetic measurements were correlated for all areas within the Rotunda—the large, circular space within the western end of the Church of the Resurrection, at the center of which is located the Holy Aedicule—to determine how much the columns of the aedicule had deviated from vertical. Additionally, a combined study involving ground-penetrating radar and architectural analysis was performed to reveal the internal layers of the aedicule and to determine the different construction phases.

Sectionof the 3-D Model of the Holy Aedicule before rehabilitation

Because of the complexity of the aedicule and the limited accessibility the team had to examine its surfaces with ground-penetrating radar, a 2-D approach was used to inspect the aedicule's internal layers. Specifically, a series of layer-by-layer scans was correlated with information from architectural analysis and historical documentation to provide contours representing the internal interfaces corresponding to the main layers. The team also identified the presence of remnants of what is known as the Holy Rock—parts of the original burial chamber that are now embedded within the current aedicule structure—as well as the primary masonry, filling mortar, and stone facades. These georeferenced contours were then integrated to create a 3-D model of the two blocks of the remnants of the Holy Rock, embedded within the western part of the aedicule.

The aedicule was examined under both static and seismic loads via elaborate finite element modeling and analysis. The bearing structure of the Holy Aedicule was assessed in terms of the seismic forces that might threaten its structural integrity as well as the static loads from its constituent materials. The seismic forces were based on the historical seismicity of Jerusalem, according to the current provisions of *Eurocode 8* and the available, international scientific literature. According to the seismic hazard map of Israel, a peak ground acceleration of 0.13*g* accounts for rock conditions in Jerusalem. This peak ground acceleration would have a 10 percent probability of being exceeded in 50 years.

Numerical Models Used to Assess the Dynamic Behavior of the Holy Aedicule

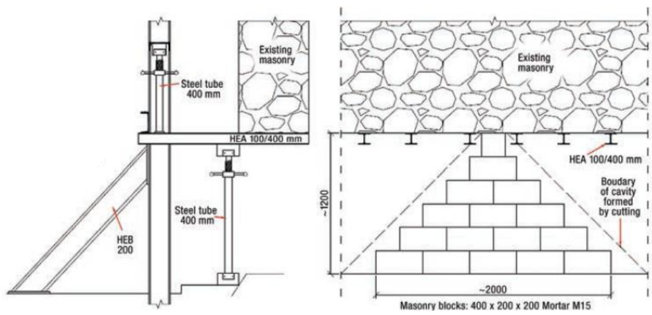
To calculate the acceleration spectrum, the provisions of the current *Eurocode 8* were applied for a Type 1 design earthquake spectrum—meaning, for regions of high or moderate seismicity—and a maximum value of 1.4 as the "importance factor," which puts the site on par with hospitals, power plants, and police stations for protection during the period following an earthquake. The numerical analysis provided the contours of maximum principal stresses for the main bearing body of the structure before the interventions. The analysis also revealed significant cracks in the internal vaults of the aedicule, at the wall that separates two chambers within the structure, and at the area of the internal stairwells where the thickness of the masonry is reduced.

Based on the findings of the NTUA study, a series of interventions was planned, including restoration mortars and grouts, as well as various new reinforcement systems. When these proposed materials and interventions were incorporated into a modified finite element model of the aedicule, it became clear to the team that the proposed rehabilitation would provide adequate strength and reinstate the monument's structural integrity.

A historic agreement—known as the Common Agreement—was signed on March 22, 2016, between the three Christian communities to implement the project, and contributions of 3.7 million euros (U.S. $4.3 million) were raised from sources all over the world to fund the effort. Especially noteworthy were contributions from two trustees of the New York City-based World Monuments Fund—Mica Ertegun and Jack Shear—and donations from Aegean Airlines. An interdisciplinary team from the NTUA was formed and included representatives of the university's schools of chemical engineering, architecture, rural and surveying engineering, and civil engineering. Restoration and conservation working teams were then selected on the basis of the members' expertise in the restoration of important Byzantine monuments and the Acropolis of Athens. Two of the conservators were employees of the Greek Ministry of Culture. A conservation laboratory and an interdisciplinary documentation and monitoring laboratory were established at the site to support the overall project.

The importance of the monument, the complexity of the project, and the site's historical and religious significance—in particular, the need to preserve the Holy Rock—meant that the organization of the worksite and the scheduling of the timetable had to accommodate various restrictions and engineering challenges. Moreover, the site had to remain accessible to pilgrims and those engaged in the performance of religious functions. In combination with safety requirements, this meant that most of the work had to be accomplished at night. Finally, a strict deadline was set to complete the rehabilitation work within 12 months after the signature of the Common Agreement to make sure that Easter celebrations could be held at the rehabilitated Holy Aedicule.

To protect the pilgrims and others at the site, the work areas were concentrated on the north and south sides of the aedicule, creating a corridor to the interior of the monument that was separated from the rest of the Rotunda by metal panels. The work site included a material storage area within the Church of the Resurrection and a conservation laboratory in the Latin Gallery, which is located on an upper floor of the church to the northeast of the aedicule. The frame installed by the British in 1947 at the north and south facades was examined via another finite element model, which indicated that the framing could not be used as a retaining wall during the repositioning of the aedicule's stone cladding. Instead, the frames were further supported and pinned at the base, and the existing steel rods connecting them at the top were retensioned. The structural analysis of the frame also led to the use of diagonal, wide-flange steel HEB 200 beams to strengthen the structure, which was then able to be used as a retaining wall.



Masonry Retaining System

Because the British engineers had not installed a frame on the east or west facades, a new frame was designed and installed to support those sides of the aedicule. Because of the configuration of the front facade of the aedicule and the fact that the monument had to remain open to pilgrims, four vertical HEB 200 beams were fixed to the rock foundation and functioned as cantilevered supports.

The stone tiles of the Rotunda were covered with a false flooring of concrete plates, which, in addition to protecting the stones, also provided even ground for the work equipment. Special crane systems were designed and manufactured to dismantle the stone facades of the aedicule, and access to the exterior surfaces at elevated portions of the structure was provided through a mobile elevation platform and the installation of temporary scaffolding.

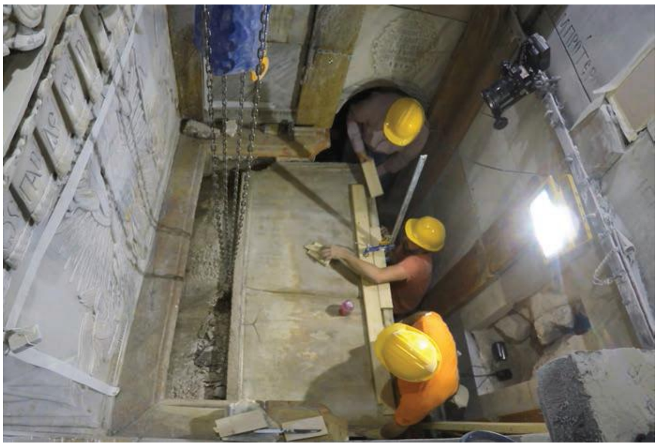
Two wooden lofts were constructed to provide access to key areas of the aedicule. One was installed inside the aedicule structure itself, directly above the tomb, to protect the tomb and the pilgrims who might be there during the interior rehabilitation work. This loft also provided access to an important painting on the wall of the tomb chamber as well as to the interior of the chamber's dome. A second loft was constructed in the Chapel of the Angel, which is the antechamber of the aedicule, to provide access to the chapel's dome for rehabilitation interventions. Additional measures were taken as the rehabilitation work proceeded.

The rehabilitation process began with the dismantling and removal of the stone panels that form the exterior facade. Dismantling took place only in select areas, not across the entire aedicule, because the deformations had been observed only at the middle to lower parts of the overall structure. Each stone slab was fully documented, including by 3-D laser scanning, and transferred to the conservation laboratory to undergo cleaning and protection interventions. The structural integrity of the remaining cladding had to be ensured following the removal of the lower panels. As a result, the aedicule's arches were supported with timber elements and scaffolding. Behind the stone panels, the disintegrated filling mortar was removed, the inner rubble-type masonry of the structure was revealed, and the joints were cleaned. A compatible and performing restoration mortar, as selected during the study, was applied to restore the masonry.

Unfortunately, some parts of the masonry—mainly corresponding to the areas around the tomb chamber—were in such a poor state of preservation that reconstruction was required to ensure the aedicule's structural integrity. The existing, low-strength masonry was removed, in some cases up to a height of 2 m and to a depth that varied depending on the curvature of the remnants of the Holy Rock. During this process, a special retaining system was designed to work with the existing frame, imposing upward vertical loads to avoid collapse of the upper part of the wall. Part of the original masonry was also removed in such a way as to form an arch, which was then filled with the reconstructed masonry.

The dislocated columns inside the aedicule as well as on the external facade were reset, the external columns vertically realigned using actuators. The changes to the deviations from vertical were verified throughout all the phases of the work by comparing them to documented information.

The homogenization of the structural layers of the aedicule and the consolidation of the Holy Rock remnants were achieved by the injection of compatible and performing grouts. Geometric and architectural data facilitated the design and documentation of the grout injection tube design. The installation of the injection pipes created a matrix at different depths, based on sections of the geometric model and the results from the ground-penetrating radar analysis. Advanced nondestructive testing techniques were used to assess the effectiveness of the grouting materials and



The opening of the Holy Tomb involved lifting a marble plate, above. A glass window, below, was installed at the south wall of the interior of the tomb to provide views of the Holy Rock.

procedures, and an analysis of the grout volume distribution showed that grouting was successful in homogenizing the interface between the restoration masonry and the Holy Rock remnants.

The grouting was carried out in three zones along the height of the aedicule. The first zone began at the floor level and moved up 1.5 m. The second zone measured from 1.5 m to 3 m of the height, reaching to the top of an arch. The third zone encompassed the uppermost portions of the aedicule facade, as well as the roof of the structure. Before the grouting work in the first zone—after the Holy Tomb had been examined with ground-penetrating radar, ultrasonic tomography, and endoscopy—the three Christian communities decided that the tomb should be opened to protect its interior from any overflow of the grout material that would then solidify inside the tomb. To open the tomb involved lifting a large marble slab that was embedded in the marble cladding around the tomb. Because this slab was already partially cut at the middle, it was quite probable that the marble would crack from the bending that could occur during the removal process. To avoid such damage, the slab was removed by sliding it open, like a drawer. The opening of the Holy Tomb of Christ, which was performed to control the grouting procedure, revealed the original rock surface on which Jesus's body is believed to have been placed. During the grouting procedure this surface was protected from grout flow, which preserved the monument's significance while also ensuring the longevity of the site. A window-like opening was also created in the interior wall opposite the tomb to control the grouting at the south interior area.

The grouting of the second and third zones also had to be undertaken with considerable care so as to not damage the interior frescoes.

The internal marble cladding of the aedicule is part of the load-bearing structure, and thus none of its members could be removed. The Coptic Chapel, however, which is a small, partially enclosed space framed in iron lattices, was relocated from the west side of the aedicule to another section within the Rotunda. A series of iron rods that had been used in the construction of the aedicule had become partially oxidized, and in some locations had even completely disintegrated; a corrosion inhibitor was applied to preserve the remaining sections of the rods.

Following the strengthening of the main masonry, the external stone panels were reassembled. The first step in this process involved the use of titanium bars to anchor the cladding. Titanium bars were chosen for their significant durability and high level of compatibility with the historical masonry. Being cylindrical with smooth surfaces, however, the bars were initially unsuitable for use as anchors. So they were passed through a deformer that created closely spaced ribs that differ from those of steel rebar in terms of distance and shape. While literature and standards exist that describe the bond created between steel rebar and concrete or masonry, those documents were not applicable to these specially deformed titanium bars. Instead, a series of extensive pull-out tests were conducted on the proposed titanium anchorage techniques. Grade 2 titanium bars were used in these bend tests, which demonstrated that the bars would neither rupture nor crack if used to anchor the stone cladding to the interior masonry wall. The cladding consists of two types of stone: a beige limestone and a dolomitic limestone with a pink hue and touches of beige.

Two key details were examined during the tests: the connection of the titanium bars to the cladding, and the bond between the bars and the existing interior wall. One end of the deformed bars was either threaded or curved. Two different types of connections between the titanium bars and the stone cladding were adopted. In the first case, a hole was drilled in the stone and the threaded end of the titanium bar was fixed with a titanium nut and washer; the hole was then filled in with a matching piece of stone. In the second case, the curved end of the bar functioned as a hook. Depending on the depth of the masonry wall, the test then used either a nut and a washer—in the case of walls with shallow depths—or a deformed bar was anchored directly to the wall using mortar, in the case of walls with greater depths. A compatible and performing restoration mortar was used, presenting a compressive strength of 16 MPa over a period of 28 days and a bond strength of 0.15 MPa. The mortar was injected into a 20 mm diameter hole for the nut-and-washer test or a 38 mm diameter hole for the mortar-anchorage test.

A titanium mesh was then installed over the strengthened masonry to augment the bond between the successive concrete layers. After the reassembly of the slabs, a compatible and performing restoration concrete was added in the layers between the external stone slabs and the reinforced masonry.

An assessment of the rehabilitation interventions was then accomplished through an integrated interdisciplinary approach. Throughout the rehabilitation process, all data pertaining to the materials were documented, including the volume and distribution of the grout, the spatial quantifications of the applied concrete, and other details. A 3-D geometric model of the aedicule was created through automated 3-D imaging combining high-resolution digital images, terrestrial laser scanning, and highly accurate geodetic measurements to represent the state of the structure following the rehabilitation interventions. This 3-D geometric model was used, in conjunction with information regarding the applied materials and implemented interventions, to optimize the finite-element model. This optimized model was used to assess the retrofitted bearing structure, and it confirmed that structural integrity was indeed achieved.

In addition, a network of reference points was established around the Holy Aedicule to support the georeferencing of the 3-D model and to monitor the eventual deformations and displacements of the monument. A 3-D network composed of 20 points was measured in eight different phases through the use of a high-precision surveying system with a ±1 mm coordinate accuracy. A permanent monitoring system was also established and activated to provide continuous remote supervision of the structure. The changes in position of the different parts of the columns at the north and south facade of the aedicule could be determined for the last 70 years because the British engineers who installed the iron frame in 1947 also registered the deviation of each column from vertical at that time. The results from this assessment convinced the rehabilitation project members that it was safe to remove the iron frame, thus "freeing" the Holy Aedicule after 70 years.

The work revealed that the problems in the bearing structure of the monument surrounding the Holy Rock were, indeed, extremely serious. If these problems had not been addressed now, the net impact on the monument would have been negative and irreversible.

The Holy Aedicule is now at a state in which structural integrity has been ensured, deformations and displacements have been negated, and the exterior and interior surfaces have been cleaned, protected, and highlighted. But the ultimate goal of any rehabilitation project, especially one that concerns such an emblematic monument, is its sustainability. Throughout the work, the ongoing documentation and monitoring was an essential tool not only for making decisions but also for elucidating factors that could jeopardize the monument's sustainability.

A critical example involves the problems of rising damp and moisture transfer within and around the aedicule. These concerns were discovered in the initial stages of the work during the monitoring of the nondestructive testing and the use of infrared thermography. Correlation of these findings with the poor state of preservation of the filling mortar and parts of the main masonry resulted in an investigation of the surrounding underground areas using geophysical methods, including the systematic documentation of a network of existing underground cisterns and channels beneath the Church of the Resurrection. Specifically, ground-penetrating radar and electrical resistivity tomography revealed an array of underground features, either natural or man-made and often interconnected with each other, that enabled the flow of moisture, potentially threatening the foundations of the aedicule.

Likewise, the geometric documentation of accessible underground areas—for example, the large cistern at the north side of the Rotunda floor as well as a channel connecting it to the aedicule—highlighted the importance of the water-drainage and water-storage infrastructure within the church throughout its history and the serious potential problems that could be caused by the resulting humidity. Various excavations around the aedicule, where remnants of structures dating to the Constantinian era have been discovered, highlighted the complexity of the surface morphology, especially beneath the Rotunda floor, which is closely correlated with the moisture transfer phenomena. This was especially true at the south part of the Rotunda floor, where an earlier excavation had revealed the existing underpinning to be highly corroded and the supporting materials to be in a state of intense deterioration. Clearly, this area had been affected by vapor condensation, leakage, and moisture transfer. The close proximity of such areas to the aedicule underlined the need to monitor and control the transfer of moisture below and around the monument.

This will be achieved through two interrelated approaches. The first approach, already adopted, involved the rehabilitation described above. These efforts addressed the moisture-related damage that the structure had sustained before its rehabilitation and improved its durability against environmental factors. In addition to these interventions, a ventilation and dehumidification system was designed and installed at the roof of the aedicule. The new system monitors and controls the microclimatic conditions within the tomb chamber and the Chapel of the Angel, as well as the space behind a new observation window that was installed in the south wall of the tomb chamber so that pilgrims could view the remnants of the Holy Rock. Data acquired from the monitoring system permits the dynamic adjustment of the function levels of ventilation and dehumidification systems. This is a critical issue, as the aedicule will have to sustain and address increasing environmental loads because of the rising number of pilgrims each year.

The second approach to controlling the transfer of moisture, which has not yet been fully implemented, focuses on the foundations of the Holy Aedicule and will involve interventions to underpin and reinforce those foundations, while also controlling water and humidity levels at the site. To this end, an integrated study is being implemented to determine exactly what type of foundation currently supports the aedicule. The study will also document the locations of conduits, cisterns, and other underground voids in the proximity of the aedicule; assess the structural condition of the foundations and their current state of reliability; and analyze the effects of long-term ground deterioration on foundation settlement and tilt.

To date, the study has determined that the surface of the natural rock of the quarry below and close to the foundation of the aedicule is strongly irregular, reaching about 3 m below the floor. Neither the aedicule nor the pillars of the Rotunda are founded directly on natural rock. Instead, they are supported on either a thin bedding layer of low silicate mortar, 20 to 30 cm thick, that has degraded because of the long-term effects of moisture, or they are founded on the rubble of older structures that are possibly not sufficiently consolidated.

A numerical analysis of the aedicule's foundation system reveals a differential settlement of the structure because of a long-term reduction in the rubble's stiffness. The proposed interventions will involve the excavation of the natural rock and the construction of a peripheral drainage and ventilation gallery, in combination with grouting of the rubble and/or removing it and replacing it with compatible and performing mortar and stonework. An excavated area south of the aedicule will be drained and ventilated, and the existing reinforced-concrete slab of the floor will be replaced by a 15 cm thick glass-fiber-reinforced concrete slab that might also feature a glass opening to facilitate an inspection of the antiquities. The peripheral drainage and ventilation gallery will include the installation of an open canal and pipes in a space below the perimeter gallery to drain the rising underground water between the new foundation and the natural rock. A ventilating system will be constructed for the best aeration and humidity regulation of the perimeter corridor, the cistern, and an earlier excavation site. In addition, a new functional sewage and rainwater network will be constructed within the perimeter of the Rotunda to replace the complex existing network.

The rehabilitation of the Holy Aedicule was successfully completed as planned and on time, with financial transparency and economy. An inauguration ceremony was held on March 22, 2017—exactly one year after the signing of the agreement that launched the restoration effort. Thanks to that effort, and a cooperative calendar, the three Christian communities each celebrated Easter on April 16 at the restored monument.

The future work planned for the site is of utmost importance to ensure the overall sustainability of the Holy Tomb of Christ and its surrounding structure.

The proposals and the related detailed studies for these additional efforts have been presented to the three Christian communities for their consideration. Because of the work completed so far, however, the Holy Tomb of Christ will continue for years to come as a living monument that speaks to all humanity, the engineering innovations that were employed serving only to amplify its voice. **CE**

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THE AUTHORS WISH TO ACKNOWLEDGE the leaders of the Christian communities: His Beatitude the Greek Orthodox Patriarch of Jerusalem Theophilos III; His Paternity Archbishop Pierbattista Pizzaballa, who was the Custos of the Holy Land until May 2016 and is now the Apostolic Administrator of the Latin Patriarchate of Jerusalem; Father Francesco Patton, who has been Custos of the Holy Land since June 2016; and His Beatitude the Armenian Patriarch of Jerusalem Nourhan Manougian. Acknowledgements are also attributed to the members of the Holy Sepulchre Common Technical Bureau: Theo Mitropoulos, Ph.D., the director of the Common Technical Bureau and construction site manager; Osama Hamdan; Carla Benelli; and Irene Badalian.

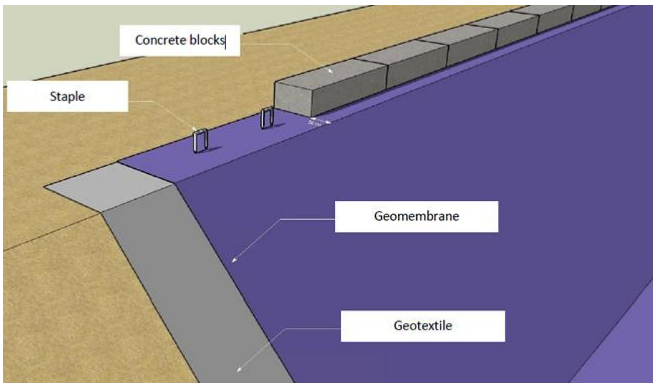
THE NATIONAL Geographic Society, in Washington, D.C., is hosting a new exhibit, "Tomb of Christ: The Church of the Holy Sepulchre Experience," at its Washington-based museum. The exhibit is scheduled to open this month and run until August 15, 2018. Described as "an immersive 3-D experience," the exhibit will enable visitors "to virtually visit the church and learn about its storied history and enduring mysteries," explains the National Geographic website that discusses the exhibition: www.nationalgeographic.org/dc/exhibitions/tomb-of-christ.

The National Technical University of Athens (NTUA) Interdisciplinary Team for the Protection of Monuments includes: Antonia Moropoulou, a professor at the NTUA School of Chemical Engineering and the chief scientific supervisor during the Holy Aedicule rehabilitation project; Emmanuel Korres, an emeritus professor in the NTUA School of Architecture; Andreas Georgopoulos, a professor in the NTUA School of Rural and Surveying Engineering, Laboratory of Photogrammetry; Constantine Spyrakos, a professor at the NTUA School of Civil Engineering, Laboratory for Earthquake Engineering; and Charalampos Mouzakis, an assistant professor at the NTUA School of Civil Engineering, Laboratory for Earthquake Engineering. The contributing authors include: Evangelia Lambrou, an associate professor at the NTUA School of Rural and Surveying Engineering, Laboratory of General Geodesy; George Pantazis, an associate professor at the NTUA School of Rural and Surveying Engineering, Laboratory of General Geodesy; Michael Kavvadas, an associate professor at the NTUA School of Civil Engineering, Department of Geotechnical Engineering; Paul Marinos, an emeritus professor at the NTUA School of Civil Engineering, Department of Geotechnical Engineering; Nikolaos Moropoulos, a civil engineer and the project manager of the rehabilitation project; Vasilis Zafeiris, a civil engineer and the assistant deputy construction site manager of the project and head of the restorers team; Kyriakos Lampropoulos, Ph.D., a researcher and teacher at the NTUA School of Chemical Engineering; Maria Apostolopoulou, a Ph.D. candidate at the NTUA School of Chemical Engineering; Charilaos Maniatakis, Ph.D., a researcher at the NTUA School of Civil Engineering, Laboratory for Earthquake Engineering; Manuel Agapakis, a mechanical engineer, John Agapakis, a chemical engineer; and Andreas Fragkiadoulakis, a mechanical engineer at the NTUA School of Chemical Engineering.

(ASCE, Civil Engineering Magazine, Volume 87, Issue 10, November 2017, pp. 54-61, 78, https://ascelibrary.org/toc/ciegag/87/10)

General Recommendations for Geomembranes in Barrier Systems

The International Geosynthetics Society's French Chapter (CFG – Le Comité Français des Géosynthétiques) has published an English-language version of its key document Fascicle 10, "General recommendations for the use of geomembranes in barrier systems." The resource, which is free for downloading on the IGS French Chatper's website, pertains to design, construction, and site inspection. The CFG's website has links to numerous other guidance documents in geosynthetics too.



An example of anchorage with concrete border. From "General Recommendations for the Use of Geomembranes in Barrier Systems" by CFG (IGS French Chapter).

GENERAL RECOMMENDATIONS, GEOMEMBRANE BARRIER SYSTEMS

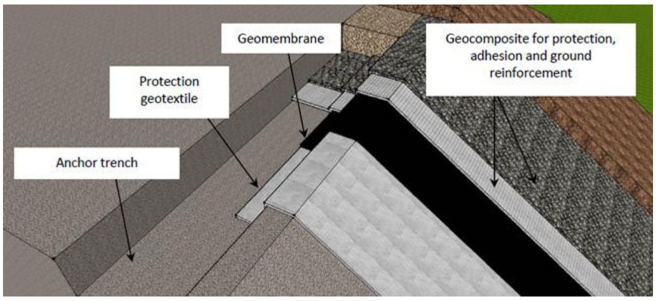
"General recommendations for the use of geomembranes in barrier systems" is intended to be used as a practical guide. The document's objective is to provide general information about lining systems, and in particular about geomembranes themselves.

"The goal is to give professionals in this field the necessary elements to assist in the conception, implementation, control, reception, monitoring, and maintenance of the works in question," the CFG notes in a release about the document's English-language availability.

Included in the publication is a collection of definitions, information, and recommendations used by professionals in the field (e.g., project managers, contractors, laboratories, geosynthetic manufacturers, installers, etc.). Applications of note include:

- Hydraulic works (e.g., dams, ponds, canals)
- Containment structures for solid and liquid materials
- Roads and railways.

Roughly 20 CFG members participated in the updating of the guide between 2010 and 2016. Their work adds a substantial body of project and research insight to the original version of the to take into account the many technical and regulation evolutions since the publication of its original version of "General recommendations for the use of geomembranes in barrier systems," which was first published in 1991.



An example of pond with vegetated upper protection. From "General Recommendations for the Use of Geomembranes in Barrier Systems" by CFG (IGS French Chapter).

The CFG itself is celebrating its 40th anniversary this year. Paris was the site of what has become known as the First International Conference on Geosynthetics (1 ICG, 1977, Paris). The activities of its chapter members over the years have been instrumental not just to the practice of geosynthetics in France but throughout the world.

"This guide of recommendations is essential for all professionals," says Paul Guinard, President of APRODEG (French Association of Producers of Geomembranes) and moderator of the working group dedicated to the revision of Fascicle 10. "That is why, for the first time, the CFG has decided to publish it in English language with the aim of imposing it to the greatest number of professionals as THE reference for the implementation of geomembranes on all the hydraulic, containment, and platforms projects throughout the world."

This new guide presents many evolutions, particularly for:

- Design: Integration of consequences classes concepts, requirement for a geotextile protection under the geomembrane, integration of certifications, definitions of minimum characteristics for geomembranes
- Realization: Recommendations for the realization of the support and the drainage, for the implementation of the geomembrane, the assemblies and the connections to the structures / upper layers
- Controls, insurance, and disputes: Advice on setting up controls, presentation of the roles of the various stakeholders, add-on insurance and litigation

Appendixes to the document provide a glossary, a bibliography and additional normative document listing, characteristics and minimum performance criteria/data for geomembranes, and specification development assistance.

Note that this document cannot be assimilated to a French homologation procedure and/or a French standard. Its use must stem strictly from a voluntary approach on the part of the user.

(Chris Kelsey / Geosynthetica, November 2, 2017, https://www.geosynthetica.net/geomembranes-barrier-systems-cfg-recommendations)

Download the 80-page PDF of General Recommendations for the Use of Geomembranes in Barrier Systems directly (http://www.cfg.asso.fr/sites/default/files/files/publications/FASCICULE_N10_english.pdf).

Monitoring Reservoir-Induced Landslides Near China's Jinsha River

Endi Zhai, Fan Qixiang And Jin Hua

With four large hydropower projects located within the geologically challenging Sichuan and Yunnan provinces, China Three Gorges instituted a monitoring and analysis program to help guard against catastrophic events.

The China Three Gorges Corp. (CTG) developed four hydropower stations along 600 km of China's Jinsha River. These plants include 6.4-GW Xiangjiaba, 10.2-GW Wudongde, 13.9-GW Xiluodu and 16-GW Baihetan. Located in the transitional region that stretches from the Tibetan Plateau and Yunnan-Guizhou Plateau to the Sichuan Basin, they are in an area with complex geological conditions that have caused hundreds of landslides.

Xiangjiaba and Xiluodu were completed first, in 2014, and investigations into the reservoirs at each showed potential geohazards including landslides, crumble accumulation and rock deformation areas.

Holocene and late-Pleistocene active faults are quite developed, widely distributed, of immense scale and in multiple directions, and have high amplitudes and complex internal structures. Some of these fault zones also consist of several parallel or intersecting secondary faults.

Main fault zones in the region include the Leshan-Yibin, Mabian-Yanjin, Ebian-Jinyang, Daliangshan, Zemuhe, Xiaojiang, Mopanshan-Yuanmou, and the Lianfeng-Huayingshan, with past earthquakes exhibiting magnitudes between 6.0 and 7.0 and more than 20 greater than 7.0.

Establishing a geohazard monitoring system

During the first years of operation at Xiangjiaba and Xiluodu, old landslides became active, causing adverse modification to the landscape.

These landslides were caused by reservoir impoundment and/or heavy rainfall. To avoid or reduce the loss of life and property, CTG researched the early prediction of landslides, using real-time monitoring and warnings in the influence zones of potential landslides.

For monitoring, an emphasis was placed on surface deformation measurements, while also taking into account what might be occurring at lower depths.

Surface monitoring involved measuring horizontal and vertical displacements, while the rate of deformation was measured using the global navigation satellite system (GNSS), which includes global positioning systems (GPS), the Russian GLObal navigation satellite systems (GLONASS) and other traditional geotechnical monitoring equipment such as inclinometers and surface monuments.

A reference network was created by installing surface deformation monitoring monuments and sub-control centers at areas having the potential for a collapsible reservoir bank or landslide.

To monitor deeper deformations, inclinometers were installed at potentially collapsible banks or landslide sites at depths usually about 5 m deeper than the sliding surfaces.

Automatic rain gauges were also installed to collect precipitation information at or near areas of concern.

A total control center was set up at CTG's Chengdu regional headquarters to store and analyze data from the affected areas.

Monitoring ground deformation for the Yulin II landslide

The Yulin II Landslide occurred in April 2017 and is located on the right bank of the Xiluodu reservoir area in Yunnan Province, about 39 km away from the dam. Large deformation of more than 10 m occurred, and some areas near the river bank collapsed into the river, but the overall landslide area just deforms. The deformation area is about 200,000 m^3 with a dimension of about 700 m perpendicular to the direction of the river. The maximum depth of the sliding surface is about 100 m, and the overall sliding volume is about 12 million m^3.

The geological condition at the landslide area has some bedrock outcrops with a formation of Ordovician and Silurian Luau (O3+S (s)). The lithology consists of dark gray, grayish yellow, yellow green sandstone, siltstone, mudstone, shale, sandy shale and marl argillaceous limestone. The bedrock is more overlaid with the by slope residual mulch. The stratum topography is N150 ~ 200 W/SW < 600 ~700, and the attitude is stable that is along the sloping shore slope. The main substance of the landslide is grey yellow ~ brown yellow gravel soil with a gravel content of about 30%, more than 0.5~2.0cm in grain size, more compact structure, lower surface and edge covered by limestone stone collapse, stone size 0.1~0.5m, with the maximum being 2 m.

A deformation body began forming in August 2016 as a result of landslides, creating cracks, sliding and vertical distortion.

Nine GNSS monitoring points, three GNSS transfer stations, one automatic Pluviometer and one sub-control center have been installed within the sliding zone in the past two to three years.

Data could be read automatically every second, but to save storage space, the data is typically read on a daily basis during the dry season and hourly in the rainy season. The rainy season in the lower reach of the Jinsha River region typically runs from May to October.

As of April 2017, the cumulative displacements measured by GNSS ranged from 10,416.2 mm to 14,228.2 mm. The settlement value was between 5,692.8 mm and 10,686.2 mm.

The slope deformation area was divided into two parts, called Zones A and B. Zone A, which had more significant movement, represents the local area of a single designated measurement point, and Zone B represents other areas within the overall landslide zone. Data collected was used to measure the relationship between the vertical displacement and reservoir level, also factoring in rainfall intensity.

This is detailed in Table 1, which lists the average and maximum displacement rates for select periods at points designated "TP03" and "TP06" when the rates were so significant that it caused CTG's management to ready its reconnaissance team for a potential emergency.

Table 1: Average and Maximum Displacement Rates for Selected Periods

Start date	End date	Reservoir Level (m)		Reservoir level rate (m/d)	Average hor. disp. rate (mm/d)	Max. hor. disp. rate (mm/d)	Average settlement rate (mm/d)	Max. settlement rate (mm/d)
				Monitoring point TP03				
9/15/13	9/30/13	552.5	540.2	0.8	59.1	114.8	51.7	89.3
3/27/14	5/23/14	562.4	540.8	0.4	46.3	183.2	41.4	150.9
3/21/15	6/14/15	593.8	545.2	0.6	49.4	172.2	45	159.6
				Monitoring point TP06				
9/15/13	9/30/13	552.46	540.2	0.8	67.7	137.7	30.4	117.8
3/27/14	5/23/14	562.44	540.8	0.4	53.4	175.4	23.9	72.9
3/21/15	6/14/15	593.8	545.2	0.6	57.8	201.6	26.3	93.9

After Xiluodu reservoir's impoundment, geological monitoring showed the landslide was reactivated — the disintegration was serious and the deformation was strong. At present, the landslide movement has decreased, but it is still in the sliding phase. The whole body tends to be unstable, but the possibility of the entire mass sliding at high speed is small.

The accumulative displacement of each measuring is still increasing, but the rate has become insignificant. The horizontal displacement across the river has reached 10 m to 14 m, the overall settlement is roughly 10 m, and the maximum deformation rate was 202 mm/day.

It is the largest landslide deformation rate measured by CTG for a landslide that has not yet collapsed. As such, a continuous monitoring and warning system are in place, and a risk assessment for the collapse condition is ongoing. A retrofit might be necessary if the risk is found to be intolerable.

Safety analysis for a deformation body surge in Xiluodu Reservoir

Due to continuous rainfall during the wet season in 2016, a deformation body located about 7 km from Xiluodo Dam was designated for emergency examination. The deformation body is located about 400 m from the Jinsha River's edge and about 500 m above it.

The deformation body began to skew and produced cracks on August 2. Multiple cracks appeared on a highway and lateral slope surface. The biggest crack paralleled the Jinsha River, with a length of about 200 m, an open width of 1 cm to 5 cm, and a vertical distortion ranging from 10 cm to 80 cm. A series of small sliding phenomenon happened at the front edge of the deformation body near the bedrock steep and a small gully.

CTG installed a number of monitoring points to obtain real-time deformation conditions, which began Aug. 18, 2016. As of April 24, 2017, the edge closest to the river had an accumulative horizontal displacement of 36 mm to 67 mm, and the back edge displacement has reached up to 46 mm.

It appeared the deformation belonged to the local superficial sliding due to insufficient drainage along the roadway. Given the current deformation situation, it is less likely that the ancient landslide could cause large-scale integration sliding. But, in the case of continuous rainfall, small sliding and deformations might happen.

Because of the close distance of the deformation body to Xiluodu Dam (7 km) and the nearby Majiahe Dam (4 km) and Huangjuebao Wharf (1 km), secondary disasters, such as surge, could occur. Thus, an urgent safety assessment was performed.

If the deformation body were to slide into the Jinsha River as a whole with the reservoir level at 574 m, the surge height would be 113.2 m at the entry point, producing a maximum surge of 50.4 m on the opposite riverbank. The surge would decay quickly downstream, peaking at 4 m at Majiahe and 2.2 m at Xiluodu.

The assessment showed the deformation body consists primarily of gravel with poor cementation, so it would not be possible for it to slide into the river as a whole. And even if it were to slide simultaneously, collisions with the bedrock slope surface would cause it to disintegrate. The speed of entry into the water would also be greatly reduced due to the slope's topography.

Therefore, it was estimated that the deformation body, at the current scale, would not pose a significant safety issue for Xiluodu.

Monitoring and stability assessment for mega landslide near hydropower station

The Jinpingzhi Landslide is located about 900 m downstream of Wudongde Dam. The overall volume of the landslide is more than 1 billion m^3. Its stability is crucial for Wudongde.

According to its topography, this landslide can be divided into five zones. Zones 1, 2 and 3 are quarternary accumulation bodies, and 4 and 5 are in-situ bedrock with good stability. Zone 2 is a strong creep deformation zone, with a maximum deformation speed of 0.5 m/year at its leading edge.

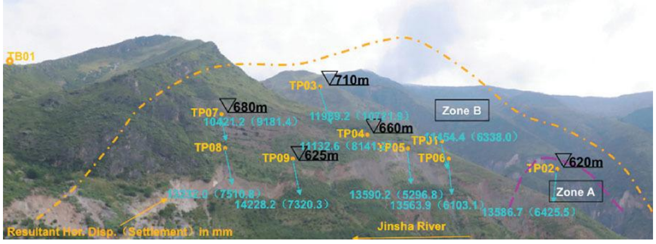
Therefore, the failure mode and damage scale for Zone 2 have been monitored and assessed with 17 monitoring points.

The general characteristics of Zone 2's deformations showed a gradual increase in the displacement rate at each monitoring point from its trailing edge to leading edge, with the direction pointing toward the Jinsha River, making it a pull-type landslide. The failure mode would be multistage traction sliding.

CTG's design consultant performed numerous field investigations, lab testing and numerical analysis for the landslide. CTG's review team reviewed monitoring data and performed a check against the consultant's work, using the limit equilibrium and Morgenstern-Price methods to calculate the safety factor in different loading conditions of the landslide's state.

CTG also performed a check for mitigation measures. These include the construction of five parallel drainage tunnels with several branch tunnels for the quick dissipation of ground water.

From the landslide's leading to trailing edge, the safety factor increased gradually, presenting the characteristics of traction-type damage. It is consistent with the deformation law. In a natural state, the leading edge safety factor is smaller than 0.9, putting it in phase with a small-scale collapse at the leading edge.



Global navigation satellite system (GNSS) monitoring points were installed to measure surface deformations, shown here alongside the cumulative deformation vectors for the Yulin II landslide. Monitoring points are designated "TP", with deformation vectors shown in blue.

To enhance the stability of the landslide, one intercepting tunnel, five drainage tunnels and branches were built in 2016. Chinese codes for a minimum factor of safety were met by reducing the water table fall to 60% of its natural state.

Conclusions

Due to the mega scale of the hydropower projects and the cascading reservoirs, CTG adopted real-time monitoring and emergency preparedness of reservoir-induced landslides as an important part of its risk assessment system. Often, the landslide areas have a very steep slope, as high as a few hundred to more than 1,000 m, and traditional geotechnical exploration and an engineering retrofit program may not be technically or economically feasible. Thus, CTG used GNSS systems (including GLONASS, Galileo and China's Baidou System) for monitoring. The landslide sliding rate reached more than 200 mm/day during times the reservoir level was dropping quickly but later decreased to less than 11 mm/day during the dry season, with no significant reservoir level change. This exceeded any warning threshold ever published.

CTS's hazard management team continues to examine the data collected and to perform analysis. Regular review meetings have been held by nationally and/or internationally wellknown geotechnical experts to diagnose the risk. So far, the risk is manageable.

Each GNSS monitoring point included a solar panel and antenna to autonomously broadcast data to China Three Gorge's regional headquarters in Chengdu.

CTG is considering similar monitoring programs for its other facilities, although the monitoring points and equipment types may differ.

Reference

Zhai, Endi, Fan Qixiang and Jin Hua, "Monitoring and Assessment of Reservoir-Induced Landslides for the Jiansha River Hydropower Project in China," *Proceedings of HydroVision International 2017*, PennWell Corp., Tulsa, Okla., 2017.

Endi Zhai is chief engineer for civil works with China Three Gorges Corp. Fan Qixiang is vice president of CTG. Jin Hua is a post-doctorate fellow working with CTG.

Peer Reviewed This article has been evaluated and edited in accordance with reviews conducted by two or more professionals who have relevant expertise. These peer reviewers judge manuscripts for technical accuracy, usefulness, and overall importance within the hydroelectric industry.

(HYDRO REVIEW, November 2017,
http://digital.hydroreview.com/hydroreview/201711/MobilePagedArticle.action?articleId=1221033#articleId1221033

ΔΙΑΚΡΙΣΕΙΣ ΕΛΛΗΝΩΝ ΓΕΩΜΗΧΑΝΙΚΩΝ

Deep Excavation CEO, Dimitrios Konstantakos, P.E. is named as the recipient of the 2018 ASCE Martin S. Kapp Foundation Engineering Award!

1801 Alexander Bell Drive Reston, VA 20191-4382
(800) 548.2723 *toll free* (703) 295.6300 *intl*
(703) 295.6333 *fax* ■ www.ASCE.org

November 21, 2017

Dimitrios C. Konstantakos, P.E., M.ASCE

Dimitrios@deepexcavation.com

Dear Mr. Konstantakos:

Congratulations! You have been selected by the Geo-Institute to receive the 2018 **Martin S. Kapp Foundation Engineering Award** *"For his contributions to innovative design and construction practices for deep excavation support systems. He has truly advanced the state of practice for deep excavations by making knowledge more accessible to practitioners."* In selecting you for this award, the committee particularly noted your development of a voice-controlled holographic geotechnical software application.

ΠΡΟΣΕΧΕΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΚΔΗΛΩΣΕΙΣ

Για τις παλαιότερες καταχωρήσεις περισσότερες πληροφορίες μπορούν να αναζητηθούν στα προηγούμενα τεύχη του «περιοδικού» και στις παρατιθέμενες ιστοσελίδες.

5th International Course on Geotechnical and Structural Monitoring, 22 - 25 May 2018, in Rome www.geotechnicalmonitoring.com

EUROCK 2018 Geomechanics and Geodynamics of Rock Masses, 22-26 May 2018, Saint Petersburg, Russia, www.eurock2018.com/en

4th GeoShanghai International Conference, May 27-30, 2018, Shanghai, China, http://geo-shanghai.org

micro to MACRO - Mathematical Modelling in Soil Mechanics, May 29-June 1, 2018, Reggio Calabria, Italy, www.microtomacro2018.unirc.it

GeoReinforcement Workshop, 4 - 5 June 2018, Munich, Germany, https://igs.wufoo.com/forms/q10dk31u19dx00v/

International Conference on Deep Foundations and Ground Improvement - Urbanization and Infrastructure Development: Future Challenges, June 5-8, 2018, Rome, Italy, www.dfi.org/dfieventlp.asp?13310

GeoBarrier Workshop, 6 - 7 June 2018, Munich, Germany, https://igs.wufoo.com/forms/q10dk31u19dx00v/

XVI Danube-European Conference on Geotechnical Engineering: Geotechnical Hazards and Risks: Experiences and Practices, 7 - 9 June 2018, Skopje, Former Republic of Yugoslav www.decge2018.mk

16th European Conference on Earthquake Engineering (16thECEE), 18-21 June 2018, Thessaloniki, Greece, www.16ecee.org

CPT'18 4th International Symposium on Cone Penetration Testing, 21-22 June 2018, Delft, Netherlands, www.cpt18.org

PATA DAYS 2018 - 9th International INQUA Meeting on Paleoseismology, Active Tectonics and Archeoseismology, 24-29 June 2018, Chalkidiki, Greece, www.patadays2018.org

NUMGE 2018 9th European Conference on Numerical Methods in Geotechnical Engineering, 25-27 June 2018, Porto, Portugal, www.numge2018.pt

RockDyn-3 - 3rd International Conference on Rock Dynamics and Applications, 25-29 June 2018, Trondheim, Norway, www.rocdyn.org

ICOLD 2018 26th Congress – 86th Annual Meeting, 1 - 7 July 2018, Vienna, Austria, www.icoldaustria2018.com

9th International Conference on Physical Modelling in Geotechnics (ICPMG 2018), 17-20 July 2018, London, UK, www.icpmg2018.london

ICSSTT 2018 - 20th International Conference on Soil Stabilization Techniques and Technologies, July 19 - 20, 2018, Toronto, Canada, https://waset.org/conference/2018/07/toronto/ICSSTT

GeoChine 2018 - 5th GeoChina International Conference Civil Infrastructures Confronting Severe Weathers and Climate Changes: From Failure to Sustainability, July 23-25, , HangZhou, China, http://geochina2018.geoconf.org

UNSAT2018 The 7th International Conference on Unsaturated Soils, 3 - 5 August 2018, Hong Kong, China, www.unsat2018.org

China- Europe Conference on Geotechnical Engineering, 13-16 August 2018, Vienna, Austria, https://china-euro-geo.com

CRETE 2018 6th International Conference on Industrial & Hazardous Waste Management, 4-7 September 2018, Chania, Crete, Greece, www.hwm-conferences.tuc.gr

EUCEET 2018 - 4th International Conference on Civil Engineering Education: Challenges for the Third Millennium, 5-8 September 2018, Barcelona, Spain, http://congress.cimne.com/EUCEET2018/frontal/default.asp

SAHC 2018 11th International Conference on Structural Analysis of Historical Constructions "An interdisciplinary approach", 11-13 September 2018, Cusco, Perú http://sahc2018.com

26th European Young Geotechnical Engineers Conference, 11 - 14 September 2018, Reinischkogel, Austria, www.tugraz.at/en/institutes/ibg/events/eygec

11th International Conference on Geosynthetics (11ICG), 16 - 20 Sep 2018, Seoul, South Korea, www.11icg-seoul.org

CHALK 2018 Engineering in Chalk 2018, 17-18 September 2018, London, U.K., www.chalk2018.org

International Symposium on Energy Geotechnics SEG - 2018, 25-28 September 2018, Lausanne, Switzerland https://seg2018.epfl.ch

HYDRO 2018 - Progress through Partnerships, 15-17 October 2018, Gdansk, Poland, www.hydropower-dams.com/hydro-2018.php?c_id=88

GEC - Global Engineering Congress Turning Knowledge into Action, 22 - 26 October, London, United Kingdom, www.ice.org.uk/events/global-engineering-congress

ARMS10 - 10th Asian Rock Mechanics Symposium, ISRM Regional Symposium, 29 October - 3 November 2018, Singapore, www.arms10.org

ACUUS 2018 16th World Conference of Associated research Centers for the Urban Underground Space "Integrated Underground Solutions for Compact Metropolitan Cities", 5 – 7 November 2018, Hong Kong, China, www.acuus2018.hk

International Symposium Rock Slope Stability 2018, 13-15 November, 2018, Chambéty, France, www.c2rop.fr/symposium-rss-2018

GeoMEast 2018 International Congress and Exhibition: Sustainable Civil Infrastructures, 24 - 28 November 2018, Cairo, Egypt, www.geomeast.org

WTC2019 Tunnels and Underground Cities: Engineering and Innovation meet Archaeology, Architecture and Art and ITA - AITES General Assembly and World Tunnel Congress, 3-9 May 2019, Naples, Italy, www.wtc2019.com

14th international Conference "Underground Construction", 3 to 5 June 2019, Prague, Czech Republic, www.ucprague.com

2019 Rock Dynamics Summit in Okinawa, 7-11 May 2019, Okinawa, Japan, www.2019rds.org

VII ICEGE ROMA 2019 - International Conference on Earthquake Geotechnical Engineering, 17 - 20 June 2019, Rome, Italy, www.7icege.com

IS-GLASGOW 2019 - 7th International Symposium on Deformation Characteristics of Geomaterials, 26 - 28 June 2019, Glasgow, Scotland, UK, https://is-glasgow2019.org.uk

cmn 2019 -Congress on Numerical Methods in Engineering, July 1 - 3, 2019, Guimarães, Portugal, www.cmn2019.pt

For additional information, please contact the secretariat of the congress, Ms. Lara Leite

CMN2019, Universidade do Minho, Departamento de Engenharia Civil, 4800-058 Guimarães - Portugal
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Fax: +351 253 510 217

The 17th European Conference on Soil Mechanics and Geotechnical Engineering, 1st - 6th September 2019, Reykjavik Iceland, www.ecsmge-2019.com

14th ISRM International Congress, 13-18 September 2019, Iguassu Falls, Brazil, www.isrm2019.com

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XVII African Regional Conference on Soil Mechanics and Geotechnical Engineering

07-10 October 2019, Cape Town, South Africa

The South African Institution of Civil Engineering cordially invites all our colleagues from Africa and beyond to attend the 17th African Regional Conference on Soil Mechanics and Geotechnical Engineering.

Hosted in one of the continent's most iconic cities, this conference will serve practitioners, academics and students of all geotechnical backgrounds. The conference will take place at the Cape Town International Convention Centre (CTICC) offering world class conferencing facilities in the heart of South Africa's mother city and will offer extensive opportunities for Technical Committee Meetings, Workshops, Seminars, Exhibitions and Sponsorships. Exciting Technical Visits, including tours to the famous Robben Island, await.

The 7th African Young Geotechnical Engineers' Conference (8 – 10 October 2019) will commence on 8 October 2019, the day following the African Regional Conference (ARC) opening. The conference venue will be shared with the ARC delegates to initiate dialogue between junior and senior engineers while young geotechnical engineers acquaint themselves with the industry standards, new geotechnical developments and resources available to further their careers. The YGE conference provides an approachable audience within a vibrant environment where young presenters under the age of 35 are encouraged to exercise their presentation and technical writing skills on a continental platform.

Organiser: SAICE

Contact person: Dr Denis Kalumba
Email: denis.kalumba@uct.ac.za

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XVI Asian Regional Conference on Soil Mechanics and Geotechnical Engineering, 21 - 25 October 2019, Taipei, China www.16arc.org

XVI Panamerican Conference on Soil Mechanics and Geotechnical Engineering, 18-22 November 2019, Cancun, Quintana Roo, Mexico, http://panamerican2019mexico.com/panamerican

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YSRM2019 - the 5th ISRM Young Scholars' Symposium on Rock Mechanics and REIF2019 - International Symposium on Rock Engineering for Innovative Future

1-4 December 2019, Okinawa, Japan

Contact Person: Prof. Norikazu Shimizu, jsrm-office@rocknet-japan.org

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Nordic Geotechnical Meeting

27-29 May 2020, Helsinki, Finland

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EUROCK 2020 Hard Rock Excavation and Support

June 2020, Trondheim, Norway

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6th International Conference on Geotechnical and Geophysical Site Characterization

07-09-2020 ÷ 11-09-2020, Budapest, Hungary

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ΕΝΔΙΑΦΕΡΟΝΤΑ ΓΕΩΤΕΧΝΙΚΑ ΝΕΑ

Massive sinkhole opens near Coromandel in Minas Gerais, Brazil

A massive sinkhole opened up on a farm near Alegre district in the municipality of Coromandel, Minas Gerais, Brazil this month. The region is known for its susceptible limestone.

The hole was discovered early November 6 by employees of a farm in which it opened. They said the sinkhole, between 20 and 30 m (65 - 98 feet) in diameter, opened overnight, in the middle of the soy field. The depth is estimated at 20 m (65 feet).

Federal University of Uberlândia geologists visited the sinkhole and concluded it is most likely caused by the dissolution of the underlying bedrock. Professor Adriano dos Santos said sinkholes in this region are common, adding that they usually appear gradually. "However, in this case, the sinkhole appeared suddenly and drew the attention of specialists," Santos said.

The sinkhole was discovered on the morning of November 6, 2017. Image courtesy Municipality of Coromandel, Diogo Tudela

Coromandel sinkhole, Brazil - November 2017. Credit: Diogo Tudela

Municipality of Coromandel officials said the area has since been isolated to prevent people and animals from falling in.

Specialists will continue monitoring the hole until it stabilizes.

Santos said that a nearby tourist attraction, the "Poço Verde/Green Well" is an old sinkhole that has since turned into a small lake.

(THE WATCHERS, November 22, 2017, https://watchers.news/2017/11/22/massive-sinkhole-opens-near-coromandel-in-minas-gerais-brazil/?utm_source=feedburner&utm_medium=email&utm_campaign=Feed%3A+adorraeli%2FtsEq+%28The+Watchers+-+watching+the+world+evolve+and+transform%29)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΣΕΙΣΜΟΙ

Sloshing of Earth's core may spike major earthquakes

The world doesn't stop spinning. But every so often, it slows down. For decades, scientists have charted tiny fluctuations in the length of Earth's day: Gain a millisecond here, lose a millisecond there. Last week at the annual meeting of the Geological Society of America here, two geophysicists argued that these minute changes could be enough to influence the timing of major earthquakes—and potentially help forecast them.

During the past 100 years, Earth's slowdowns have correlated surprisingly well with periods with a global increase in magnitude-7 and larger earthquakes, according to Roger Bilham of the University of Colorado (CU) in Boulder and Rebecca Bendick at the University of Montana in Missoula. Usefully, the spike, which adds two to five more quakes than typical, happens well after the slow-down begins. "The Earth offers us a 5-years heads up on future earthquakes, which is remarkable," says Bilham, who presented the work[(1)].

Most seismologists agree that earthquake prediction is a minefield. And so far, Bilham and Bendick have only fuzzy, hard-to-test ideas about what might cause the pattern they found. But the finding is too provocative to ignore, other researchers say. "The correlation they've found is remarkable, and deserves investigation," says Peter Molnar, a geologist also at CU.

The research started as a search for synchrony in earthquake timing. Individual oscillators, be they fireflies, heart muscles, or metronomes, can end up vibrating in synchrony as a result of some kind of cross-talk—or some common influence. To Bendick, it didn't seem a far jump to consider the faults that cause earthquakes, with their cyclical buildup of strain and violent discharge, as "really noisy, really crummy oscillators," she says. She and Bilham dove into the data, using the only complete earthquake catalog for the past 100 years: magnitude-7 and larger earthquakes.

In work published in August[(2)] in *Geophysical Research Letters* they reported two patterns: First, major quakes appeared to cluster in time—although not in space. And second, the number of large earthquakes seemed to peak at 32-year intervals. The earthquakes could be somehow talking to each other, or an external force could be nudging the earth into rupture.

Exploring such global forces, the researchers eventually discovered the match with the length of day. Although weather patterns such as El Nino can drive day length to vary back and forth by a millisecond over a year or more, a periodic, decades-long fluctuation of several milliseconds—in particular, its point of peak slow down about every three decades or so—lined up with the quake trend perfectly. "Of course that seems sort of crazy," Bendick says. But maybe it isn't. When day length changes over decades, Earth's magnetic field also develops a temporary ripple. Researchers think slight changes in the flow of the molten iron of the outer core may be responsible for both effects. Just what happens is uncertain—perhaps a bit of the molten outer core sticks to the mantle above. That might change the flow of the liquid metal, altering the magnetic field, and transfer enough momentum between the mantle and the core to affect day length.

Seismologists aren't used to thinking about the planet's core, buried 2900 kilometers beneath the crust where quakes happen. But they should, Bilham said during his talk here. The core is "quite close to us. It's closer than New York from here," he said.

At the equator, Earth spins 460 meters per second. Given this high velocity, it's not absurd to think that a slight mismatch in speed between the solid crust and mantle and the liquid core could translate into a force somehow nudging quakes into synchrony, Molnar says. Of course, he adds, "It might be nonsense." But the evidence for some kind of link is compelling, says geophysicist Michael Manga of the University of California, Berkeley. "I've worked on earthquakes triggered by seasonal variation, melting snow. His correlation is much better than what I'm used to seeing."

One way or another, says James Dolan, a geologist at the University of Southern California in Los Angeles, "we're going to know in 5 years." That's because Earth's rotation began a periodic slow-down 4-plus years ago. Beginning next year, Earth should expect five more major earthquakes a year than average—between 17 to 20 quakes, compared with the anomalously low four so far this year. If the pattern holds, it will put a new spin on earthquake forecasting.

(Paul Voosen / SCIENCE, Oct. 30, 2017, http://www.sciencemag.org/news/2017/10/sloshing-earth-s-core-may-spike-major-earthquakes)

[(1)] A Five Year Forecast for Increased Global Seismic Hazard (Invited Presentation)

GSA Annual Meeting in Seattle, Washington, USA - 2017, Sunday, 22 October 2017

BILHAM, Roger, Geological Sciences and CIRES, University of Colorado at Boulder, UCB 399, Boulder, CO 80309-0399 and BENDICK, Rebecca, Department of Geosciences, University of Montana, Missoula, MT 59812, Roger.Bilham@colorado.edu

On five occasions in the past century a 25-30% increase in annual numbers of Mw≥7 earthquakes has coincided with a slowing in the mean rotation velocity of the Earth, with a corresponding decrease at times when the length-of-day (LoD) is short. The correlation between Earth's angular deceleration (d[LoD]/dt) and global seismic productivity is yet more striking, and can be shown to precede seismicity by 5-6 years, permitting societies at risk from earthquakes an unexpected glimpse of future seismic hazard. The cause of Earth's variable rotation is the exchange of angular momentum between the solid and fluid Earth (atmospheres, oceans and outer core). Maximum LoD is preceded by an angular deceleration of the Earth by 6-8 years corresponding to a π/4 phase lag of the 24-33 year peak-to-peak period of multidecadal oscillations of Earth's rotation. We show delayed global seismic productivity is most pronounced at equatorial latitudes 10°N-30°S. Two mechanisms may be responsible: (1) decreased oblateness (a reduction in J2) that attends a slowing of Earth's rotation and (2) lithospheric overshoot, a process whereby the equatorial lithosphere sluggishly overrides the decelerating underlying mantle westward, much as a loose cannon slides upon the deck of a rolling ship. The observed relationship is unable to indicate precisely when and where these future earthquakes will occur, although we note that most of the additional Mw>7 earthquakes have historically occurred near the equator in the West and East Indies. A striking example is that since 1900 more than 80% of all M≥7 earthquakes on the eastern Caribbean plate boundary have occurred 5 years following a maximum deceleration (including the 2010 Haiti earthquake). Calculations show the asthenosphere to have an appropriate viscosity to account for the delay between deceleration and subduction zone seismicity, however, a geodetic test of the anticipated westward overshoot would be of utility. Whatever the mechanism, the 5-6 year advanced warning of increased seismic hazards afforded by the first derivative of the LoD is fortuitous, and has utility in disaster planning. The year 2017 marks six years following a deceleration episode that commenced in 2011, suggesting that the world has now entered a period of enhanced global seismic productivity with a duration of at least five years.

Session No. 62

T217. Challenges in Tectonics: Synergies between Meeting Societal Needs and Advancing Interdisciplinary Research in Tectonics and Structural Geology

https://gsa.confex.com/gsa/2017AM/webprogram/Paper300667.html

[2] Do week global stresses synchronize earthquakes?

R. Bendick and R. Bilham

Insofar as slip in an earthquake is related to the strain accumulated near a fault since a previous earthquake, and this process repeats many times, the earthquake cycle approximates an autonomous oscillator. Its asymmetric slow accumulation of strain and rapid release is quite unlike the harmonic motion of a pendulum and need not be time predictable, but still resembles a class of repeating systems known as integrate-and-fire oscillators, whose behavior has been shown to demonstrate a remarkable ability to synchronize to either external or self-organized forcing. Given sufficient time and even very weak physical coupling, the phases of sets of such oscillators, with similar though not necessarily identical period, approach each other. Topological and time series analyses presented here demonstrate that earthquakes worldwide show evidence of such synchronization. Though numerous studies demonstrate that the composite temporal distribution of major earthquakes in the instrumental record is indistinguishable from random, the additional consideration of event renewal interval serves to identify earthquake groupings suggestive of synchronization that are absent in synthetic catalogs. We envisage the weak forces responsible for clustering originate from lithospheric strain induced by seismicity itself, by finite strains over teleseismic distances, or by other sources of lithospheric loading such as Earth's variable rotation. For example, quasi-periodic maxima in rotational deceleration are accompanied by increased global seismicity at multidecadal intervals.

Geophysical Research Letters, 26 August 2017

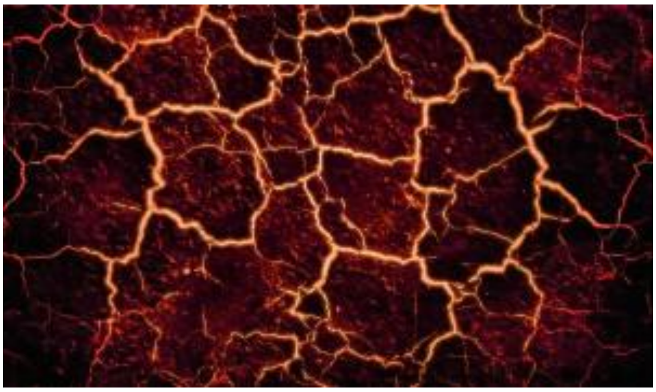
http://onlinelibrary.wiley.com/doi/10.1002/2017GL074934/abstract

New Research Says Earth's Core Could Predict Earthquakes 5 Years Earlier

Two researchers from the United States created a hypothesis that the molten iron core of the Earth could give us a five year heads up to the next major catastrophic earthquake.

Two geophysicists have found evidence that the flow of iron around Earth's core might clue scientists into the next major earthquakes.

"The Earth offers us a five-year heads up on future earthquakes, which is remarkable," suggests one of the researchers, Roger Bilham from the University of Colorado (CU) in Boulder.



Seismologists and geophysicists have already theorized that the Earth's outer core contributes to small fluctuations in the length of the average day. These differences are so small and represent the tiniest slowings to the speed at which the Earth travels.

Bilham and Rebecca Bendick from the University of Montana noted that there's a correlation between the length variations and major magnitude 7 earthquakes over the last 100 years. The two researchers theorize that the molten iron moving around Earth's core could be the cause.

"The correlation they've found is remarkable, and deserves investigation," Peter Molnar from Colorado University, who wasn't involved in the study, said in an interview with *Science*.

If the research of Bilham and Bendick hold up during peer reviews, then seismologists and other researchers would have one more resource to predict earthquakes. This new measurement could give us as much as five years warning before another major earthquake strikes -- or at the very least, a rising presence of high-powered tremors.

"I've worked on earthquakes triggered by seasonal variation, melting snow," Michael Manga of the University of California, Berkeley, told *Science*. "[This] correlation is much better than what I'm used to seeing."

Currently, the movement of the iron core is one of a handful of factors affecting the Earth's magnetic field as well as the length of day (LOD). Previous research noted that in the absence of an external force, the angular momentum of the Earth has to be reliant upon the internal forces to be constant. Thus, the core, mantle, crust, tides, atmosphere, and cryosphere all serve as pieces of the larger puzzle on precisely how long each day lasts. A change in one area (like the atmospheric angular momentum or AAM) has to be accounted for in another region (like the earth's core) so to properly maintain the balance.

"The year 2017 marks six years following a deceleration episode that commenced in 2011," write the researchers, "suggesting that the world has now entered a period of enhanced global seismic productivity with a duration of at least five years."

If the research is correct, we're to expect between 17 to 20 heavy earthquakes each year starting in 2018.

The research was initially published in August but is now being presented at recent meetings of the Geological Society of America. While the research has yet to be peer-reviewed, reception of the research has been met with piqued interest.

For now, the research is certainly something to think over. With larger climate swings predicted over the next century, would the molten core compensate more for the atmospheric change? Thus, are we destined to see more seismic activity as a result of already devastating climate change issues?

(Shelby Rogers / INTERESTING ENGINEERING, November, 03rd 2017, https://interestingengineering.com/new-research-says-earths-core-could-predict-earthquakes-5-years-earlier?_source=newsletter&_campaign=23YV3EQVYEBgn&_uid=9wdL9JEwej&_h=9480fc0933eb231a0575c535417bef075ed6e805&utm_source=newsletter&utm_medium=mailing&utm_campaign=Newsletter-03-11-2017)

Ancient construction is a model for earthquake-safe buildings

Pagoda at Horyu-ji Temple in Nara, Japan.

The pagoda at the Horyu-ji temple in Japan is a testament to architectural design that was ahead of its time. Built in 607 AD, the 122-foot-tall structure is still standing, now one of the world's oldest wooden buildings at 1,410 years old.

It's also an enduring symbol of forward-thinking engineering concepts that are applied today in protecting large structures against earthquakes. Horyu-ji's pagoda is a monument to stability in a land of seismic instability; it has stayed upright despite nearly 50 earthquakes of magnitude 7.0-plus having struck Japan during the building's lifespan.

Japanese builders used a shinbashira — a large column within a shaft in the building's center — to act as a shock absorber and buffer between the floors.

This same technology is used today in the form of tuned mass dampers, also known as harmonic absorbers, which help reduce vibrations from an earthquake. Dampers can come in steel, liquid or concrete and are housed in numerous large buildings, skyscrapers and bridges in the United States and around the world.

Like automobiles driven on a bumpy road, buildings in wind and seismic regions are a dynamic problem. Who would ever buy or manufacture a car without shock absorbers? The dynamic laws of physics are the same for each.

Besides damper technology, other remarkable examples of ancient construction methods still holding up against earthquakes abound in iconic structures around the world.

In China, some of its oldest buildings, including the Forbidden City, have withstood earthquakes thanks to an ancient building technique called dougong, which dates back over 2,000 years. Dougong is a series of interlocking wooden brackets used to support overhanging roofs, a signature of Chinese architecture. This method distributes weight more evenly.

The oft-photographed Wooden Pagoda in Shanxi province, designed with dougong, was built in 1056 along a seismic belt and has withstood many earthquakes. Today, architects are employing dougong for retro-aesthetic and structural reasons; one of those examples being the China Art Museum in Shanghai.

Peru's Machu Picchu, an Inca citadel sitting on a mountain 7,970 feet above sea level, is another monument to earthquake-protection ingenuity with ties to today's technology.

In an earthquake-prone region, Incan workers devised a system similar to Legos, with the stones fitting together without mortar. That inspired California-based architects to explore creating a similar design.

Large structures without extra building protection like dampers may have imperiled structural integrity when the earth shakes violently. The current building codes in the U.S. and worldwide only require that new buildings be designed for collapse prevention. They do not require what is referred to as "performance-based designs" that would make the buildings perform much better in an earthquake.

Some people think that if they move into a brand new building that meets all the modern building codes, their building will perform well during earthquakes.

This is simply not true.

(Douglas P. Taylor / New York Daily News Contributor, Wednesday, November 8, 2017, http://www.nydailynews.com/life-style/ancient-construction-model-earthquake-safe-buildings-article-1.3620347)

Researchers Create Largest, Longest Multiphysics Earthquake Simulation to Date

Researchers at LMU and TUM in Munich are up for best paper at SC17 after simulating one of the largest, most violent earthquakes in history.

Just before 8:00 a.m. local time on December 26, 2004, people in southeast Asia were starting their days when the third strongest recorded earthquake in history ripped a 1,500-kilometer tear in the ocean floor off the coast of the Indonesian island of Sumatra.

The earthquake lasted between 8 and 10 minutes (one of the longest ever recorded), and lifted the ocean floor several meters, creating a tsunami with 30-meter waves that devastated whole communities. The event caused nearly 200,000 deaths across 15 countries, and released as much energy above and below ground as multiple centuries of US energy usage.

The Sumatra-Andaman Earthquake, as it is called, was as surprising as it was violent. Despite major advancements in earthquake monitoring and warning systems over the last 50 years, earth scientists were unable to predict it because relatively little data exists about such large-scale seismological events. Researchers have a wealth of information related to semi-regular, lower-to-medium-strength earthquakes, but disasters such as the Sumatra-Andaman—events that only happen every couple hundred years—are too rare to create reliable data sets.

In order to more fully understand these events, and hopefully provide better prediction and mitigation methods, a team of researchers from the Ludwig-Maximilians-Universität Munich (LMU) and Technical University of Munich (TUM) is using supercomputing resources at the Leibniz Supercomputing Centre (LRZ) to better understand these rare, extremely dangerous seismic phenomena.

"Our general motivation is to better understand the entire process of why some earthquakes and resulting tsunamis are so much bigger than others," said TUM Professor Dr. Michael Bader. "Sometimes we see relatively small tsunamis when earthquakes are large, or surprisingly large tsunamis connected with relatively small earthquakes. Simulation is one of the tools to get insight into these events."

The team strives for "coupled" simulations of both earthquakes and subsequent tsunamis. It recently completed its largest earthquake simulation yet. Using the SuperMUC supercomputer at LRZ, the team was able to simulate 1,500 kilometers of non-linear fracture mechanics—the earthquake source—coupled to seismic waves traveling up to India and Thailand over a little more than 8 minutes of the Sumatra-Andaman earthquake. Through several in-house computational innovations, the team achieved a 13-fold improvement in time to solution. In recognition of this achievement, the project was nominated for the best paper award at SC17, one of the world's premier supercomputing conferences, held this year on November 12–17 in Denver, Colorado.

Megathrust earthquakes, massive scale simulations

Earthquakes happen as rock below Earth's surface breaks suddenly, often as a result of the slow movement of tectonic plates.

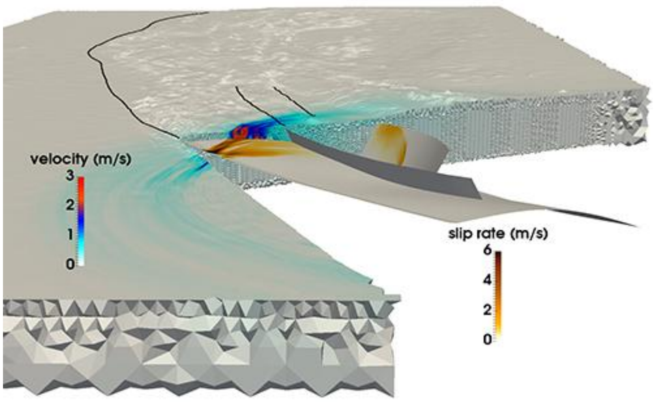
One rough predictor of an ocean-based earthquake's ability to unleash a large tsunami is whether plates are grinding against one another or colliding head-on. If two or more plates collide, one plate will often force the other below it. Regions where this process occurs are called subduction zones and can host very large, shallowly dipping faults—so called "megathrusts." Energy release across such huge zones of weakness tends to create violent tsunamis, as the ocean floor rises a significant amount, temporarily displacing large amounts of water.

Until recently, though, researchers doing computational geophysics had great difficulties simulating subduction earthquakes at the necessary level of detail and accuracy. Large-scale earthquake simulations are difficult generally, but subduction events are even more complex.

"Modeling earthquakes is a multiscale problem in both space and time," said Dr. Alice Gabriel, the lead researcher from the LMU side of the team. "Reality is complex, meaning that incorporating the observed complexity of earthquake sources invariably involves the use of numerical methods, highly efficient simulation software, and, of course, high-performance computing (HPC). Only by exploiting HPC can we create models that can both resolve the dynamic stress release and ruptures happening with an earthquake while also simulating seafloor displacement over thousands of kilometers."

When researchers simulate an earthquake, they use a computational grid to divide the simulation into many small pieces. They then compute specific equations for various aspects of the simulation, such as generated seismic shaking or ocean floor displacement, among others, over "time steps," or simulation snapshots over time that help put it in motion, much like a flip book.

The finer the grid, the more accurate the simulation, but the more computationally demanding it becomes. In addition, the more complex the geometry of the earthquake, the more complex the grid becomes, further complicating the computation. To simulate subduction earthquakes, computational scientists have to create a large grid that can also accurately represent the very shallow angles at which the two continental plates meet. This requires the grid cells around the subduction area to be extra small, and often slim in shape.



Using LRZ's SuperMUC supercomputer, a joint research team from the Technical University of Munich and Ludwigs-Maximilians-Uni Munich were able to create the largest multiphysics simulation of an earthquake and tsunami. This image shows rupture propagation and the resulting seismic wave field during 2004 Sumatra-Andaman earthquake. Copyright: C. Uphoff, S.Rettenberger, M. Bader, Technical University of Munich. E. Madden, T. Ulrich, S. Wollherr, A. Gabriel, Ludwigs-Maximilians-Universität.

Unlike continental earthquakes, which have been better documented through computation and observation, subduction events often happen deep in the ocean, meaning that it is much more difficult to constrain a simulation by ground shaking observations and detailed, reliable data from direct observation and laboratory experiments.

Furthermore, computing a coupled, large-scale earthquake-tsunami simulation requires using data from a wide variety of sources. Researchers must take into account the seafloor shape, the shape and strength of the plate boundary ruptured by the earthquake and the material behaviour of Earth's crust at each level, among other aspects. The team has spent the last several years developing methods to more efficiently integrate these disparate data sources into a consistent model.

To reduce the enormous computing time, the team exploited a method called "local time stepping." In areas where the simulations require much more spatial detail, researchers also must "slow down" the simulation by performing more time steps in these areas. Other sections that require less detail may execute much bigger—and thus—far fewer time steps.

If the team had to run its entire simulation at a uniform small time step, it would have required roughly 3 million individual iterations. However, only few cells of the computational grid required this time step size. Major parts could be computed with much larger time steps, some requiring only 3000 time steps. This reduced the computational demand significantly and led to much of the team's 13-fold speedup. This advancement also led to the team's simulation being the largest, longest first-principles simulation of an earthquake of this type.

Forward motion

Due to its close collaboration with LRZ staff, the team had

opportunities to use the entire SuperMUC machine for its simulations. Bader indicated that these extremely large-scale runs are invaluable for the team to gain deeper insights in its research. "There is a big difference if you run on a quarter of a machine or a full machine, as that last factor of 4 often reveals the critical bottlenecks," he said.

The team's ability to take full advantage of current-generation supercomputing resources has it excited about the future. It's not necessarily important that next-generation machines offer the opportunity for the LMU-TUM researchers to run "larger" simulations—current simulations can effectively simulate a large enough geographic area. Rather, the team is excited about the opportunity to modify the input data and run many more iterations during a set amount of computing time.

"We have been doing one individual simulation, trying to accurately guess the starting configuration, such as the initial stresses and forces, but all of these are still uncertain," Bader said. "So we would like to run our simulation with many different settings to see how slight changes in the fault system or other factors would impact the study. These would be larger parameter studies, which is another layer of performance that a computer would need to provide."

Gabriel also mentioned that next-generation machines will hopefully be able to simulate urgent, real-time scenarios that can help predict hazards as they relate to likely aftershock regions. The team is excited to see the next-generation architectures at LRZ and the other Gauss Centre for Supercomputing centres, the High-Performance Computing Center Stuttgart and the Jülich Supercomputing Centre.

In Bader's view, the team's recent work not only represents its largest-scale simulation to date, but also the increasingly strong collaboration between the domain scientists and computational scientists in the group. "This paper has a strong seismology component and a strong HPC component," he said. "This is really a 50-50 paper for us. Our collaboration has been going nicely, and it is because it isn't about getting ours or theirs. Both groups profit, and this is really nice joint work."

This work was carried out using Gauss Centre for Supercomputing resources based at the Leibniz Supercomputing Centre.

(Eric Gedenk / GCS NewsFlash 18/2017, http://www.gauss-centre.eu/SharedDocs/Meldungen/GAUSS-CENTRE/EN/2017/news_18_Largest_Multiphysics_Earthquake.html)

Αίσθηση από τις αποκαλύψεις
Το ραδόνιο «δείχνει» ενδεχόμενο σεισμό

Οι δηλώσεις του Διευθυντή του Γεωδυναμικού Ινστιτούτου Αθηνών κ. Άκη Τσελέντη χθες το πρωί για τη σεισμικότητα στη χώρα μας προκάλεσαν προβληματισμό αλλά δεν ξάφνιασαν την επιστημονική κοινότητα. Είναι άλλωστε γνωστό πως βρισκόμαστε σε μια από τις πλέον σεισμογενείς περιοχές του πλανήτη.

Ωστόσο η δήλωση του καθηγητή Άκη Τσελέντη ότι το Γεωδυναμικό Ινστιστούτο Αθηνών έχει αναπτύξει ένα μοναδικό δίκτυο με ραδόνια και υπάρχει η δυνατότητα να προβλεφθούν σεισμοί ήταν που προκάλεσε αίσθηση στο πανελλήνιο.

«Εχουμε βρει ότι το ραδόνιο, πριν από μεγάλους σεισμούς, αφήνει σημάδια. Έχουμε εγκαταστήσει πέντε σταθμούς, εξοπλίζοντάς τους με συσκευές από τη Ρωσία, έχοντας σημαντικά αποτελέσματα. Σκοπός μας είναι να κάνουμε ένα κέντρο προδρόμων», επισήμανε μεταξύ άλλων ο κ. Τσελέντης.

Ήδη εδώ και δεκαετίες Έλληνες επιστήμονες έχουν εξειδικευτεί στη μελέτη του στοιχείου αυτού και όπως υποστηρίζει στο protothema.gr ο καθηγητής Πυρηνικής Φυσικής που διετέλεσε μέλος του ΑΠΘ Κωνσταντίνος Παπαστεφάνου, υπάρχει η δυνατότητα πρόγνωσης σεισμού με τη μελέτη του αερίου ραδόνιο:

«Το ραδόνιο είναι ένα ραδιενεργό αέριο που αποπνέει από τη γη και φυσικά όταν υπάρξει ξαφνικά μια αυξημένη διαρροή τότε αυτό σημαίνει ότι κάποιο ρήγμα έχει ανοίξει και διαφεύγει από εκεί. Τώρα οι σεισμολόγοι -γεωφυσικοί γενικά που παρακολουθούν τα ρήγματα εάν καταγράφουν μεταξύ άλλων και το ραδόνιο, μπορούν να κάνουν μια πρόβλεψη. Ωστόσο να επισημάνω ότι θέλει ένα αρκετό διάστημα να γίνει η παρακολούθησή του, να διαπιστωθεί η αυξημένη διαρροή και να φανεί ότι κάποιο ρήγμα έχει ανοίξει και έχει αυξηθεί η διαρροή του.

Στους σεισμούς υπάρχουν αρκετά πρόδρομα φαινόμενα, ένα εκ των οποίων είναι το ραδόνιο. Βγαίνουν κι άλλα αέρια τα οποία αν καταγραφούν για μια αρκετά μεγάλη περίοδο και δει κανείς πότε σημειώνονται αυξήσεις, μπορεί να προβλέψει ότι κάτι έχει γίνει. Και βέβαια από το μέγεθος μπορεί να εκτιμήσει πόσο διάστημα έχει συμβεί αυτή η διαρροή και να προβλέψει το μέγεθος κάποιου σεισμού από το ρήγμα το οποίο βγαίνει» τόνισε στο protothema.gr ο κ. Παπαστεφάνου.

Σύμφωνα με μελέτες ερευνητών σεισμολόγων τόσο στην Ελλάδα όσο και στο εξωτερικό, τρεις έως εννέα εβδομάδες πριν σημειωθεί κάποια σεσμική δόνηση «απελευθερώνονται» ποσότητες ραδονίου και από τις μελέτες των επιστημόνων υπάρχουν μεγάλες πιθανότητες άνω του 50% να εκδηλωθεί κάποιος σεισμός.

Χαρακτηριστική περίπτωση πρόβλεψης σεισμού με ραδόνιο ήταν στις 6 Απριλίου του 2009 όταν έγινε ο φονικός εγκέλαδος των 6,3 Ρίχτερ στην Λ' Άκουιλα της Ιταλίας που είχε στοιχίσει τη ζωή σε 308 άτομα (ανάμεσά τους και έναν Έλληνα), ενώ τουλάχιστον 65.000 έμειναν χωρίς σπίτι.

Εκείνη την περίοδο πριν από τον σεισμό, ο τεχνικός στο σεισμογραφικό κέντρο του Gran Sasso, ο τότε 60χρονος Giampaolo Giuliani υποστήριζε τότε ότι σε ένα μήνα θα γινόταν μεγάλος σεισμός, έκανε δηλώσεις στην τηλεόραση και είχε αναρτήσει και την πρόγνωσή του στο διαδίκτυο.

Στήριζε την πρόγνωσή του στα υψηλά επίπεδο ραδονίου που εκπέμπονταν από το έδαφος. Τον κατηγόρησαν ότι πανικοβάλει τον κόσμο και η Γραμματεία Πολιτικης Προστάσίας τον υποχρέωσε να κατεβάσει όλες τις σχετικές αναρτήσεις του, δηλώνοντας μάλιστα πως «δεν υπάρχει κανένας κίνδυνος».

Μόλις μία εβδομάδα πριν από τον κύριο σεισμό μάλιστα ζήτησαν τη σύλληψή του επειδή είχε πείσει τον δήμαρχο της περιοχής Sulmona ότι επίκειται σεισμός και εκείνος με τη σειρά του πίεζε τους σεισμολόγους να απαντήσουν αν είναι πιθανό ο Giuliani να έχει δίκιο.

Ο τεχνικός επέμεινε ότι θα γίνει μεγάλος σεισμός με επίκεντρο 50 χιλιόμετρα από την Aquila στις 30 Μαρτίου. Ο σεισμός των 6,3 έγινε στις 6 Απριλίου. Η αλήθεια είναι ότι ο 60χρονος τότε τεχνικός είχε πέσει έξω κατά έξι ημέρες, το επίκεντρο όμως και ο σεισμός είχαν επαληθευτεί.

(Βασίλης Γούλας / ΠΡΩΤΟ ΘΕΜΑ, 15/11/2017, http://www.protothema.gr/greece/article/731735/to-radonio-deihnei-endehomeno-seismo-/)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΓΕΩΛΟΓΙΑ

How to turn a volcano into a power station

Erta Ale volcano in eastern Ethiopia

Ethiopia tends to conjure images of sprawling dusty deserts, bustling streets in Addis Ababa or the precipitous cliffs of the Simien Mountains – possibly with a distance runner bounding along in the background. Yet the country is also one of the most volcanically active on Earth, thanks to Africa's Great Rift Valley, which runs right through its heart.

Rifting is the geological process that rips tectonic plates apart, roughly at the speed your fingernails grow. In Ethiopia this has enabled magma to force its way to the surface, and there are over 60 known volcanoes. Many have undergone colossal eruptions in the past, leaving behind immense craters that pepper the rift floor. Some volcanoes are still active today. Visit them and you find bubbling mud ponds, hot springs and scores of steaming vents.

Steam rising at Aluto volcano, Ethiopia

This steam has been used by locals for washing and bathing, but underlying this is a much bigger opportunity. The surface activity suggests extremely hot fluids deep below, perhaps up to 300 – 400 °C (572 - 752 °F). Drill down and it should be possible access this high temperature steam, which could drive large turbines and produce huge amounts of power. This matters greatly in a country where 77% of the population has no access to electricity, one of the lowest levels in Africa.

Geothermal power has recently become a serious proposition thanks to geophysical surveys suggesting that some volcanoes could yield a gigawatt of power. That's the equivalent of several million solar panels or 500 wind turbines from each. The total untapped resource is estimated to be in the region of 10GW.

Converting this energy into power would build on the geothermal pilot project that began some 20 years ago at Aluto volcano in the lakes region 200 km (124 miles) south of Addis Ababa. Its infrastructure is currently being upgraded to increase production tenfold, from 7MW to 70MW. In sum, geothermal looks like a fantastic low-carbon renewable solution for Ethiopia that could form the backbone of the power sector and help lift people out of poverty.

The Rift Valley
https://www.youtube.com/watch?v=z5sdGyKqtkA

Scratching the surface

The major problem is that, unlike more developed geothermal economies like Iceland, very little is known about Ethiopia's volcanoes. In almost all cases, we don't even know when the last eruption took place – a vital question since erupting volcanoes and large-scale power generation will not make happy bedfellows.

In recent years, the UK's Natural Environment Research Council (NERC) has been funding RiftVolc, a consortium of British and Ethiopian universities and geological surveys, to address some of these issues. This has focused on understanding the hazards and developing methods for exploring and monitoring the volcanoes so that they can be exploited safely and sustainably.

Teams of scientists have been out in the field for the past three years deploying monitoring equipment and making observations. Yet some of the most important breakthroughs have come through an entirely different route – through researchers analysing satellite images at their desks.

This has produced exciting findings at Aluto. Using a satellite radar technique, we discovered that the volcano's surface is inflating and deflating. The best analogy is breathing – we found sharp "inhalations" inflating the surface over a few months, followed by gradual "exhalations" which cause slow subsidence over many years. We're not exactly sure what is causing these ups and downs, but it is good evidence that magma, geothermal waters or gases are moving around in the depths some five km below the surface.

Taking the temperature

In our most recent paper, we used satellite thermal images to probe the emissions of Aluto's steam vents in more detail. We found that the locations where gases were escaping often coincided with known fault lines and fractures on the volcano.

When we monitored the temperature of these vents over several years, we were surprised to find that most were quite stable. Only a few vents on the eastern margin showed measurable temperature changes. And crucially, this was not happening in synchronicity with Aluto's ups and downs – we might have expected that surface temperatures would increase following a period of inflation, as hot fluids rise up from the belly of the volcano.

It was only when we delved into the rainfall records that we came up with an explanation: the vents that show variations appear to be changing as a delayed response to rainfall on the higher ground of the rift margin. Our conclusion was that the vents nearer the center of the volcano were not perturbed by rainfall and thus represent a better sample of the hottest waters in the geothermal reservoir. This obviously makes a difference when it comes to planning where to drill wells and build power stations on the volcano, but there's a much wider significance.

This is one of the first times anyone has monitored a geothermal resource from space, and it demonstrates what can be achieved. Since the satellite data is freely available, it represents an inexpensive and risk-free way of assessing geothermal potential.

A productive geothermal well on Aluto

With similar volcanoes scattered across countries like Kenya, Tanzania and Uganda, the technique could allow us to discover and monitor new untapped geothermal resources in the Rift Valley as well as around the world. When you zoom back and look at the big picture, it is amazing what starts to come into view.

Written by William Hutchison, Juliet Biggs and Tamsin Mather (The Conversation)

(Steven Young / THE WATCHERS, November 02, 2017, https://watchers.news/2017/11/02/how-to-turn-a-volcano-into-a-power-station/?utm_source=feedburner&utm_medium=email&utm_campaign=Feed%3A+adorraeli%2FtsEq+%28The+Watchers+-+watching+the+world+evolve+and+transform%29)

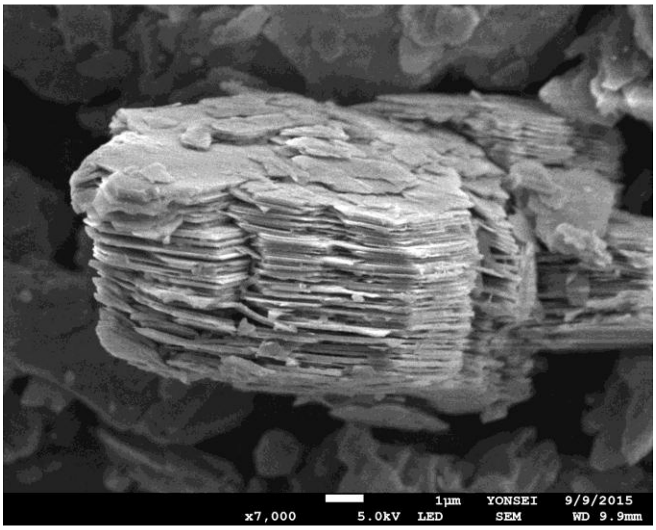
New insights into processes that cause volcanism

The first observation of a super-hydrated phase of the clay mineral kaolinite could improve our understanding of processes that lead to volcanism and affect earthquakes.

In high-pressure and high-temperature X-ray measurements that were partly conducted at DESY (German Electron Synchrotron), scientists created conditions similar to those in so-called subduction zones where an oceanic plate dives under the continental crust. The transport and release of water during subduction causes strong volcanic activity. An international team led by scientists of Yonsei University in the Republic of Korea, presents the results in the scientific journal Nature Geoscience.

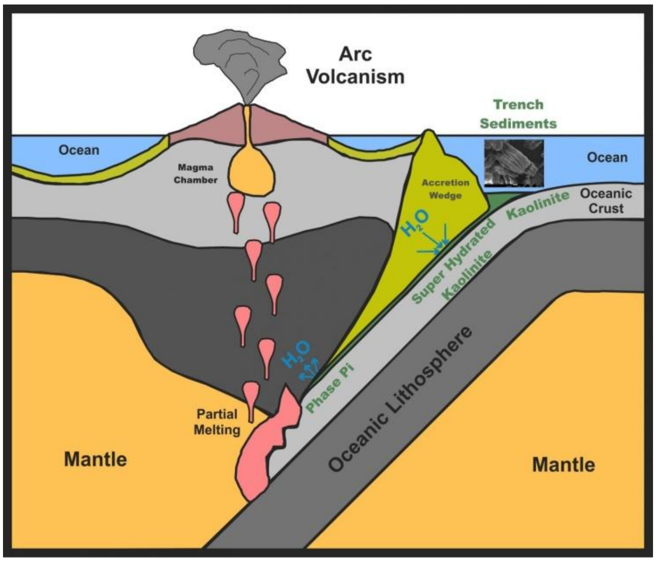
In a subduction zone, a heavy oceanic plate meets a second, lighter continental plate and moves under it and into the earth's mantle. With the oceanic plate, water enters the earth as it is trapped in minerals of the oceanic crust or overlaying sediments. These minerals slowly sink deeper into the mantle over millions of years. With increasing depth, temperature and pressure, the minerals become instable, break down and transform into new compounds.

During these transformations, water is released and rises into the surrounding, hotter mantle where it decreases the melting temperature of the mantle rock. "When the mantle rocks melt, magma is generated. This can lead to volcanic activity when the magma rises to the surface," explains Yongjae Lee from Yonsei University who led the study. "While we know that the water cycle in subduction zones influences volcanism and possibly seismicity, we don't know much about the processes that form this cycle."



Ordinary kaolinite under an electron microscope. Credit: Yonsei University/Yongjae Lee

Since these processes take place many kilometers under Earth's surface, it is impossible to observe them directly. Even the Kola Superdeep Borehole in Russia, the deepest borehole on Earth, reaches no deeper than 12 262 m (40 230 feet). One way to learn more about the transformations in greater depths of subduction zones is to create similar conditions in the laboratory. High-pressure and high-temperature measurements allow scientists to take a close look at the structural changes in the different minerals that form the crust and sediments.



Kaolinite sinks into the subduction zone with the oceanic plate. As it changes into the newly discovered phase it takes in water from its surroundings and releases it upon further structure change down in the mantle. Credit: Wikimedia Commons, MagentaGreen (modified) CC BY SA 3.0

One of these minerals is kaolinite, a clay mineral containing aluminium that is an important part of the oceanic sediments. The scientists were now able to observe the formation of a new phase of the mineral, so-called super-hydrated kaolinite. They examined a sample of kaolinite in the presence of water at pressures and temperatures corresponding to those at different depths in subduction zones. With X-ray diffraction and infrared spectra measurements, structural and chemical changes were characterized.

At a pressure of circa 2.5 Giga-Pascal (GPa), more than 25 000 times the average pressure at sea level, and a temperature of 200 °C (392 °F), the super-hydrated phase was observed. These conditions are present at a depth of about 75 km (46.6 miles) in subduction zones. In the new phase, water molecules are enclosed between the layers of the mineral. The super-hydrated kaolinite contains more water than any other known aluminosilicate mineral in the mantle. When pressure and temperature sink back to ambient conditions, the structure reverts to its original form.

In measurements carried out at the Extreme Conditions Beamline P02.2 at DESYs X-ray source PETRA III, the scientists examined the breakdown of the new phase at even higher pressures and temperatures. "Our beamline provides an environment to investigate samples at extreme pressures and temperatures. Using a so-called graphite resistive heated diamond anvil cell, we were able to observe the changes at a pressure of up to 19 Giga-Pascal and a temperature of up to 800 degrees," says DESY-scientist Hanns-Peter Liermann of the Extreme Conditions Beamline who co-authored the study. The super-hydrated kaolinite broke down at 5 Giga-Pascal and 500 °C (932 °F), two additional transformations happened at higher pressures and temperatures. During these transformations, the water that was intercalated in the kaolinite is released.

The observation of the formation and breakdown of the super-hydrated kaolinite bears important information about the processes that occur over a depth range of about 75 km to 480 km (46.6 to 298.26 miles) in subduction zones. The release of water that takes place when the super-hydrated kaolinite breaks down could be an important part of the water cycle that causes volcanism along subduction zones. The breakdown probably happens below a depth of about 200 km (124 miles), the released water could then contribute to the formation of magma.

Additionally, the super-hydrated kaolinite could influence seismicity. During the formation of the new phase, the water that surrounds kaolinite is removed from the environment. This could change the friction between the subducting and the overlying slabs. The scientists assume that other minerals in the sediment or crust could undergo similar transformations. Thus, the study could improve the understanding of the geochemical processes in subduction zones of the earth.

Reference

"A role for subducted super-hydrated kaolinite in the Earth’s deep water cycle" - Huijeong Hwang, Donghoon Seoung, Yongjae Lee, Zhenxian Liu, Hanns-Peter Liermann, Hyunchae Cynn, Thomas Vogt, Chi-Chang Kao, Ho-Kwang Mao; Nature Geoscience, 2017; DOI: 10.1038/s41561-017-0008-1

(Steven Young / THE WATCHERS, November 23, 2017, https://watchers.news/2017/11/23/new-insights-into-processes-that-cause-volcanism/?utm_source=feedburner&utm_medium=email&utm_campaign=Feed%3A+adorraeli%2FtsEq+%28The+Watchers+-+watching+the+world+evolve+and+transform%29)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΛΟΙΠΑ

The Kilogram doesn't weigh a kilogram any more

The Kilogram doesn't weigh a kilogram anymore. This sad news was announced during a seminar at CERN on Thursday, October 26 by Professor Klaus von Klitzing, who was awarded the 1985 Nobel Prize in Physics for the discovery of the quantized Hall effect. "We are about to witness a revolutionary change in the way the kilogram is defined," he declared.

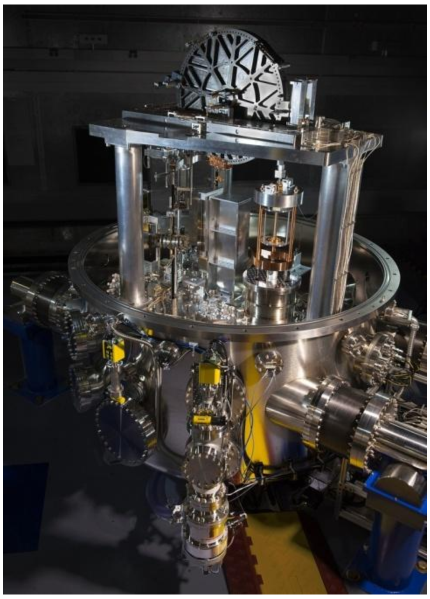
Together with six other units – meter, second, ampere, kelvin, mole, and candela – the kilogram, a unit of mass, is part of the International System of Units (SI) that is used as a basis to express every measurable object or phenomenon in nature in numbers. This unit's current definition is based on a small platinum and iridium cylinder, known as "le grand K", that weighs exactly one kilogram.

The cylinder was crafted in 1889 and, since then, has been kept safe under three glass bell jars in a high-security vault on the outskirts of Paris. There is one problem: the current standard kilogram is losing weight. About 50 micrograms, at the latest check. Enough to be different from its once-identical copies stored in laboratories around the world.

Replica of the national prototype kilogram standard no. K20 kept by the US government National Institute of Standards and Technology (NIST), Bethesda, Maryland. (Image: National Institute of Standards and Technology)

To solve this weight(y) problem, scientists have been looking for a new definition of the kilogram.

At the quadrennial General Conference on Weights and Measures in 2014, the scientific metrology community formally agreed to redefine the kilogram in terms of the Planck constant (h), a quantum-mechanical quantity relating a particle's energy to its frequency, and, through Einstein's equation $E = mc^2$, to its mass. Planck's constant is one of the fundamental numbers of our universe, a quantity fixed universally in nature, such as the speed of light or the electric charge of a proton.



The National Institute of Standards and Technology (NIST)-4 Kibble balance measured Planck's constant to within 13 parts per billion in 2017, accurate enough to assist with the redefinition of the kilogram. Credit: J. L. Lee/NIST

Planck's constant will be assigned an exact fixed value based on the best measurements obtained worldwide. The kilogram will be redefined through the relationship between Planck's constant and mass.

"There's nothing to be worried about," says Klaus von Klitzing. "The new kilogram will be defined in such a way that (nearly) nothing will change in our daily life. It won't make the kilogram more precise either, it will just make it more stable and more universal."

However, the redefinition process is not that simple. The International Committee for Weights and Measures, the governing body responsible for ensuring international agreement on measurements, has imposed strict requirements on the procedure to follow: three independent experiments measuring the Planck constant must agree on the derived value of the kilogram with uncertainties below 50 parts per billion, and at least one must achieve an uncertainty below 20 parts per billion. Fifty parts per billion, in this case, equals approximately 50 micrograms – about the weight of an eyelash.

Two types of experiment have proved able to link the Planck constant to mass with such extraordinary precision. One method, led by an international team known as the Avogadro Project, entails counting the atoms in a silicon-28 sphere that weighs the same as the reference kilogram. The second method involves a sort of scale known as a watt (or Kibble) balance. Here, electromagnetic forces are counterbalanced by a test mass calibrated according to the reference kilogram.

And that's where the important discovery made by Klaus von Klitzing in 1980, which earned him the Nobel Prize in Physics, comes into play. In order to get extremely precise measurements of the current and voltage making up the electromagnetic forces in the watt balance, scientists use two different quantum-electrical universal constants. One of these is the von Klitzing constant, which is known with extreme precision and can, in turn, be defined in terms of the Planck constant and the charge of the electron. The von Klitzing constant describes how resistance is quantized in a phenomenon called the "quantum Hall effect", a quantum-mechanical phenomenon observed when electrons are confined in an extra-thin metallic layer subjected to low temperatures and strong magnetic fields.

"This is truly a big revolution," von Klitzing says. "In fact, it has been dubbed the biggest revolution in metrology since the French Revolution, when the first global system of units was introduced by the French Academy of Sciences."

CERN is playing its part in this revolution. The Laboratory participated in a metrology project launched by the Swiss Metrology Office (METAS) to build a watt balance, which will be used to disseminate the definition of the new kilogram through extremely precise measurements of the Planck constant. CERN provided a crucial element of the watt balance: the magnetic circuit, which is needed to generate the electromagnetic forces balanced by the test mass. The magnet needs to be extremely stable during the measurement and provide a very homogenous magnetic field.

(Steven Young / THE WATCHERS, November 05, 2017, https://watchers.news/2017/11/05/how-much-does-a-kilogram-weigh/?utm_source=feedburner&utm_medium=email&utm_campaign=Feed%3A+adorraeli%2FtsEq+%28The+Watchers+-+watching+the+world+evolve+and+transform%29)

ΗΛΕΚΤΡΟΝΙΚΑ ΠΕΡΙΟΔΙΚΑ

www.geoengineer.org

Κυκλοφόρησε το Τεύχος #150 του **Newsletter** του **Geoengineer.org** (Νοεμβρίου 2017) με πολλές χρήσιμες πληροφορίες για όλα τα θέματα της γεωμηχανικής. Υπενθυμίζεται ότι το Newsletter εκδίδεται από τον συνάδελφο και μέλος της ΕΕΕΕΓΜ Δημήτρη Ζέκκο (secretariat@geoengineer.org).

Ενδεικτικά αναφέρονται:

- New study links Raton Basin earthquakes to oil and gas wastewater injections
- "Geo-Trends Review" : The first crowdsourcing-based content magazine in Geotechnical Engineering is here!
- Village in Fiji relocated after landslide and cyclone disasters
- Typhoon Lan causes flooding and landslides in Japan (video)
- World's first floating wind farm powers up offshore Scotland
- Scientists explore underwater active seismic fault...
- Arabian sedimentary basin simulator launched by Saudi Aramco
- Mexico's Popocatépetl volcano erupts again (video)
- Floods and landslides leave many dead in Vietnam
- Scientists in Japan improve seismic resistance of metals
- Mexico City Earthquake GEER Report Ver. 1
- The results of the "Geotechnical Business Confidence Survey" by GeoWorld, for the 3nd quarter of 2017!
- Kaikoura Earthquake responsible for "slow motion" quakes in New Zealand

http://campaign.r20.constantcontact.com/render?m=1101304736672&ca=b3570e4f-4fe1-4597-b10c-326747f45680

ITACET Foundation
Foundation for Education and Training on Tunnelling and Underground Space Use
Newsletter #27
November 2017

Κυκλοφόρησε το Τεύχος #27 του **Newsletter** του **ITACET Foundation** (Νοεμβρίου 2017) με τα παρακάτω περιεχόμενα:

- President's address
- The Foundation Council meets in Dubai
- Training session reports
  - Innovative perspectives for efficient tunnel operation
  - Risk management in tunnelling
  - Sustainability and eco-friendly tunnelling
  - WTC 2017: excavation and support in soft ground conditions
- Forthcoming sessions
  - Flood Control and Tunnelling, Shanghai, China, 25th November 2017
  - Control and Monitoring of Tunnels and Underground Space, Thimphu, Bhutan, 27th - 28th November 2017
  - Choice of Excavation Method: Conventional or
  - Mechanized?, Mexico City, Mexico, 1st - 2nd February 2018 (to be confirmed)
- Other events in preparation
  - Underground Space Use, Lagos, Nigeria, 21st March 2018
  - Basic Principles of Tunnelling, Dubai, UAE, 21st – 22nd April 2018
  - Utility Tunnels, China (date and venue not yet fixed).
  - Structural Use of Fibre-reinforced Concrete, Paris, France (date not yet fixed)
  - Innovations in Tunnelling, Brazil (date and venue not yet fixed)
- Foundation scholarship recipients
  - The ITACET foundation grants two new scholarships
  - Helping young minds dig deeper
  - Encouraging news from scholarship student in the uk
- Other news
  - Targeting a wider public through linkedin

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https://powow4.iroquois.fr/web_browser.php?p=YT00MDM3MjA0O2I9NDQ7Yz00NDtkPTIxNTUzMDQ7ZT0zOTgwOTAwO2Y9MjA2NzU4NDtoPQ%3D%3D

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