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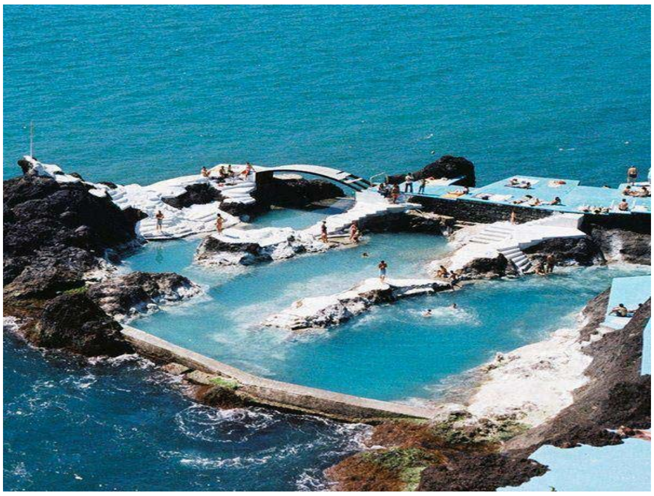


Fast Track Approach to Design and Construction at Grand Ethiopian Renaissance Dam

Bruno Ferraro, Alberto Bezzi, Claudio Rossini and Paolo Mastrofini

Being constructed on the Nile River, Grand Ethiopian Renaissance Dam will feature the largest roller compacted concrete volume dam in the world at 10.2 Mm^3. Its reservoir of 70 km^3 will be comparable to those of Bennett (Canada) and Kraskoyarsk (Russia). This article reveals the approach allows a radical reduction -- at least 50% -- of total project implementation time and full control of project cost.

The Grand Ethiopian Renaissance Dam (GERD) and hydroelectric project is located 700 km northeast of the capital city Addis Abeba, in the Benishangul–Gumaz region of Ethiopia, along the Blue Nile River. When it is completed, with its concrete volume of 10.2 million m^3, GERD will feature the largest dam in Africa.

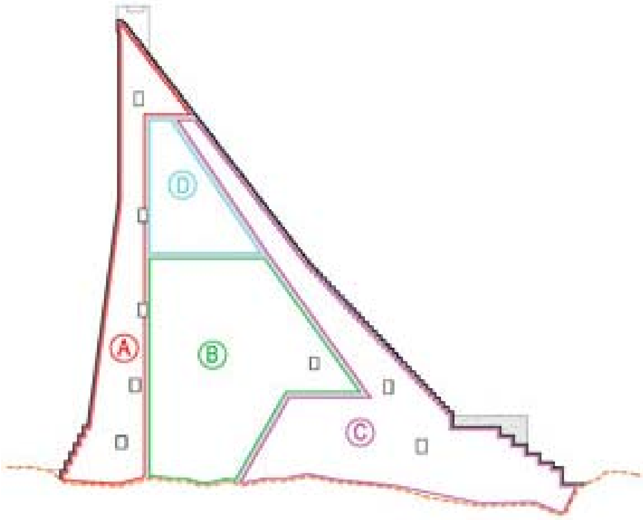
State-owned Ethiopian Electric Power (EEP) hired Salini-Impregilo SpA as the Engineering, Procurement and Construction (EPC) Contractor. Studio Ing. G. Pietrangeli, based out of Italy, is the civil works designer.

GERD's water retaining structures include the following: the Main Dam, a roller compacted concrete (RCC) structure that is 1,800 m long and 175 m high, and a Saddle Dam, a concrete faced rock fill (CFRD) structure, 5,000 m long and 60 m high, with embankment volume of 17 million m^3. See Figure 1 for more details.

Two powerhouses located at the toe of the Main Dam will house 16 Francis units at 375 MW each, totaling 6,000 MW in capacity, for an expected annual generation of 15 TWh. The Project also includes a gated spillway, two non-gated emergency spillways, one 500 kV substation and switchyard, a 240 km transmission line and 120 km of access roads.

In the 1960s, the United States Department of Interior's Bureau of Reclamation conceived the water resources development plan for the Upper Blue Nile River in Ethiopia, which featured a dam site named Border. Since then, the plans and studies remained as they were created until 2010, when Salini–Impregilo and Studio Pietrangeli resumed studies and site investigations.

GERD is the first storage dam being built on the main-stream Blue Nile, upstream of Roseires Reservoir (located in Sudan), very close to the USBR's border site.



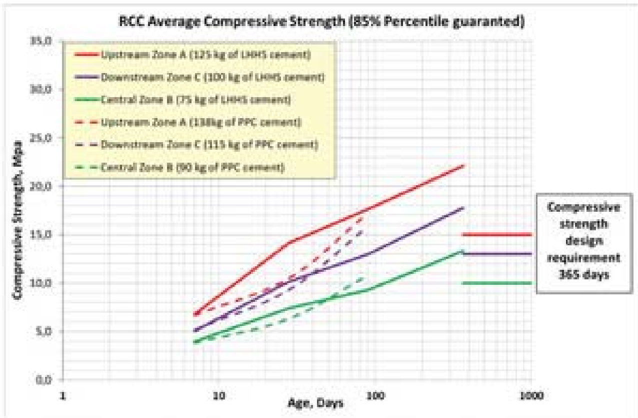


Figure 1--RCC Average Compressive Strength (85th Percentile Guaranteed)

In 2011, construction was in full swing. GERD represents the most daring challenge, in terms of "fast-track project," being undertaken by Salini-Impregilo.

Fast-track approach

The Fast Track Implementation method is based on the concurrent development of all relevant phases of a large hydroelectric project, investigations, studies, design and construction. Successful application in three Ethiopian projects, 420-MW Gibe II, 460-MW Beles Multipurpose and 1,870-MW Gibe III, reveals the approach allows a radical reduction -- at least 50% -- of total project implementation time and full control of project cost.

The main challenges for schedule control of GERD are the size of the related works, combined with its remote location. Neither of these two challenges is unique in the water infrastructure industry, but its combination is acute at GERD. The EPC is facing the task through a threefold approach: a two level design, continuous investigations during construction and adaptive management of construction methods.

Level 1 design represents the final definition of a section of works; it contains all the elements required to understand the technical solution, including studies and calculations. Level 2 represents the detailed construction/manufacturing design, e.g. construction drawings, detailed technical specifications, method statements, commissioning and testing procedures, etc. Experience has taught that the most effective measure for smooth construction progress is the adoption of reliable design and practicable construction solutions; in other words, solutions that are considered "as simple as possible, but not simpler than required."

EPC has extensive in-house capacity for site investigation and testing, and routinely applies such capacity, during construction, to supplement, integrate and update information provided by the initial campaign. Large availability of earthmoving and drilling equipment allows prompt access and execution of boreholes and in-situ tests over the entire project area. This, together with the availability of state-of-the-art and fully equipped laboratories at the site, enables quick and reliable characterization of foundation conditions of structures and construction materials available in potential quarries and borrow areas. The above allows preventive definition and management of geotechnical and construction risks.

Technological innovation

Adoption of the "as simple as possible" criterion did not hinder technological innovation, e.g. for topographic and geological surveys. With a zoom-in approach, different technologies are utilized in design investigation: satellites (200 km), airborne laser scanning (2 km), drone-aided photogrammetry (200 m) and "giraffe technique" (10 m).

This image, taken on site in January 2015, shows the massive scope of the Grand Ethiopian Renaissance project's Main Dam, photographed from the right abutment.

The drones, equipped with a digital 16 Megapixel camera, internal GPS and various sensors that include ground proximity, temperature, altitude, wind velocity and direction, were employed to prepare detailed geo-referenced orthophotos, orthophotomosaics, Digital Terrain Models (DTM) and contour lines. Flight plans were preliminarily prepared taking into account the morphology of the sites and the extension of the area to be surveyed and the required survey accuracy; these were then uploaded into the drone controller.

During the survey, which is preceded by the selection of suitable starting and landing points as well as landing corridors, the drones are radio monitored up to a distance of about 3 km and work progress is displayed in real-time on a laptop. The self-piloting software allows the drone to adjust and adapt the flight plan in real time following the actual conditions of wind, battery level, presence of unforeseen obstacles and other parameters, thus reducing to a minimum the need for human intervention.

The geotechnical assessment of dam foundation has primary importance in the design process and during the construction phase; it is a prerequisite of the foundation treatment and supports post-construction monitoring. In order to speed up foundation mapping and to improve accuracy of the information acquired, an innovative technique has recently been tested during the foundation preparation works.

Large areas of the foundation were photographed using a camera attached to a telescopic pole, nicknamed, Giraffe. The camera, remotely controlled using a tablet with a Wi-Fi connection, takes pictures of the foundation surface from a maximum height of 10 m, assuring the proper framing and overlap necessary for the photogrammetry processing. Ground control points, about 10 every 400 m^2, are topographically surveyed. Pictures are then processed by photogrammetric technique, obtaining a georeferenced three-dimensional model of the foundation surface that contains all the information on topography, main lithological limits and rock defects (i.e., length and orientation of discontinuities).

Drones were deployed equipped with a camera and various sensors to prepare detailed geo-referenced ortho photos, digital terrain models, contour lines and additional data.

This procedure is faster and more accurate than a traditional geological/geotechnical survey. It has the added advantage of having georeferenced images and a DTM that allow the survey to be documented for future reference/verification. The procedure also carries out specific measurements on the digital model itself. The speed of execution makes this method particularly suitable for large areas and situations in which concrete is being poured very shortly after mapping: a useful feature for the fast-track approach.

Maximum use of national resources

Maximizing the use of national resources for project implementation is an essential element for harvesting both direct and indirect economic impacts of the large investment associated with GERD. Direct economic impacts are those deriving from the construction of the project, such as electricity generation, employment, and other services provided by the structure. Indirect and induced impacts are those that stem from the linkages between the direct consequences of a project and the rest of the economy. Among them are impacts due to changes in output and input use in sectors other than those affected directly by the project, or changes in relative prices, employment and factory wages. Maximum use of national resources enhances indirect economic benefits.

At the same time, maximum use of national resources entails management issues that need to be addressed. Typical examples include: difficulty in securing adequate staffing due to the remoteness of the GERD site, sufficient and reliable provision of cement to meet the extremely high demand associated with the required RCC placement rates. Ethiopian cements proved initially unsuitable for RCC. The issue was solved with extensive laboratory and field tests that finally lead to the definition of suitable RCC mixes employing improved locally produced cements.

This experience, obtained in co-operation with the major Ethiopian cement producers, contributed to improve the cement manufacturing process and the quality of cement available on the local market resulting in beneficial effects for the overall Ethiopian economy.

River Diversion

The original river diversion scheme featured an initial phase when the river was flowing in its natural gorge while diversion culverts, together with the right and left portions of the Main Dam, were to be constructed on both banks. Upon completion of the diversion culverts, the river was to be diverted in the culverts, during one dry season (November-May). River diversion featured construction of the central section of the Main Dam in the river gorge, which was to provide a temporary sill where the river could overflow during the wet season. For the success of this scheme, it was essential to complete the construction of the central section of the Main Dam during one dry season.

The river diversion scheme changed with the introduction of 2.5 m^3 rock excavation for an additional channel on the right bank, including appurtenant cofferdams and training walls.

However, when foundation excavation revealed a much deeper river gorge and extensive sediments in the riverbed, the scheme had to be radically revised. The river diversion scheme changed with the introduction of 2.5 Mm^3 of rock excavation for an additional channel on the right bank, including appurtenant cofferdams and training walls.

The rapid adaptation of plans permitted limited impact to the river diversion schedule, a key milestone of any dam construction plan.

Hydrological Safety

With its 60-km^3 active capacity, the GERD reservoir will play an important role in attenuating large flood peaks with remarkable benefits for the hydrological safety of downstream countries.

A system of three spillways safeguards the project against the Probable Maximum Flood 30,200 m^3/s peak discharge. The different typology and location of the spillways introduces redundancy in the system, a key ingredient to guarantee the highest standard of hydrological safety.

The main service spillway of the Project is a gated structure, located on a saddle area to the immediate left of the main dam; its discharge capacity, at maximum reservoir level is about 15,000 m^3/s. A second spillway is located on the overflow section of the main dam. It is a free-crest type and can discharge up to 2,800 m^3/s.

The third spillway is located on the right abutment of the saddle dam; the excavation required for its realization is used for embankment construction. The saddle dam spillway is a side channel un-gated waterway. Its sill is set 2 m higher than the full storage level (FSL = 640 m asl). It is designated as an emergency spillway because it will come into operation when the combined discharge of the other two spillways equals the 1,000-year floods.

The peak discharge capacity is about 1500 m^3/s. The redundancy of the spillway system assure the capacity of discharging the PMF even in case of malfunctioning of one gate (N1-rule) and the 10,000 y flood in case of malfunctioning of two gates (N2- rule).

RCC Placement Rates

Extensive time has been devoted to the study and optimization of each RCC ingredient and of the most appropriate RCC mixes for different areas of the dam. RCC uses three classes of aggregates (crushed rock) from gneiss-granite quarry: 8mm (sand); 8-20 mm (grain size) and 20-50 mm (pea size).

Two types of cement are used:

CEM I 42,5 LHHS (Portland Low Heat of Hydration and High Sulfate resistance), and

CEM IV-A 32,5 R (Pozzolanic cement).

Cement contents vary, through the cross section of the dam. Equivalent values in the case of pozzolanic cement are: 138/90/100 kg/m^3, in zone A, B and C respectively.

Comprehensive testing on plasticizer/retarder admixtures allowed such setting times to be attained to maintain warm joint conditions up to 12-16 hours after RCC spreading. Admixture dosages vary, at GERD, between 1.0% and 1.75% of cement weight. Achieving warm joint conditions guarantees design cohesion values for the lifts, while minimizing joint treatment time.

Tests during RCC production included: VeBe time, air content, fresh density, and in situ density. Quality control of placed RCC involved core drilling after three months from laying and include: density, compressive strength, direct tensile strength (on parent RCC and joints), joints cohesion, friction angle and permeability.

Large-scale RCC production started in December 2013, and monthly placement rates progressively increased from 75,000 to 235,000 m^3 in December 2014, with peaks of 23,200 m^3/day.

Production plants consist of a primary 2,000 t/hr crushing station and an auxiliary one of 400 t/hr. Coarse aggregates pass through an air pre-cooler plant which, together with an ice plant, yield RCC at 17 °C. Two batching plants feature eight mixers for a total capacity of 1,120 m^3/hour; delivery of mixes takes place by conveyors belts and 32/40 t dumpers.

RCC production process is continuously optimized. Since January 2015, the overall placement area has been about 50,000 m^2, subdivided in 6 working zones, each one of about 9,000 m^2. Eight RCC lifts, each one 0.4m thick, are placed in each zone before production moves to another zone. This translates in one cold joint and seven warm ones. The cold joint is Type 2 (above 72 hours after compaction) and coincides with the lowest/starting one on which construction returns after completing the eight lifts of the other five zones. This method allows mitigation of temperature rise by heat dissipation from the lift surface during the stop period, as well as maximizes the number of warm joints. Reduced dosage of admixture is used for the eighth lift, which allows anticipating the necessary treatment. RCC ramps (using sloping layer method with 6% gradient) ensure satisfactory connection between different areas of the dam.

The adoption of a mixed system, including horizontal layers and sloping layers ramps, well reflects the "fast track" system and its added benefit of continuously studying and optimizing production processes during construction while achieving the required RCC characteristics.

RCC Temperature Control

Temperature control is one of the most important issues during the construction of a large RCC gravity dam, especially in the presence of volumes and production rates, such as those associated with the GER Main Dam. The cement dosage of each area of the dam is intended to meet design strength and permeability requirements based on the results of extensive RCC test campaigns.

A world record for roller compacted concrete placement was set at the construction site in December 2014, with peaks of 23,200 Mm^3/day.

The main measures to control temperature rise in the Grand Ethiopian Renaissance Dam are: pre-cooling of materials, mixes with low cement content, appropriate construction schedule, and solar radiation protection by continuous curing. Furthermore, a temperature monitoring and early warning procedure has been implemented in order to verify, during the progress of works, agreement between calculated and recorded temperatures. The early warning procedure includes the definition of threshold values and an indication of prompt actions to be taken in case anomalous temperatures are detected.

The temperature limits at different ages are portrayed in a graph indicating four zones with different safety factors against mass cracking, namely: safe, early warning, warning and risk of crack.

These temperature limits are defined on the basis of the mechanical characteristics of the RCC mixes. Particular attention was paid to the definition of tensile strain capacity; detailed analysis of direct tensile tests (providing both strength and modulus) and creep tests were carried out for the evaluation of this key parameter.

Thermal behavior during long-term construction of the dam is being analyzed by software developed by Studio Pietrangeli. The main purpose of the thermal study is to manage the risk of crack development by controlling the RCC temperature rise and it is accomplished by defining maximum allowable placing temperatures in relation to construction rate and environmental conditions.

The thermal model is based on the finite difference method, which considers several factors that include the following:

- Time-dependent ambient conditions: fluctuation of air temperature and solar radiation, heat transfer by convection from the external surface of RCC lift;
- Time variation of thermo-mechanical properties of the RCC/Grout Enriched-RCC mixes: adiabatic temperature rise, elastic modulus, creep, tensile strain capacity; and
- Production parameters: placing temperature, construction start, lift height and lift placement rate.

The thermal properties of the three mixes used in construction of the Grand Ethiopian Renaissance Dam, (i.e., specific heat, thermal diffusivity, thermal expansion coefficient, adiabatic temperature rise, etc.) were preliminarily estimated during laboratory testing and subsequently validated by back analysis of full-scale trial tests. Full-scale trials were conducted on an RCC dam block used in the river diversion scheme; the block, measuring approximately 130 x 14 x 20 m, was equipped with 31 thermocouples.

Back analysis was extremely useful to accurately define the adiabatic temperature rise. As of January 2015, with about 20% of the works completed (2.3 Mm^3 of RCC placed), temperature measurements in the dam body confirm the good match with the values predicted by the calibrated model. It can be noted that the peak temperature and the correspondent time predicted by the model are slightly higher than the measured values, which is on the safe side.

Conclusions

Salini-Impregilo's experience in Ethiopia, and teaming with Studio Pietrangeli, have demonstrated that large infrastructure projects can be efficiently implemented using a fast track approach.

Project management for scheduling and cost control are maintained by the following:

- Early start of activities because site investigations and feasibility design are carried out concurrently to produce the basic design on which risks are identified, discussed and agreed between the parties;

- Use of the Engineering Procurement and Construction form of contract that sets the obligations of the parties; and
- Salini-Impregilo's knowledge of the country and capability of fast response to changed conditions, during execution of the works.

For more information and up to date news about this dam and the associated hydropower projects, visit HydroWorld.com and search for renaissance.

Bruno Ferraro is GERD Project Manager for Salini-Impregilo. Alberto Bezzi is GERD Project Coordinator for Studio Pietrangeli. Claudio Rossini is a geotechncial engineer for Studio Pietrangeli. Paolo Mastrofini is a geologist/materials engineer for Salini-Impregilo.

(Hydro Review Worldwide, Vol. 23, Issue 4, July 2015, http://www.hydroworld.com/articles/print/volume-23/issue-4/features/fast-track-approach-to-design-and-construction-at-grand-ethiopian-renaissance-dam.html)

ΝΕΑ ΑΠΟ ΤΙΣ ΕΛΛΗΝΙΚΕΣ ΚΑΙ ΔΙΕΘΝΕΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΝΩΣΕΙΣ

ΕΛΛΗΝΙΚΗ ΕΠΙΣΤΗΜΟΝΙΚΗ ΕΤΑΙΡΕΙΑ ΕΔΑΦΟΜΗΧΑΝΙΚΗΣ & ΓΕΩΤΕΧΝΙΚΗΣ ΜΗΧΑΝΙΚΗΣ

Πρακτικά διεθνών συνεδρίων για την εκπαίδευση γεωτεχνικών

Αγαπητά μέλη της ΕΕ,

Με την βοήθεια του Δημήτρη Ζέκκου / Geoengineer ανέβηκαν στην ιστοσελίδα της ISSMGE http://www.issmge.org/en/resources/publications/tc306-international-conferences-database τα πρακτικά των τελευταίων δύο διεθνών συνεδρίων για την εκπαίδευση γεωτεχνικών. Η αναζήτηση μπορεί να γίνει είτε διατρέχοντας την πλήρη λίστα, είτε με λέξεις κλειδιά, είτε αναζητώντας άρθρα συγκεκριμένου συγγραφέα, π.χ. Burland ή Simpson.

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

Numerical Analysis in Geotechnics, 20 August 2015, Hanoi, Vietnam, nag2015secretariat@gmail.com

Subsea Tunnels, 2-3 September 2015, Seoul, Korea www.tu-seoul2015.org

SICAT 2015 - Symposium on Innovation and Challenges in Asian Tunnelling 2015, 2 to 3 September 2015, Singapore, tucss@cma.sg, www.tucss.org.sg.

China Shale Gas 2015 - an ISRM Specialized Conference, 6-8 September 2015, Wuhan, China, http://english.whrsm.cas.cn/ic/ic/201405/t20140509_120692.html

"Underground Construction" Conference, 8-9 September 2015, Krakow, Poland, www.inzynieria.com

13th International Benchmark on the Numerical Analysis of Dams, 9 - 11 September 2015, Lausanne | Switzerland http://icold2015bmw.epfl.ch

International Symposium on Geohazards and Geomechanics 10-11 September, 2015, Coventry, U.K., www.warwick.ac.uk/isgg2015

24th European Young Geotechnical Engineers Conference in Durham, UK, 11-12 September, 2015, https://www.dur.ac.uk/conference.booking/details/?id=419

16th European Conference on Soil Mechanics and Geotechnical Engineering "Geotechnical Engineering for Infrastructure and Development", 13 - 17 September 2015, Edinburgh, UK, www.xvi-ecsmge-2015.org.uk

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GEO-EXPO 2015 Scientific and Expert Conference in Zenica, Bosnia and Herzegovina
18 - 19 September 2015, Zenica, Bosnia and Herzegovina
www.geotehnika.ba

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2015 Cutting Edge "Urban Tunneling", September 21-23, 2015, Denver, USA, www.ucaofsmecuttingedge.comwww.ucaofsmecuttingedge.com

Workshop on Volcanic Rocks & Soils, 24 - 25 September 2015, Isle of Ischia, Italy, www.associazionegeotecnica.it

The 7th International Symposium on Roller Compacted Concrete (RCC) Dams, Chengdu, China, Sept. 24th-25th, 2015, www.chincold.org.cn

Athens 2015 International Landfill Mining Conference, September 24-25, 2015, Athens, http://www.erasmus.gr/microsites/1050/welcome-address

TranSoilCold 2015 - The 2nd International Symposium on Transportation Soil Engineering in Cold Regions, September 24-26, 2015, Novosibirsk, Russia, http://transoilcold2015.stu.ru/index.htm

International Conference on Landslides and Slope Stability (SLOPE 2015), September 27-30, 2015, Bali, Indonesia, www.slope2015.com

Sardinia 2015 International Waste Management and Landfill Symposium, 5-9 October 2015, Santa Margherita di Pula, Italy, www.sardiniasymposium.it

GE Basements and Underground Structures Conference 2015, 6 - 7 October 2015, London, UK, http://basements.geplus.co.uk

EUROCK 15 ISRM European Regional Symposium & 64th Geomechanics Colloquy, 7 – 9 October 2015, Salzburg, Austria, www.eurock2015.com

Shotcrete for Underground Support XII New Developments in Rock Engineering, TBM tunnelling, Deep Excavation and Underground Space Technology, October 11-13, 2015, Singapore, www.engconf.org/conferences/civil-and-environmental-engineering/shot-crete-for-underground-support-xii

5th International Symposium on Geotechnical Safety and Risk (ISGSR 2015), 13-16 October 2015, Rotterdam, The Netherlands www.isgsr2015.org

International Workshop on Tsunamis in the World: from Source Understanding to Risk Mitigation, 14 to 16 October, 2015, Heraklion, Greece, www.gein.noa.gr/itw2015

LTBD2015 3rd International Workshop on Long-Term Behaviour and Environmentally Friendly Rehabilitation Technologies of Dams Hohai University, Nanjing, October 17-19, 2015, LTBD2015@gmail.com

COST TUI208 International Workshop Civil Engineering Applications of Ground Penetrating Radar, 19–20 October 2015, Athens, Greece, http://pavnet.civil.ntua.gr

HYDRO 2015, 26-28 October 2015, Bordeaux, France, www.hydropower-dams.com/pdfs/hydro2015.pdf

International Conference on Engineering Geology in New Millennium, 26-31 October 2015, New Delhi, India, http://isegindia.org/pdfs/1st%20circular-international-IAEG.pdf

6th International Conference on Earthquake Geotechnical Engineering, 2-4 November 2015, Christchurch, New Zealand, www.6icege.com

SEOUL 2015 - 25th World Road Congress Roads and Mobility – Creating New Value from Transport, 2–6 November, 2015, Seoul, Republic of Korea, http://www.aipcrseoul2015.org

4° Πανελλήνιο Συνέδριο Αναστηλώσεων, Νοέμβριος 2015, Θεσσαλονίκη, www.etepam.gr.

The 15th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering, 9-13 November 2015, Fukuoka, Japan, http://www.15arc.org

Tunnels and Underground Construction 2015, 11-13 November 2015, Žilina, Slovak Republic, www.tps2015.sk

15th Pan-American Conference on Soil Mechanics and Geotechnical Engineering, 15 - 18 November 2015, Buenos Aires, Argentina, http://conferencesba2015.com.ar

GEOMATE, 16 -18 November 2015, Osaka, Japan, www.geomate.org

VIII South American Congress on Rocks Mechanics, 15 - 18 November 2015, Buenos Aires, Argentina, http://conferencesba2015.com.ar

Sixth International Conference on Deformation Characteristics of Geomaterials IS Buenos Aires 2015, November 15th to 18th 2015, www.saig.org.ar/ISDCG2015

JTC-1 TR3 Forum Slope Safety Preparedness for Effects of Climate Change, 18 and 19 November 2015 Naples, Italy, www.cmcc.it/events/workshop-slope-safety-preparedness-for-effects-of-climate-changes

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The conference will be associated with a technical exhibition, where national and international companies are showcasing their products and services in: Geosynthetics, Geotextiles, Geomembranes, Waterproofing Membranes, Geosynthetic Clay Liners (GCL), Geogrids, Geonets, Geocomposites, Geofoam, Geocells, Geopipes, Water Management Systems, Leachate Collection Systems, Irrigation Solutions, Erosion Controls and many more.

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TBM DiGs Tunnel Boring Machines in Difficult Grounds, 18-20 November 2015, Singapore, www.tbmdigs.org

Arabian Tunnelling Conference & Exhibition: Innovative Underground Infrastructure - And Opportunities, 23-25 November 2015, Dubai, UAE, www.atcita.com

Geo-Environment and Construction, 26-28 November 2015, Tirana, Albania, Prof. Dr. Luljeta Bozo, lulibozo@gmail.com; luljeta_bozo@universitetipolis.edu.al

ICSGE 2015 - The International Conference on Soft Ground Engineering, 3-4 December 2015, Singapore, www.geoss.sg/icsge2015

The 1st International Conference on Geo-Energy and Geo-Environment (GeGe2015) 4th and 5th December 2015, Hong Kong, http://gege2015.ust.hk

2015 6th International Conference Recent Advances in Geotechnical Engineering and Soil Dynamics, December 7-11, 2015, New Delhi (NCR), India, wason2009@gmail.com; wasonfeq@iitr.ernet.in, sharmamukat@gmail.com; mukutfeq@iitr.ernet.in, gvramanaiitdelhi@gmail.com, ajaycbri@gmail.com

Southern African Rock Engineering Symposium an ISRM Regional Symposium, 5 January 2016, Cape Town, South Africa, http://10times.com/southern-african-rock

ASIA 2016 - Sixth International Conference on Water Resources and Hydropower Development in Asia, 1-3 March 2016, Vientiane, Lao PDR, www.hydropower-dams.com/pdfs/asia20161.pdf

GeoAmericas 2016 3rd Panamerican Conference on Geosynthetics, 11 – 14 April 2016, Miami Beach, USA, www.geoamericas2016.org

International Symposium on Submerged Floating Tunnels and Underwater Structures (SUFTUS-2016), 20-22 April 2016, Chongqing, China, www.cmct.cn/suftus

World Tunnel Congress 2016 "Uniting the Industry", April 22-28, 2016, San Francisco, USA, http://www.wtc2016.us

International Symposium "Design of piles in Europe - How did EC7 change daily practice?", 28-29 April 2016, Leuven, Belgium, www.etc3.be/symposium2016

7th In-Situ Rock Stress Symposium 2016 - An ISRM Specialised Conference, 10-12 May 2016, Tampere, Finland, www.rs2016.org

84th ICOLD Annual Meeting, 16-20 May 2016, Johannesburg, South Africa, www.icold2016.org

2nd International Conference on Rock Dynamics and Applications (RocDyn-2), 18 – 20 May 2016, Suzhou, China http://rocdyn.org

13th International Conference Underground Construction Prague 2016 and 3rd Eastern European Tunnelling Conference (EETC 2016), 23 to 25 May 2016, Prague, Czech Republic, www.ucprague.com

GEOSAFE: 1st International Symposium on Reducing Risks in Site Investigation, Modelling and Construction for Rock Engineering - an ISRM Specialized Conference, 25 – 27 May 2016, Xi'an, China, www.geosafe2016.org/dct/page/1

14th International Conference of the Geological Society of Greece, 25-27 May, Thessaloniki, Greece, www.ege2016.gr

NGM 2016 - The Nordic Geotechnical Meeting, 25 - 28 May 2016, Reykjavik, Iceland, www.ngm2016.com

International Mini Symposium Chubu (IMS-Chubu) New concepts and new developments in soil mechanics and geotechnical engineering, 26 - 28 May 2016, Nagoya, Aichi, Japan, www.jiban.or.jp/index.php?option=com_content&view=article&id=1737:2016052628&catid=16:2008-09-10-05-02-09&Itemid

19SEAGC – 2AGSSEAC Young Geotechnical Engineers Conference, 30th May 2016, Petaling Jaya, Selangor, Malaysia, seagc2016@gmail.com

19th Southeast Asian Geotechnical Conference & 2nd AGSSEA Conference Deep Excavation and Ground Improvement, 31 May – 3 June 2016, Subang Jaya, Malaysia, seagc2016@gmail.com

ISSMGE TC211 Conference Session within the framework of the 19th Southeast Asian Geotechnical Conference "GROUND IMPROVEMENT works: Recent advances in R&D, design and QC/QA"

ISL 2016 12th International Symposium on Landslides Experience, Theory, Practice, Napoli, June 12th-19th, 2016, www.isl2016.it

4th GeoChina International Conference Sustainable Civil Infrastructures: Innovative Technologies for Severe Weathers and Climate Changes, July 25-27, 2016, Shandong, China, http://geochina2016.geoconf.org

6th International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics August 1-6, 2016, Greater Noida (NCR), India, www.6icragee.com

EUROC 2016 - ISRM European Regional Symposium Rock Mechanics & Rock Engineering: From Past to the Future, 29-31 August 2016, Ürgüp-Nevşehir, Cappadocia, Turkey http://eurock2016.org

3rd ICTG – 3rd International Conference on Transportation Geotechnics 4 - 7 September 2016, Guimaraes, Portugal, www.civil.uminho.pt/3rd-ICTG2016

IAS'5 5th International Conference on Geotechnical and Geophysical Site Characterisation, 5-9 September 2016, Gold Coast, Queensland, Australia http://www.isc5.com.au

SAHC 2016 - 10th international Conference on Structural Analysis of Historical Constructions 13-15 September 2016, Leuven, Belgium, www.sahc2016.be

13 Baltic States Geotechnical Conference Historical Experiences and Challenges of Geotechnical Problems in Baltic Sea Region, 15 - 17 September 2016, Vilnius, Lithuania, http://www.13bsgc.lt

EuroGeo 6 – European Regional Conference on Geosynthetics, 25 – 29 Sep 2016, Istanbul, Turkey, www.eurogeo6.org

ARMS 9, 9th Asian Rock Mechanics Symposium, ISRM Regional Symposium, 18-20 October 2016, Bali, Indonesia, http://arms9.com

GeoAsia 6 - 6th Asian Regional Conference on Geosynthetics 8-11 November 2016, New Delhi, India, http://seags.ait.asia/news-announcements/11704

RARE 2016 Recent Advances in Rock Engineering 16-18 November 2016, Bangalore, India, www.rare2016.in

AfriRock 2017, 1st African Regional Rock Mechanics Symposium, 12 – 17 February 2017, Cape Town, South Africa, www.saimm.co.za/saimm-events/upcoming-events

World Tunnel Congress 2017
Surface problems – Underground solutions
9 to 16 June 2017, Bergen, Norway
www.wtc2017.no

"Surface problems – Underground solutions" is more than a slogan; for ITA-AITES and its members it is a challenge and commitment to contribute to sustainable development. The challenges are numerous and the availability of space for necessary infrastructure ends up being the key to good solutions. The underground is at present only marginally utilized. The potential for extended and improved utilization is enormous.

EUROCK 2017
13-15 June 2017, Ostrava, Czech Republic

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19th International Conference on Soil Mechanics and Geotechnical Engineering, 17 - 22 September 2017, Seoul, Korea, www.icsmge2017.org

GeoAfrica 2017
3rd African Regional Conference on Geosynthetics
9 – 13 October 2017, Morocco

11th International Conference on Geosynthetics (11ICG)
16 - 20 Sep 2018, Seoul South Korea
csyoo@skku.edu

10th Asian Rock mechanics Symposium - ARMS10
October 2018, Singapore

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AFTES International Congress
"The value is Underground"
13-16 November 2017, Paris, France

World Tunnel Congress 2018
20-26 April 2018, Dubai, United Arab Emirates

☙ ❧

14th ISRM International Congress
2019, Foz de Iguaçu, Brazil

Contact Person: Prof. Sergio A. B. da Fontoura
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ΕΝΔΙΑΦΕΡΟΝΤΑ ΓΕΩΤΕΧΝΙΚΑ ΝΕΑ

Wedding Cake Rock Will Collapse At Any Time

Scientists have recently revealed that the famous rock of Australia that became popular spot for selfies on social media may collapse at any time.

Scientists have recently revealed that the famous rock of Australia that became popular spot for selfies on social media may collapse at any time. The Office for National Parks and Wildlife (NPWS) recently banned public access at the point to conduct research on the stability of rock-known as the "wedding cake" because of its shape and located in Sydney in New South Wales.

A drone, which was flown over the entire structure from top to sea, showed that the rock below the surface is fractured. The authorities decided to refuse access to the rock after hundreds of photos shared on various social networks with people to perform dangerous stunts on the brink.

The regional director of the NPWS in New South Wales Gary Dunnett explains that the rock is on the verge of collapse at the edge of the cliff. In the photographs, pieces of rock and deep cracks that have formed along the cliffs are visible.

Gary Dunnett said "We have now received the results and the report is clear -- standing on the rock platform risks a truly tragic outcome,"

Source: dailytelegraph.com.au , CNN

(Geoengineer.org, Monday, 29 June 2015

China: Hydropower Plant Caused landslide

The Three Gorges Dam is accused of causing landslide that has claimed two lives and left several others injured in the southwestern Wushan County. The authorities said that 17 boats capsized due to the waves that caused by the land-slide.

The Three Gorges Dam is accused of causing landslide that has claimed two lives and left several others injured in the southwestern Wushan County.

The plant owner of China Three Gorges Corporation said "The project was not affected by the landslide, though it continues to monitor the reservoir's levels."

The Three Gorges Dam created a gigantic reservoir of 600 kilometers.

The water level has alarming consequences. The embank-ments of the reservoir are subject to frequent changes, increasing the possibility of landslides. What is more, the huge lake affects the local climate, making extreme weather events - especially heavy rainfall more likely to happen.

Source: hydroworld.com

(Geoengineer.org, Wednesday, 01 July 2015)

Λεωφόρος του 4ου αιώνα π.Χ.
Αρχαίος δρόμος αποκαλύφθηκε στην παραλία του Μεγάλου Καβουριού

Τμήμα αρχαίας αμαξιτής οδού, μήκους 300 μέτρων, έφερε στο φως αρχαιολογική έρευνα στην παραλία του Μεγάλου Καβουρίου στη Βουλιαγμένη.

Η πορεία της οδού, η οποία βρέθηκε στην περιοχή ανάμεσα στον παραλιακό πεζόδρομο και την οδό Καβουρίου, οδηγεί στο συμπέρασμα ότι ο δρόμος συνέδεε τον αρχαίο δήμο των Αιξωνιδών Αλών, ο οποίος αντιστοιχεί στη σημερινή Βούλα και Βουλιαγμένη, με το παραλιακό μέτωπο όπου βρισκόταν το λιμάνι.

Όπως αναφέρει το υπουργείο Πολιτισμού, τα κεραμικά θραύσματα και τα νομίσματα που βρέθηκαν στην ανασκαφή δείχνουν ότι ο δρόμος παρέμενε σε χρήση όλη τη διάρκεια του 4ου αι. π.Χ.

Στην πορεία του προς τα ανατολικά, ο δρόμος πιθανότατα διασταυρώνονταν με την «Αστική Οδό» που συνέδεε την Αθήνα με το Σούνιο. Η κεντρική αυτή αρτηρία των παράλιων δήμων Αλιμούντος, Ευωνύμου, Αιξωνής και Αιξωνίδων Αλών έχει ανασκαφεί τμηματικά.

Στην περιοχή της Βούλας η Αστική Οδός έχει εντοπιστεί και ερευνηθεί κυρίως κατά μήκος της Λεωφόρου Βάρης στην περιοχή Πηγαδάκια. Η Αστική Οδός συναντούσε και την αρχαία παραλιακή οδό που ακολουθούσε την ακτή από το Φάληρο ως τη Βούλα.

Οι εργασίες στο Καβούρι ξεκίνησαν αρχικά στο πλαίσιο του έργου ΕΣΠΑ «Διάφορες Κατασκευές και Αναπλάσεις στην περιοχή Μεγάλου Καβουρίου Βουλιαγμένης» και στη συνέχεια χρηματοδοτήθηκαν από τον κ. Αθανάσιο Μαρτίνο, η προσφορά του οποίου έδωσε στην υπηρεσία την ευκαιρία να ολοκληρώσει την έρευνα και να μετατρέψει την παραλία του Μεγάλου Καβουριού σε αρχαιολογικό πάρκο.

Ο δρόμος πρέπει να συνέδεε τον αρχαίο δήμο Αιξωνιδών Αλών με το λιμάνι της περιοχής

Όλες οι εργασίες πραγματοποιήθηκαν με ευθύνη της Εφορείας Αρχαιοτήτων Δυτικής Αττικής Πειραιώς και Νήσων (πρώην ΚΣΤ΄ Εφορεία Προϊστορικών και Κλασικών Αρχαιοτήτων) και έγιναν με την επίβλεψη της αρμόδιας για την περιοχή αρχαιολόγου κ. Μ. Γιαμαλίδη και τη συνεργασία των αρχαιολόγων Ι. Εβρενόπουλου και Κ. Νταϊφά.

(Newsroom ΔΟΛ, 20 Ιουλ. 2015, http://news.in.gr/culture/article/?aid=1500013761)

Tunnelling under the radar - How Crossrail quietly dug up London

It may not be the fastest marathon that London has ever witnessed, but it is certainly one of the most impressive. Crossrail's 26 miles of twin bore tunnels under the capital mark an extraordinary achievement for UK engineering, with the final breakthrough in Farringdon in late May capping a three-year excavation odyssey.

Now that the rail tunnels are complete, work is underway in fitting out the stations, and track is already being laid. The central section of the line, which runs from Paddington to Abbey Wood, is due to open in December 2018.

Perhaps the most remarkable thing of all – and something that Crossrail's workers speak of with great pride – is the fact that Europe's biggest construction project has been taking place right beneath the feet of millions of Londoners, and many are not even aware of its existence. This is testament to how smoothly the tunnelling has progressed, and the level of detail and planning that has accompanied it.

Crossrail tunnel running west from Farringdon towards Tottenham Court Road

Linda Miller, a project manager now overseeing work on one of Crossrail's main hubs at Farringdon, speaks with genuine enthusiasm about such a massive undertaking going below the radar of so many people.

"The huge news for us here on Crossrail is that there's been no news," Miller told me and other assembled media on a recent site visit. "If I talk to my neighbours, or people at the school gate, they barely know Crossrail, and that is our huge and fantastic piece of news."

It's an achievement she attributes to a combination of factors, not least the investment in the eight giant tunnel boring machines (TBMs) which have gradually snaked their way under London for the past three years, often within inches of existing tunnels and sewers in the city's crowded subterranean network.

"We bought what I consider to be the best machines in the world, honestly, and I've been doing tunnelling a long time," she says. "We bought state of the art Herrenknecht machines, all eight of them, fabulously crafted, incredible high quality, and they drove with exacting precision like I've never experienced before – being in the right place where they were supposed to be to the millimetre."

The construction site where the east ticket hall will be located, with Smithfield Market in the background.

The TBMs cost in the region of £10m each, but by all accounts have been a worthwhile investment. Using terabytes of data gathered around the clock from sensors across key locations in the city - all crunched through a bespoke software system – Crossrail engineers have been able to guide the TBMs with extreme precision, constantly monitoring for problems in the surrounding earth and nearby infrastructure.

According to Miller, another key factor has been the investment in people. Learning from previous tunnelling projects where the right expertise has not always been present at the tunnel face, Crossrail invested in ensuring geo-technical engineers were on site continuously.

"Crossrail took that up and said, 'you know what, this is gong to be expensive, but we're actually going to get very highly qualified educated people, we're going to pay for them to stand at the face of the tunnel and be on the construction site teams 24 hours a day, seven days a week, nights, weekends, Sundays'," Miller explains.

The result has been a project that has so far come in on time and on budget, with barely a negative mention in the mainstream press. This is something that can't always be said of marquee UK construction, with the Wembley redevelopment and Heathrow extensions recent examples of projects where things have not run quite so smoothly.

The cutter head of TBM Elizabeth, which is slowly being broken apart and removed from the tunnel.

So what now of the eight TBMs that have been so integral to Crossrail's success so far? Their mission now complete, most have already been disassembled, to be reused on other projects or sold on. At Farringdon, we were brought down to see TBM Elizabeth, which alongside TBM Victoria was responsible for the longest stretch of tunnelling - the 8.3km drive from Limmo Peninsula, near Canning Town, to Farringdon.

After making the final breakthrough in May, most of Elizabeth has already been removed. The 150m long body of the TBM is being recovered piece by piece, ferried back along the tunnel and brought to the surface at Stepney Green. Meanwhile, the 7.1m diameter cutting head is currently being broken up into manageable one to two ton pieces, and removed via the site at Farringdon.

"It's a complicated piece of work," explains Roger Mears, project manager on the eastern tunnels. "It's taken about three months to remove everything from those TBMs. The actual cutting of the cutter heads only takes about three weeks, but removing the bearing takes another couple of weeks. And we've got the gantries then that form the train of that TBM, and they're being pulled back to Stepney Green."

The only thing that might be left behind is the can, the large outer cylinder of metal that houses the TBM. Mears tells me that there are even provisional plans to recover that via another tunnel, but that a final decision has yet to be made. In the meantime Mears, Miller and the rest of the Crossrail team are continuing their work, buoyed by the success to date, and excited by the challenges to come.

"I've been in construction on great big projects for 25 years, and I've never had as much fun, and loved it as much as I've loved this job," says Miller.

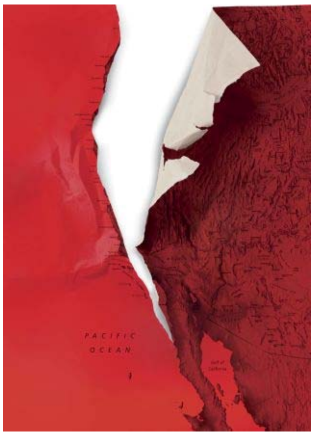
"You can talk to any of our workforce out there and they will be bursting with pride. They get that they're working on something meaningful, and challenging, and interesting, and as one of our young workers would say, 'Epic'."

(Andrew Wade / theengineer, 24 July 2015, http://www.theengineer.co.uk/tunnelling-under-the-radar-how-crossrail-quietly-dug-up-london/1020785.article?cmpid=tenews_1384210)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΣΕΙΣΜΟΙ

The Really Big One

An earthquake will destroy a sizable portion of the coastal Northwest. The question is when.



The next full-margin rupture of the Cascadia subduction zone will spell the worst natural disaster in the history of the continent.

When the 2011 earthquake and tsunami struck Tohoku, Japan, Chris Goldfinger was two hundred miles away, in the city of Kashiwa, at an international meeting on seismology. As the shaking started, everyone in the room began to laugh. Earthquakes are common in Japan—that one was the third of the week—and the participants were, after all, at a seismology conference. Then everyone in the room checked the time.

Seismologists know that how long an earthquake lasts is a decent proxy for its magnitude. The 1989 earthquake in Loma Prieta, California, which killed sixty-three people and caused six billion dollars' worth of damage, lasted about fifteen seconds and had a magnitude of 6.9. A thirty-second earthquake generally has a magnitude in the mid-sevens. A minute-long quake is in the high sevens, a two-minute quake has entered the eights, and a three-minute quake is in the high eights. By four minutes, an earthquake has hit magnitude 9.0.

When Goldfinger looked at his watch, it was quarter to three. The conference was wrapping up for the day. He was thinking about sushi. The speaker at the lectern was wondering if he should carry on with his talk. The earthquake was not particularly strong. Then it ticked past the sixty-second mark, making it longer than the others that week. The shaking intensified. The seats in the conference room were small plastic desks with wheels. Goldfinger, who is tall and solidly built, thought, No way am I crouching under one of those for cover. At a minute and a half, everyone in the room got up and went outside.

It was March. There was a chill in the air, and snow flurries, but no snow on the ground. Nor, from the feel of it, was there ground on the ground. The earth snapped and popped and rippled. It was, Goldfinger thought, like driving through rocky terrain in a vehicle with no shocks, if both the vehicle and the terrain were also on a raft in high seas. The quake passed the two-minute mark. The trees, still hung with the previous autumn's dead leaves, were making a strange rattling sound. The flagpole atop the building he and his colleagues had just vacated was whipping through an arc of forty degrees. The building itself was base-isolated, a seismic-safety technology in which the body of a structure rests on movable bearings rather than directly on its foundation. Goldfinger lurched over to take a look. The base was lurching, too, back and forth a foot at a time, digging a trench in the yard. He thought better of it, and lurched away. His watch swept past the three-minute mark and kept going.

Oh, shit, Goldfinger thought, although not in dread, at first: in amazement. For decades, seismologists had believed that Japan could not experience an earthquake stronger than magnitude 8.4. In 2005, however, at a conference in Hokudan, a Japanese geologist named Yasutaka Ikeda had argued that the nation should expect a magnitude 9.0 in the near future—with catastrophic consequences, because Japan's famous earthquake-and-tsunami preparedness, including the height of its sea walls, was based on incorrect science. The presentation was met with polite applause and thereafter largely ignored. Now, Goldfinger realized as the shaking hit the four-minute mark, the planet was proving the Japanese Cassandra right.

For a moment, that was pretty cool: a real-time revolution in earthquake science. Almost immediately, though, it became extremely uncool, because Goldfinger and every other seismologist standing outside in Kashiwa knew what was coming. One of them pulled out a cell phone and started streaming videos from the Japanese broadcasting station NHK, shot by helicopters that had flown out to sea soon after the shaking started. Thirty minutes after Goldfinger first stepped outside, he watched the tsunami roll in, in real time, on a two-inch screen.

In the end, the magnitude-9.0 Tohoku earthquake and subsequent tsunami killed more than eighteen thousand people, devastated northeast Japan, triggered the meltdown at the Fukushima power plant, and cost an estimated two hundred and twenty billion dollars. The shaking earlier in the week turned out to be the foreshocks of the largest earthquake in the nation's recorded history. But for Chris Goldfinger, a paleoseismologist at Oregon State University and one of the world's leading experts on a little-known fault line, the main quake was itself a kind of foreshock: a preview of another earthquake still to come.

Most people in the United States know just one fault line by name: the San Andreas, which runs nearly the length of California and is perpetually rumored to be on the verge of unleashing "the big one." That rumor is misleading, no matter what the San Andreas ever does. Every fault line has an upper limit to its potency, determined by its length and width, and by how far it can slip. For the San Andreas, one of the most extensively studied and best understood fault lines in the world, that upper limit is roughly an 8.2—a powerful earthquake, but, because the Richter scale is logarithmic, only six per cent as strong as the 2011 event in Japan.

Just north of the San Andreas, however, lies another fault line. Known as the Cascadia subduction zone, it runs for seven hundred miles off the coast of the Pacific Northwest, beginning near Cape Mendocino, California, continuing along Oregon and Washington, and terminating around Vancouver Island, Canada. The "Cascadia" part of its name comes from the Cascade Range, a chain of volcanic mountains that follow the same course a hundred or so miles inland. The "subduction zone" part refers to a region of the planet where one tectonic plate is sliding underneath (subducting) another. Tectonic plates are those slabs of mantle and crust that, in their epochs-long drift, rearrange the earth's continents and oceans. Most of the time, their movement is slow, harmless, and all but undetectable. Occasionally, at the borders where they meet, it is not.

Take your hands and hold them palms down, middle fingertips touching. Your right hand represents the North American tectonic plate, which bears on its back, among other things, our entire continent, from One World Trade Center to the Space Needle, in Seattle. Your left hand represents an oceanic plate called Juan de Fuca, ninety thousand square miles in size. The place where they meet is the Cascadia subduction zone. Now slide your left hand under your right one. That is what the Juan de Fuca plate is doing: slipping steadily beneath North America. When you try it, your right hand will slide up your left arm, as if you were pushing up your sleeve. That is what North America is not doing. It is stuck, wedged tight against the surface of the other plate.

Without moving your hands, curl your right knuckles up, so that they point toward the ceiling. Under pressure from Juan de Fuca, the stuck edge of North America is bulging upward and compressing eastward, at the rate of, respectively, three to four millimetres and thirty to forty millimetres a year. It can do so for quite some time, because, as continent stuff goes, it is young, made of rock that is still relatively elastic. (Rocks, like us, get stiffer as they age.) But it cannot do so indefinitely. There is a backstop—the craton, that ancient unbudgeable mass at the center of the continent—and, sooner or later, North America will rebound like a spring. If, on that occasion, only the southern part of the Cascadia subduction zone gives way—your first two fingers, say—the magnitude of the resulting quake will be somewhere between 8.0 and 8.6.*That's* the big one. If the entire zone gives way at once, an event that seismologists call a full-margin rupture, the magnitude will be somewhere between 8.7 and 9.2. That's the very big one.

Flick your right fingers outward, forcefully, so that your hand flattens back down again. When the next very big earthquake hits, the northwest edge of the continent, from California to Canada and the continental shelf to the Cascades, will drop by as much as six feet and rebound thirty to a hundred feet to the west—losing, within minutes, all the elevation and compression it has gained over centuries. Some of that shift will take place beneath the ocean, displacing a colossal quantity of seawater. (Watch what your fingertips do when you flatten your hand.) The water will surge upward into a huge hill, then promptly collapse. One side will rush west, toward Japan. The other side will rush east, in a seven-hundred-mile liquid wall that will reach the Northwest coast, on average, fifteen minutes after the earthquake begins. By the time the shaking has ceased and the tsunami has receded, the region will be unrecognizable. Kenneth Murphy, who directs FEMA's Region X, the division responsible for Oregon, Washington, Idaho, and Alaska, says, "Our operating assumption is that everything west of Interstate 5 will be toast."

In the Pacific Northwest, everything west of Interstate 5 covers some hundred and forty thousand square miles, including Seattle, Tacoma, Portland, Eugene, Salem (the capital city of Oregon), Olympia (the capital of Washington), and some seven million people. When the next full-margin rupture happens, that region will suffer the worst natural disaster in the history of North America. Roughly three thousand people died in San Francisco's 1906 earthquake. Almost two thousand died in Hurricane Katrina. Almost three hundred died in Hurricane Sandy. FEMA projects that nearly thirteen thousand people will die in the Cascadia earthquake and tsunami. Another twenty-seven thousand will be injured, and the agency expects that it will need to provide shelter for a million displaced people, and food and water for another two and a half million. "This is one time that I'm hoping all the science is wrong, and it won't happen for another thousand years," Murphy says.

In fact, the science is robust, and one of the chief scientists behind it is Chris Goldfinger. Thanks to work done by him and his colleagues, we now know that the odds of the big Cascadia earthquake happening in the next fifty years are roughly one in three. The odds of the very big one are roughly one in ten. Even those numbers do not fully reflect the danger—or, more to the point, how unprepared the Pacific Northwest is to face it. The truly worrisome figures in this story are these: Thirty years ago, no one knew that the Cascadia subduction zone had ever produced a major earthquake. Forty-five years ago, no one even knew it existed.

In May of 1804, Meriwether Lewis and William Clark, together with their Corps of Discovery, set off from St. Louis on America's first official cross-country expedition. Eighteen months later, they reached the Pacific Ocean and made camp near the present-day town of Astoria, Oregon. The United States was, at the time, twenty-nine years old. Canada was not yet a country. The continent's far expanses were so unknown to its white explorers that Thomas Jefferson, who commissioned the journey, thought that the men would come across woolly mammoths. Native Americans had lived in the Northwest for millennia, but they had no written language, and the many things to which the arriving Europeans subjected them did not include seismological inquiries. The newcomers took the land they encountered at face value, and at face value it was a find: vast, cheap, temperate, fertile, and, to all appearances, remarkably benign.

A century and a half elapsed before anyone had any inkling that the Pacific Northwest was not a quiet place but a place in a long period of quiet. It took another fifty years to uncover and interpret the region's seismic history. Geology, as even geologists will tell you, is not normally the sexiest of disciplines; it hunkers down with earthly stuff while the glory accrues to the human and the cosmic—to genetics, neuroscience, physics. But, sooner or later, every field has its field day, and the discovery of the Cascadia subduction zone stands as one of the greatest scientific detective stories of our time.

The first clue came from geography. Almost all of the world's most powerful earthquakes occur in the Ring of Fire, the volcanically and seismically volatile swath of the Pacific that runs from New Zealand up through Indonesia and Japan, across the ocean to Alaska, and down the west coast of the Americas to Chile. Japan, 2011, magnitude 9.0; Indonesia, 2004, magnitude 9.1; Alaska, 1964, magnitude 9.2; Chile, 1960, magnitude 9.5—not until the late nineteen-sixties, with the rise of the theory of plate tectonics, could geologists explain this pattern. The Ring of Fire, it turns out, is really a ring of subduction zones. Nearly all the earthquakes in the region are caused by continental plates getting stuck on oceanic plates—as North America is stuck on Juan de Fuca—and then getting abruptly unstuck. And nearly all the volcanoes are caused by the oceanic plates sliding deep beneath the continental ones, eventually reaching temperatures and pressures so extreme that they melt the rock above them.

The Pacific Northwest sits squarely within the Ring of Fire. Off its coast, an oceanic plate is slipping beneath a continental one. Inland, the Cascade volcanoes mark the line where, far below, the Juan de Fuca plate is heating up and melting everything above it. In other words, the Cascadia subduction zone has, as Goldfinger put it, "all the right anatomical parts." Yet not once in recorded history has it caused a major earthquake—or, for that matter, any quake to speak of. By contrast, other subduction zones produce major earthquakes occasionally and minor ones all the time: magnitude 5.0, magnitude 4.0, magnitude why are the neighbors moving their sofa at midnight. You can scarcely spend a week in Japan without feeling this sort of earthquake. You can spend a lifetime in many parts of the Northwest—several, in fact, if you had them to spend—and not feel so much as a quiver. The question facing geologists in the nineteen-seventies was whether the Cascadia subduction zone had ever broken its eerie silence.

In the late nineteen-eighties, Brian Atwater, a geologist with the United States Geological Survey, and a graduate student named David Yamaguchi found the answer, and another major clue in the Cascadia puzzle. Their discovery is best illustrated in a place called the ghost forest, a grove of western red cedars on the banks of the Copalis River, near the Washington coast. When I paddled out to it last summer, with Atwater and Yamaguchi, it was easy to see how it got its name. The cedars are spread out across a low salt marsh on a wide northern bend in the river, long dead but still standing. Leafless, branchless, barkless, they are reduced to their trunks and worn to a smooth silver-gray, as if they had always carried their own tombstones inside them.

What killed the trees in the ghost forest was saltwater. It had long been assumed that they died slowly, as the sea level around them gradually rose and submerged their roots. But, by 1987, Atwater, who had found in soil layers evidence of sudden land subsidence along the Washington coast, suspected that that was backward—that the trees had died quickly when the ground beneath them plummeted. To find out, he teamed up with Yamaguchi, a specialist in dendrochronology, the study of growth-ring patterns in trees. Yamaguchi took samples of the cedars and found that they had died simultaneously: in tree after tree, the final rings dated to the summer of 1699. Since trees do not grow in the winter, he and Atwater concluded that sometime between August of 1699 and May of 1700 an earthquake had caused the land to drop and killed the cedars. That time frame predated by more than a hundred years the written history of the Pacific Northwest—and so, by rights, the detective story should have ended there.

But it did not. If you travel five thousand miles due west from the ghost forest, you reach the northeast coast of Japan. As the events of 2011 made clear, that coast is vulnerable to tsunamis, and the Japanese have kept track of them since at least 599 A.D. In that fourteen-hundred-year history, one incident has long stood out for its strangeness. On the eighth day of the twelfth month of the twelfth year of the Genroku era, a six-hundred-mile-long wave struck the coast, levelling homes, breaching a castle moat, and causing an accident at sea. The Japanese understood that tsunamis were the result of earthquakes, yet no one felt the ground shake before the Genroku event. The wave had no discernible origin. When scientists began studying it, they called it an orphan tsunami.

Finally, in a 1996 article in *Nature*, a seismologist named Kenji Satake and three colleagues, drawing on the work of Atwater and Yamaguchi, matched that orphan to its parent—and thereby filled in the blanks in the Cascadia story with uncanny specificity. At approximately nine o' clock at night on January 26, 1700, a magnitude-9.0 earthquake struck the Pacific Northwest, causing sudden land subsidence, drowning coastal forests, and, out in the ocean, lifting up a wave half the length of a continent. It took roughly fifteen minutes for the Eastern half of that wave to strike the Northwest coast. It took ten hours for the other half to cross the ocean. It reached Japan on January 27, 1700: by the local calendar, the eighth day of the twelfth month of the twelfth year of Genroku.

Once scientists had reconstructed the 1700 earthquake, certain previously overlooked accounts also came to seem like clues. In 1964, Chief Louis Nookmis, of the Huu-ay-aht First Nation, in British Columbia, told a story, passed down through seven generations, about the eradication of Vancouver Island's Pachena Bay people. "I think it was at nighttime that the land shook," Nookmis recalled. According to another tribal history, "They sank at once, were all drowned; not one survived." A hundred years earlier, Billy Balch, a leader of the Makah tribe, recounted a similar story. Before his own time, he said, all the water had receded from Washington State's Neah Bay, then suddenly poured back in, inundating the entire region. Those who survived later found canoes hanging from the trees. In a 2005 study, Ruth Ludwin, then a seismologist at the University of Washington, together with nine colleagues, collected and analyzed Native American reports of earthquakes and saltwater floods. Some of those reports contained enough information to estimate a date range for the events they described. On average, the midpoint of that range was 1701.

It does not speak well of European-Americans that such stories counted as evidence for a proposition only after that proposition had been proved. Still, the reconstruction of the Cascadia earthquake of 1700 is one of those rare natural puzzles whose pieces fit together as tectonic plates do not: perfectly. It is wonderful science. It was wonderful *for* science. And it was terrible news for the millions of inhabitants of the Pacific Northwest. As Goldfinger put it, "In the late eighties and early nineties, the paradigm shifted to 'uh-oh.' "

Goldfinger told me this in his lab at Oregon State, a low prefab building that a passing English major might reasonably mistake for the maintenance department. Inside the lab is a walk-in freezer. Inside the freezer are floor-to-ceiling racks filled with cryptically labelled tubes, four inches in diameter and five feet long. Each tube contains a core sample of the seafloor. Each sample contains the history, written in seafloorese, of the past ten thousand years. During subduction-zone earthquakes, torrents of land rush off the continental slope, leaving a permanent deposit on the bottom of the ocean. By counting the number and the size of deposits in each sample, then comparing their extent and consistency along the length of the Cascadia subduction zone, Goldfinger and his colleagues were able to determine how much of the zone has ruptured, how often, and how drastically.

Thanks to that work, we now know that the Pacific Northwest has experienced forty-one subduction-zone earthquakes in the past ten thousand years. If you divide ten thousand by forty-one, you get two hundred and forty-three, which is Cascadia's recurrence interval: the average amount of time that elapses between earthquakes. That timespan is dangerous both because it is too long—long enough for us to unwittingly build an entire civilization on top of our continent's worst fault line—and because it is not long enough. Counting from the earthquake of 1700, we are now three hundred and fifteen years into a two-hundred-and-forty-three-year cycle.

It is possible to quibble with that number. Recurrence intervals are averages, and averages are tricky: ten is the average of nine and eleven, but also of eighteen and two. It is not possible, however, to dispute the scale of the problem. The devastation in Japan in 2011 was the result of a discrepancy between what the best science predicted and what the region was prepared to withstand. The same will hold true in the Pacific Northwest—but here the discrepancy is enormous. "The science part is fun," Goldfinger says. "And I love doing it. But the gap between what we know and what we should do about it is getting bigger and bigger, and the action really needs to turn to responding. Otherwise, we're going to be hammered. I've been through one of these massive earthquakes in the most seismically prepared nation on earth. If that was Portland"—Goldfinger finished the sentence with a shake of his head before he finished it with words. "Let's just say I would rather not be here."

The first sign that the Cascadia earthquake has begun will be a compressional wave, radiating outward from the fault line. Compressional waves are fast-moving, high-frequency waves, audible to dogs and certain other animals but experienced by humans only as a sudden jolt. They are not very harmful, but they are potentially very useful, since they travel fast enough to be detected by sensors thirty to ninety seconds ahead of other seismic waves. That is enough time for earthquake early-warning systems, such as those in use throughout Japan, to automatically perform a variety of lifesaving functions: shutting down railways and power plants, opening elevators and firehouse doors, alerting hospitals to halt surgeries, and triggering alarms so that the general public can take cover. The Pacific Northwest has no early-warning system. When the Cascadia earthquake begins, there will be, instead, a cacophony of barking dogs and a long, suspended, what-was-that moment before the surface waves arrive. Surface waves are slower, lower-frequency waves that move the ground both up and down and side to side: the shaking, starting in earnest.

Soon after that shaking begins, the electrical grid will fail, likely everywhere west of the Cascades and possibly well beyond. If it happens at night, the ensuing catastrophe will unfold in darkness. In theory, those who are at home when it hits should be safest; it is easy and relatively inexpensive to seismically safeguard a private dwelling. But, lulled into nonchalance by their seemingly benign environment, most people in the Pacific Northwest have not done so. That nonchalance will shatter instantly. So will everything made of glass. Anything indoors and unsecured will lurch across the floor or come crashing down: bookshelves, lamps, computers, cannisters of flour in the pantry. Refrigerators will walk out of kitchens, unplugging themselves and toppling over. Water heaters will fall and smash interior gas lines. Houses that are not bolted to their foundations will slide off—or, rather, they will stay put, obeying inertia, while the foundations, together with the rest of the Northwest, jolt westward. Unmoored on the undulating ground, the homes will begin to collapse.

Across the region, other, larger structures will also start to fail. Until 1974, the state of Oregon had no seismic code, and few places in the Pacific Northwest had one appropriate to a magnitude-9.0 earthquake until 1994. The vast majority of buildings in the region were constructed before then. Ian Madin, who directs the Oregon Department of Geology and Mineral Industries (DOGAMI), estimates that seventy-five per cent of all structures in the state are not designed to withstand a major Cascadia quake. FEMA calculates that, across the region, something on the order of a million buildings—more than three thousand of them schools—will collapse or be compromised in the earthquake. So will half of all highway bridges, fifteen of the seventeen bridges spanning Portland's two rivers, and two-thirds of railways and airports; also, one-third of all fire stations, half of all police stations, and two-thirds of all hospitals.

Certain disasters stem from many small problems conspiring to cause one very large problem. For want of a nail, the war was lost; for fifteen independently insignificant errors, the jetliner was lost. Subduction-zone earthquakes operate on the opposite principle: one enormous problem causes many other enormous problems. The shaking from the Cascadia quake will set off landslides throughout the region—up to thirty thousand of them in Seattle alone, the city's emergency-management office estimates. It will also induce a process called liquefaction, whereby seemingly solid ground starts behaving like a liquid, to the detriment of anything on top of it. Fifteen per cent of Seattle is built on liquefiable land, including seventeen day-care centers and the homes of some thirty-four thousand five hundred people. So is Oregon's critical energy-infrastructure hub, a six-mile stretch of Portland through which flows ninety per cent of the state's liquid fuel and which houses everything from electrical substations to natural-gas terminals. Together, the sloshing, sliding, and shaking will trigger fires, flooding, pipe failures, dam breaches, and hazardous-material spills. Any one of these second-order disasters could swamp the original earthquake in terms of cost, damage, or casualties—and one of them definitely will. Four to six minutes after the dogs start barking, the shaking will subside. For another few minutes, the region, upended, will continue to fall apart on its own. Then the wave will arrive, and the real destruction will begin.

Among natural disasters, tsunamis may be the closest to being completely unsurvivable. The only likely way to outlive one is not to be there when it happens: to steer clear of the vulnerable area in the first place, or get yourself to high ground as fast as possible. For the seventy-one thousand people who live in Cascadia's inundation zone, that will mean evacuating in the narrow window after one disaster ends and before another begins. They will be notified to do so only by the earthquake itself—"a vibrate-alert system," Kevin Cupples, the city planner for the town of Seaside, Oregon, jokes—and they are urged to leave on foot, since the earthquake will render roads impassable. Depending on location, they will have between ten and thirty minutes to get out. That time line does not allow for finding a flashlight, tending to an earthquake injury, hesitating amid the ruins of a home, searching for loved ones, or being a Good Samaritan. "When that tsunami is coming, you run," Jay Wilson, the chair of the Oregon Seismic Safety Policy Advisory Commission (OSSPAC), says. "You protect yourself, you don't turn around, you don't go back to save anybody. You run for your life."

The time to save people from a tsunami is before it happens, but the region has not yet taken serious steps toward doing so. Hotels and businesses are not required to post evacuation routes or to provide employees with evacuation training. In Oregon, it has been illegal since 1995 to build hospitals, schools, firehouses, and police stations in the inundation zone, but those which are already in it can stay, and any other new construction is permissible: energy facilities, hotels, retirement homes. In those cases, builders are required only to consult with DOGAMI about evacuation plans. "So you come in and sit down," Ian Madin says. "And I say, 'That's a stupid idea.' And you say, 'Thanks. Now we've consulted.' "

These lax safety policies guarantee that many people inside the inundation zone will not get out. Twenty-two per cent of Oregon's coastal population is sixty-five or older. Twenty-nine per cent of the state's population is disabled, and that figure rises in many coastal counties. "We can't save them," Kevin Cupples says. "I'm not going to sugarcoat it and say, 'Oh, yeah, we'll go around and check on the elderly.' No. We won't." Nor will anyone save the tourists. Washington State Park properties within the inundation zone see an average of seventeen thousand and twenty-nine guests a day. Madin estimates that up to a hundred and fifty thousand people visit Oregon's beaches on summer weekends. "Most of them won't have a clue as to how to evacuate," he says. "And the beaches are the hardest place to evacuate from."

Those who cannot get out of the inundation zone under their own power will quickly be overtaken by a greater one. A grown man is knocked over by ankle-deep water moving at 6.7 miles an hour. The tsunami will be moving more than twice that fast when it arrives. Its height will vary with the contours of the coast, from twenty feet to more than a hundred feet. It will not look like a Hokusai-style wave, rising up from the surface of the sea and breaking from above. It will look like the whole ocean, elevated, overtaking land. Nor will it be made only of water—not once it reaches the shore. It will be a five-story deluge of pickup trucks and doorframes and cinder blocks and fishing boats and utility poles and everything else that once constituted the coastal towns of the Pacific Northwest.

To see the full scale of the devastation when that tsunami recedes, you would need to be in the international space station. The inundation zone will be scoured of structures from California to Canada. The earthquake will have wrought its worst havoc west of the Cascades but caused damage as far away as Sacramento, California—as distant from the worst-hit areas as Fort Wayne, Indiana, is from New York. FEMA expects to coördinate search-and-rescue operations across a hundred thousand square miles and in the waters off four hundred and fifty-three miles of coastline. As for casualties: the figures I cited earlier—twenty-seven thousand injured, almost thirteen thousand dead—are based on the agency's official planning scenario, which has the earthquake striking at 9:41 A.M. on February 6th. If, instead, it strikes in the summer, when the beaches are full, those numbers could be off by a horrifying margin.

Wineglasses, antique vases, Humpty Dumpty, hip bones, hearts: what breaks quickly generally mends slowly, if at all. OSSPAC estimates that in the I-5 corridor it will take between one and three months after the earthquake to restore electricity, a month to a year to restore drinking water and sewer service, six months to a year to restore major highways, and eighteen months to restore health-care facilities. On the coast, those numbers go up. Whoever chooses or has no choice but to stay there will spend three to six months without electricity, one to three years without drinking water and sewage systems, and three or more years without hospitals. Those estimates do not apply to the tsunami-inundation zone, which will remain all but uninhabitable for years.

How much all this will cost is anyone's guess; FEMA puts every number on its relief-and-recovery plan except a price. But whatever the ultimate figure—and even though U.S. taxpayers will cover seventy-five to a hundred per cent of the damage, as happens in declared disasters—the economy of the Pacific Northwest will collapse. Crippled by a lack of basic services, businesses will fail or move away. Many residents will flee as well. OSSPAC predicts a mass-displacement event and a long-term population downturn. Chris Goldfinger didn't want to be there when it happened. But, by many metrics, it will be as bad or worse to be there afterward.

On the face of it, earthquakes seem to present us with problems of space: the way we live along fault lines, in brick buildings, in homes made valuable by their proximity to the sea. But, covertly, they also present us with problems of time. The earth is 4.5 billion years old, but we are a young species, relatively speaking, with an average individual allotment of three score years and ten. The brevity of our lives breeds a kind of temporal parochialism—an ignorance of or an indifference to those planetary gears which turn more slowly than our own.

This problem is bidirectional. The Cascadia subduction zone remained hidden from us for so long because we could not see deep enough into the past. It poses a danger to us today because we have not thought deeply enough about the future. That is no longer a problem of information; we now understand very well what the Cascadia fault line will someday do. Nor is it a problem of imagination. If you are so inclined, you can watch an earthquake destroy much of the West Coast this summer in Brad Peyton's "San Andreas," while, in neighboring theatres, the world threatens to succumb to Armageddon by other means: viruses, robots, resource scarcity, zombies, aliens, plague. As those movies attest, we excel at imagining future scenarios, including awful ones. But such apocalyptic visions are a form of escapism, not a moral summons, and still less a plan of action. Where we stumble is in conjuring up grim futures in a way that helps to avert them.

That problem is not specific to earthquakes, of course. The Cascadia situation, a calamity in its own right, is also a parable for this age of ecological reckoning, and the questions it raises are ones that we all now face. How should a society respond to a looming crisis of uncertain timing but of catastrophic proportions? How can it begin to right itself when its entire infrastructure and culture developed in a way that leaves it profoundly vulnerable to natural disaster?

The last person I met with in the Pacific Northwest was Doug Dougherty, the superintendent of schools for Seaside, which lies almost entirely within the tsunami-inundation zone. Of the four schools that Dougherty oversees, with a total student population of sixteen hundred, one is relatively safe. The others sit five to fifteen feet above sea level. When the tsunami comes, they will be as much as forty-five feet below it.

In 2009, Dougherty told me, he found some land for sale outside the inundation zone, and proposed building a new K-12 campus there. Four years later, to foot the hundred-and-twenty-eight-million-dollar bill, the district put up a bond measure. The tax increase for residents amounted to two dollars and sixteen cents per thousand dollars of property value. The measure failed by sixty-two per cent. Dougherty tried seeking help from Oregon's congressional delegation but came up empty. The state makes money available for seismic upgrades, but buildings within the inundation zone cannot apply. At present, all Dougherty can do is make sure that his students know how to evacuate.

Some of them, however, will not be able to do so. At an elementary school in the community of Gearhart, the children will be trapped. "They can't make it out from that school," Dougherty said. "They have no place to go." On one side lies the ocean; on the other, a wide, roadless bog. When the tsunami comes, the only place to go in Gearhart is a small ridge just behind the school. At its tallest, it is forty-five feet high—lower than the expected wave in a full-margin earthquake. For now, the route to the ridge is marked by signs that say "Temporary Tsunami Assembly Area." I asked Dougherty about the state's long-range plan. "There is no long-range plan," he said.

Dougherty's office is deep inside the inundation zone, a few blocks from the beach. All day long, just out of sight, the ocean rises up and collapses, spilling foamy overlapping ovals onto the shore. Eighty miles farther out, ten thousand feet below the surface of the sea, the hand of a geological clock is somewhere in its slow sweep. All across the region, seismologists are looking at their watches, wondering how long we have, and what we will do, before geological time catches up to our own.

(Kathryn Schulz / The New Yorker / Annal of Seismology, 20.07.2015,
http://www.newyorker.com/magazine/2015/07/20/the-really-big-one)

Tectonic Model Shows North America May Once Have Been Linked to Australia or Antarctica

North America may have once been attached to Australia, according to research just published in *Lithosphere* and spearheaded by U.S. Geological Survey geologist James Jones and his colleagues at Bucknell University and Colorado School of Mines.

Approximately every 300 million years, the Earth completes a supercontinent cycle wherein continents drift toward one another and collide, remain attached for millions of years, and eventually rift back apart. Geologic processes such as subduction and rifting aid in the formation and eventual break-up of supercontinents, and these same processes also help form valuable mineral resource deposits. Determining the geometry and history of ancient supercontinents is an important part of reconstructing the geologic evolution of Earth, and it can also lead to a better understanding of past and present mineral distributions.

North America is a key component in reconstructions of many former supercontinents, and there are strong geological associations between the western United States and Australia, which is one of the world's leading mineral producers.

In this study, Jones and others synthesized mineral age data from ancient sedimentary rocks in the Trampas and Yankee Joe basins of Arizona and New Mexico. They found that the ages of many zircon crystals—mineral grains that were eroded from other rocks and embedded in the sedimentary deposits—were approximately 1.6 to 1.5 billion years old, an age range that does not match any known geologic age provinces in the entire western United States.

This surprising result actually mirrors previous studies of the Belt-Purcell basin (located in Montana, Idaho and parts of British Columbia, Canada) and a recently recognized basin in western Yukon, Canada, in which many zircon ages between 1.6 and 1.5 billion years old are common despite the absence of matching potential source rocks of this age.

However, the distinctive zircon ages in all three study locations do match the well known ages of districts in Australia and, to a slightly lesser known extent, Antarctica.

This publication marks the first time a complete detrital mineral age dataset has been compiled to compare the Belt basin deposits to strata of similar age in the southwestern United States. "Though the basins eventually evolved along very different trajectories, they have a shared history when they were first formed," said Jones. "That history gives us clues as to what continents bordered western North America 1.5 billion years ago."

The tectonic model presented in this paper suggests that the North American sedimentary basins were linked to sediment sources in Australia and Antarctica until the break up of the supercontinent Columbia. The dispersed components of Columbia ultimately reformed into Rodinia, perhaps the first truly global supercontinent in Earth's history, around 1.0 billion years ago. Continued sampling and analysis of ancient sedimentary basin remnants will remain a critical tool for further testing global supercontinent reconstructions.

The paper can be accessed online
http://lithosphere.gsapubs.org/content/early/2015/05/13/L438.1.

(GeoCommunity Spatial News, June 08, 2015)

Tectonic and sedimentary linkages between the Belt-Purcell basin and southwestern Laurentia during the Mesoproterozoic, ca. 1.60–1.40 Ga

James V. Jones, Christopher G. Daniel and Michael F. Doe

Abstract

Mesoproterozoic sedimentary basins in western North America provide key constraints on pre-Rodinia craton positions and interactions along the western rifted margin of Laurentia. One such basin, the Belt-Purcell basin, extends from southern Idaho into southern British Columbia and contains a >18-km-thick succession of siliciclastic sediment deposited ca. 1.47–1.40 Ga. The ca. 1.47–1.45 Ga lower part of the succession contains abundant distinctive non-Laurentian 1.61–1.50 Ga detrital zircon populations derived from exotic cratonic sources. Contemporaneous metasedimentary successions in the southwestern United States - the Trampas and Yankee Joe basins in Arizona and New Mexico—also contain abundant 1.61–1.50 Ga detrital zircons. Similarities in depositional age and distinctive non-Laurentian detrital zircon populations suggest that both the Belt-Purcell and southwestern U.S. successions record sedimentary and tectonic linkages between western Laurentia and one or more cratons including North Australia, South Australia, and (or) East Antarctica. At ca. 1.45 Ga, both the Belt-Purcell and southwest U.S. successions underwent major sedimentological changes, with a pronounced shift to Laurentian provenance and the disappearance of 1.61–1.50 Ga detrital zircon. Upper Belt-Purcell strata contain strongly unimodal ca. 1.73 Ga detrital zircon age populations that match the detrital zircon signature of Paleoproterozoic metasedimentary rocks of the Yavapai Province to the south and southeast. We propose that the shift at ca. 1.45 Ga records the onset of orogenesis in southern Laurentia coeval with rifting along its northwestern margin. Bedrock uplift associated with orogenesis and widespread, coeval magmatism caused extensive exhumation and erosion of the Yavapai Province ca. 1.45–1.36 Ga, providing a voluminous and areally extensive sediment source—with suitable zircon ages—during upper Belt deposition. This model provides a comprehensive and integrated view of the Mesoproterozoic tectonic evolution of western Laurentia and its position within the supercontinent Columbia as it evolved into Rodinia.

(Lithosphere / Geological Society of America,
http://lithosphere.gsapubs.org/content/early/2015/05/13/L438.1)

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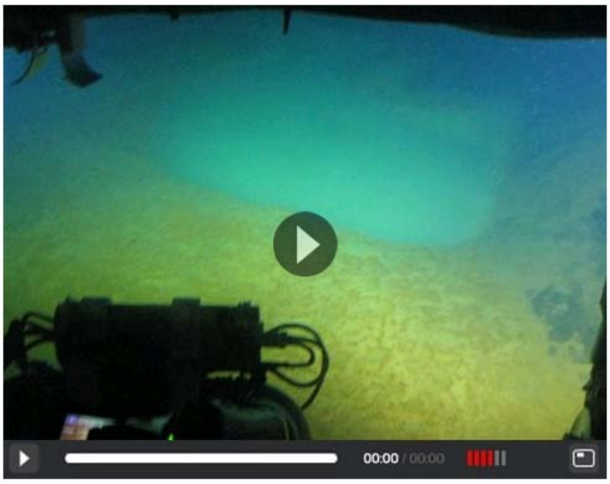
Κατάδυση στην Καλλίστη
Εξωπραγματικές υποθαλάσσιες λίμνες στην καλδέρα της Σαντορίνης

Κάτω από τους πανύψηλους γκρεμούς της καλδέρας, ανάμεσα στην Οία και το Μεροβίγλι, ένα εξωπραγματικό φαινόμενο θα έκανε το ξακουστό ηλιοβασίλεμα της Σαντορίνης να μοιάζει φτωχό: υποθαλάσσιες λίμνες ανθρακούχου νερού, οι οποίες ιριδίζουν με τα χρώματα του οπαλίου μέσα σε κοιλότητες του βυθού.

Οι «Λίμνες της Καλλίστης», όπως ονομάστηκαν οι σχηματισμοί, είναι οι πρώτες υποθαλάσσιες λίμνες του είδους τους, αναφέρει διεθνής ερευνητική ομάδα στην επιθεώρηση **Scientific Reports** του ομίλου Nature.

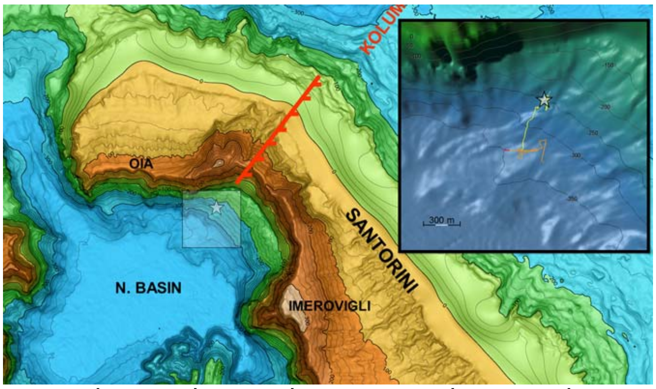


Οι Λίμνες της Καλλίστης ανακαλύφθηκαν μέσα στην καλδέρα σε βάθος 250 μέτρων (Εικόνα, βίντεο: Rich Camilli, Woods Hole Oceanographic Institution)

Οι υποθαλάσσιες λίμνες είναι στρώματα πυκνού νερού που βυθίζονται στον πυθμένα αντί να αναμειγνύονται με το θαλασσινό νερό. Μέχρι σήμερα, όμως, όλες οι γνωστές υποθαλάσσιες λίμνες αποτελούνταν από νερό που εμπλουτίζεται με μεγάλες ποσότητες αλατιού, οπότε γίνεται πιο πυκνό από το νερό στο γύρω περιβάλλον.

Οι Λίμνες της Καλλίστης διαφέρουν. «Σε αυτή την περίπτωση, η αυξημένη πυκνότητα της λίμνης δεν οφείλεται στο αλάτι. Πιστεύουμε ότι μπορεί να είναι το διοξείδιο του άνθρακα που κάνει το νερό πυκνότερο και το αναγκάζει να συγκεντρώνεται στο βυθό» λέει ο Ριτς Καμίλι, ερευνητής του διάσημου Ωκεανογραφικό Ινστιτούτο του Γουντς Χολ στη Μασαχουσέτη.

Το ινστιτούτο συνεργάστηκε στη μελέτη με το Πανεπιστήμιο Αθηνών, το Ελληνικό Κέντρο Θαλάσσιων Ερευνών και ερευνητικά ιδρύματα στην Ισπανία και τη Γαλλία.



Το αστέρι σημειώνει τη θέση των υποβρύχιων λιμνών στο βυθό ανάμεσα στην Οία και το Μεροβίγλι (Πηγή: Camilli et al.)

Η υποβρύχια μελέτη ξεκίνησε μετά την ανησυχητική **συσσώρευση μάγματος** που άρχισε το 2011 κάτω από το μεγάλο ηφαίστειο της Σαντορίνης, και αργότερα ευτυχώς **κόπασε**.

Οι λίμνες ανακαλύφθηκαν σε βάθος 250 μέτρων από ρομποτικό υποβρύχιο που μελετούσε ένα μεγάλο ρήγμα στον πυθμένα μέσα στην καλδέρα του ηφαιστείου (ο κρατήρας κατέρρευσε στην γιγάντια έκρηξη που εξαφάνισε τον μινωικό πολιτισμό γύρω στο 1600 π.Χ. Το νησί της Σαντορίνης είναι ό,τι απέμεινε πάνω από την επιφάνεια του Αιγαίου).

Οι λίμνες μελετήθηκαν με ένα ακόμα ρομποτικό σκάφος καθώς και με ένα επανδρωμένο υποβρύχιο. Οι επιτόπιες μετρήσεις έδειξαν ότι οι ημιδιαφανείς σχηματισμοί περιέχουν μεγάλες ποσότητες διαλυμένου διοξειδίου του άνθρακα και έχουν θερμοκρασία περίπου 5 βαθμούς υψηλότερη από το γύρω νερό.

Επιπλέον, οι λίμνες είναι αρκετά όξινες και εχθρικές για τους περισσότερους μικροοργανισμούς. Δεν αποκλείεται όμως να φιλοξενούν μικρόβια που παράγουν άμορφο πυρίτιο: σωματίδια οπαλίου, ενός πολύτιμου ιριδίζοντος πετρώματος. Αυτό θα εξηγούσε την παράξενη, γαλακτερή και ιριδίζουσα εμφάνιση των υποβρύχιων στρωμάτων.

Το διοξείδιο του άνθρακα που συγκεντρώνονται στις υποβρύχιες λίμνες πρέπει να προέρχεται από τον πυθμένα. Το ηφαιστειακό σύμπλεγμα της Σαντορίνης είναι η το πιο ενεργό τμήμα του Ελληνικού Ηφαιστειακού Τόξου, κατά μήκος του οποίου η τεκτονική πλάκα της Αφρικής γλιστράει κάτω από την πλάκα της Ευρασίας.

Το CO2 ίσως προέρχεται από μάγμα που απελευθερώνει το αέριο που περιέχει καθώς αποσυμπιέζεται. Μια άλλη εξήγηση είναι ότι προέρχεται από ασβεστολιθικά πετρώματα που βυθίζονται και υποβάλλονται σε ακραίες πιέσεις και θερμοκρασίες.

Μέχρι την ανακάλυψη των λιμνών της Καλλίστης, επισημαίνει ο Δρ Καμίλι, οι επιστήμονες πίστευαν ότι το διοξείδιο του άνθρακα που αναβλύζει από τον πυθμένα απλώς διαλύεται στο θαλασσινό νερό. Η ανακάλυψη δείχνει ότι σε ορισμένες περιπτώσεις το αέριο παραμένει εγκλωβισμένο σε ένα βαρύ στρώμα νερού που επικάθεται στον πυθμένα.

Παρόλα αυτά, οι υποβρύχιες λίμνες είναι πιθανότατα παροδικοί σχηματισμοί.

Η ανακάλυψή τους, επισημαίνουν οι ερευνητές σε ανακοίνωσή τους, κατέστη εφικτή χάρη στην πρόοδο των τεχνολογιών υποβρύχιας έρευνας. Το ερευνητικό πρόγραμμα έλαβε εξάλλου χρηματοδότηση και από το Πρόγραμμα Αστροβιολογίας της NASA, το οποίο μελετά ασυνήθιστα περιβάλλοντα στη γη τα οποία θα μπορούσαν να δώσουν μια εικόνα για τη ζωή σε άλλους πλανήτες.

Από ελληνικής πλευράς, στη μελέτη συμμετείχαν η Παρασκευή Νομικού, η Αριάδνη Αργυράκη και ο Στέφανος Κίλλιας της Σχολής Γεωλογίας του Πανεπιστημίου Αθηνών, καθώς και ο Άγγελος Μαλλιός και ο Δημήτρης Σακελλαρίου του ΕΛΚΕΘΕ.

(Βαγγέλης Πρατικάκης / Newsroom ΔΟΛ, 20 Ιουλ. 2015, http://news.in.gr/science-technology/article/?aid=1500013720).

The Kallisti Limnes, carbon dioxide-accumulating subsea pools

Richard Camilli, **Paraskevi Nomikou**, **Javier Escartín**, **Pere Ridao**, **Angelos Mallios**, **Stephanos P. Kilias**, **Ariadne Argyraki and the Caldera Science Team**

Abstract

Natural CO_2 releases from shallow marine hydrothermal vents are assumed to mix into the water column, and not accumulate into stratified seafloor pools. We present newly discovered shallow subsea pools located within the Santorini volcanic caldera of the Southern Aegean Sea, Greece, that accumulate CO_2emissions from geologic reservoirs. This type of hydrothermal seafloor pool, containing highly concentrated CO_2, provides direct evidence of shallow benthic CO_2 accumulations originating from sub-seafloor releases. Samples taken from within these acidic pools are devoid of calcifying organisms, and channel structures among the pools indicate gravity driven flow, suggesting that seafloor release of CO_2 at this site may preferentially impact benthic ecosystems. These naturally occurring seafloor pools may provide a diagnostic indicator of incipient volcanic activity and can serve as an analog for studying CO_2 leakage and benthic accumulations from subsea carbon capture and storage sites.

Introduction

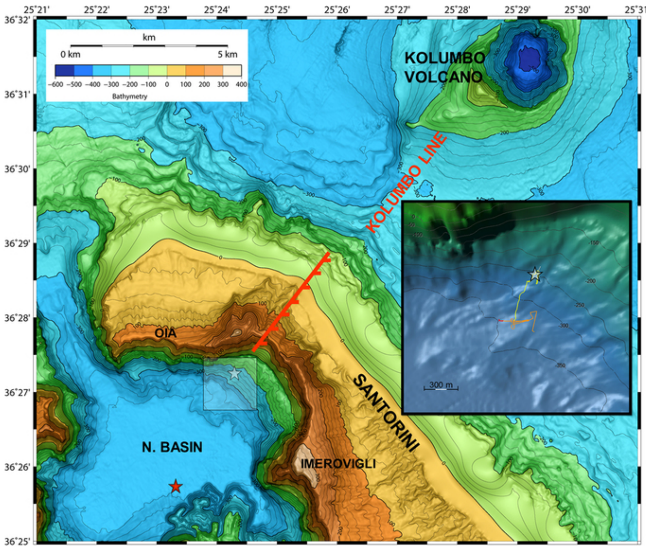
Anthropogenic carbon dioxide (CO_2) inputs and naturally occurring marine hydrothermal venting can profoundly impact marine food webs and ecosystems[1,2,3]. Sub-seafloor storage of CO_2 within geological formations is gaining international acceptance as a mechanism for reducing CO_2 emissions and lessening the impacts of ocean acidification[4,5]. However, specific concerns over leakage of CO_2 from sub-seafloor injection sites necessitate field studies in order to understand associated risks[6,7].

The Santorini volcanic group and Kolumbo submarine volcano are located along the Hellenic Volcanic Arc in the southern Aegean[8,9]. The prehistoric Minoan eruption of the Santorini caldera, circa 1627-1600 B.C.[10], was one of the largest in human history, with a total eruption volume of up to 60 km^3[8]. This eruption buried prehistoric settlements, including the flourishing Bronze Age city of Akrotiri[10,11].

Subsequent volcanic eruptions formed the Kameni islands, which emerged in 197 B.C. at the center of the caldera. Historical records from the past five centuries reveal a characteristic interval of 61 ± 68 years between eruptions, with the latest eruption occurring in 195012.

In January 2011, following more than six decades of quiescence, the Santorini caldera entered a renewed phase of unrest characterized by sustained seismicity, caldera-wide inflation, and increased gas emissions. Spherical Mogi models of deformation from January 2011 to April 2012 suggest a source centered 1.5 km north of Nea Kameni, 4 km beneath the caldera's Northern Basin13 (Fig. 1), and a corresponding volume increase of 1 to 2×10^7 m^3 14,15. Isotopic analysis of magmatic and thermal decarbonation gas emissions indicate increasing mantle CO_2 contribution16. These variations coincide with episodic charging of its shallow magma chamber by high-flux batches of deeper melts which historically control small effusive and large explosive eruptions15.

Figure 1: Topographic relief map of the northern Santorini volcanic field.



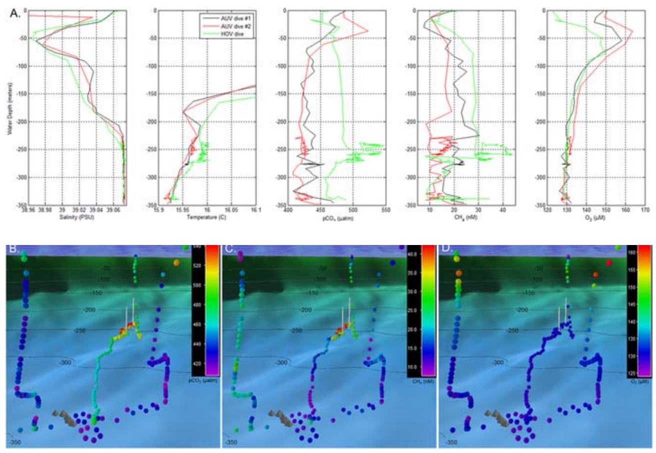
A red star icon shows the location of the center of inflation deduced from InSAR data15, the white star icon shows the location of the Kallisti Limnes CO_2 pools. The onshore Kolumbo fault is indicated by a dashed red line, which along with the Kolumbo line, describes the northeast portion of the Christianna-Santorini-Kolumbo (CSK) tectonic line. The inset box shows a detailed view from the southwest of the caldera slope bathymetry around the study site; submersible vehicle track lines are indicated as red, orange, and yellow lines, corresponding to the first and second AUV dives, and the HOV dive, respectively. Sonar and vehicle position data was processed using MB—System Revision 1.15 (including source code derived from other sources, described at http://www.ldeo.columbia.edu/res/pi/MB-System/html/mbsystem_copyright.html), GMT-4.5.7, MATLAB, and Fledermaus version 7.4.1 c software.

On July 21, 2012 our research team explored the North Basin using an experimental autonomous underwater vehicle (AUV) to survey this area of the crater (Supplementary Fig. S1). In addition to engineering demonstration operations, our deployment objectives included better characterization of the caldera's subsea regions of activity to aid the Santorini archipelago's hazard preparedness.

Results

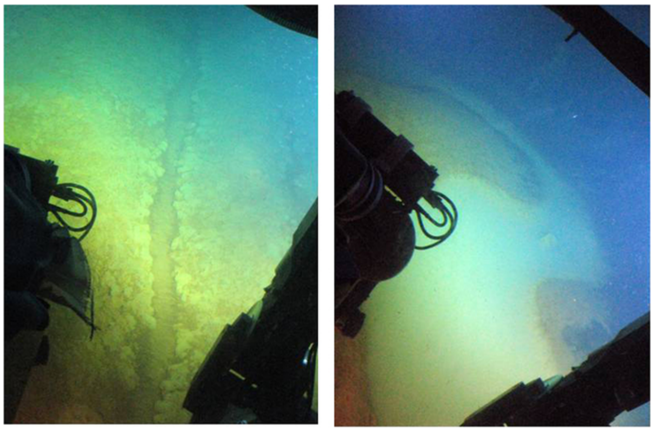
The two initial AUV survey operations were conducted at an altitude of between 5 and 20 meters above the seafloor. The first dive was completed in one hour and the second in approximately 1.5 hours, with 2.5 hours elapsing between the dives. In-situ data recorded by AUV's payload sensors indicated a water column interval between −270 and −230 m depth containing temperature, methane, and carbon dioxide anomalies (Fig. 2). Based on these geochemical signals, we launched a close inspection survey with a human occupied submersible vehicle (HOV) to investigate the seafloor in close proximity (altitude of less than 1 meter). The HOV survey commenced two hours after completion of the second ROV dive at a previously-identified hydrothermal field8,9 in the North Basin. Northeast of this hydrothermal site we encountered small (0.1 to 1 m diameter) mounds of unconsolidated flocculent orange-colored microbial mats extending up the steep NE caldera wall at a depth range of −300 to −250 m. In these shallower depths the flocculent mats are larger and denser than mounds located deeper within the basin. In steep areas along the caldera wall, linear ridges and flow channels develop within meter-thick orange flocculent microbial mats and Fe-rich clastic sediments. These channels are less than 1 m deep and up to 2 m wide, with NE-SW down slope trending lengths in excess of 20 m (Fig. 3). Upslope of the flow channels, between −250 and −235 m depth, and within 1 km of the cliff-top town of Oia, we discovered an interconnected series of meandering, iridescent white pools (Fig. 3). These 1 to 5 m diameter pools, named *Kallisti Limnes (translation from Ancient Greek: Most Beautiful Lakes)*, are situated within localized depressions in terraced scallops of the slope wall. Unlike other sites of known CO_2venting16 along the Christianna-Santorini-Kolumbo (CSK) tectonic line17, ebullition was not observed at the Kallisti Limnes and visual inspection yielded no evidence of flow movement or percolation.

Figure 2: Water column profile data recorded during AUV and HOV survey operations.



A. Water column profiles of salinity, temperature, carbon dioxide partial pressure, and dissolved methane, and dissolved oxygen distributions recorded during two initial AUV reconnaissance dives and the subsequent HOV investigation dive. Anomalies are visible in the 270 to 230 meter depth range. B., C. and D. show geo-referenced pCO_2, methane, and dissolved oxygen distributions respectively, recorded during the AUV and HOV dive missions. Colored circles indicate dissolved chemical concentrations with corresponding color bar key located in the upper right. Chemical measurements are shown as viewed from the Santorini North Basin, above the center of inflation, looking toward the Kolumbo volcano. Gray pyramid-shaped icons indicate locations of hydrothermal vent mounds identified within the North Basin during prior ROV dive operations; white vertical lines indicate the uppermost and lowermost locations of the Kallisti Limnes on the caldera wall. The dark blue color field with gray grid in the upper portion of B., C., and D. indicates the sea surface.

Figure 3: Carbon dioxide-accumulating subsea pools.



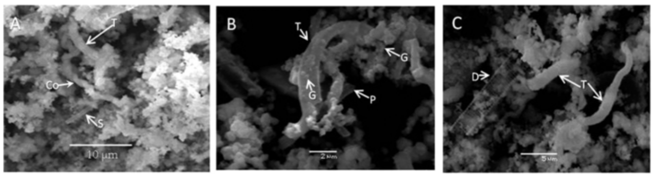
Οι υποθαλάσσιες λίμνες είναι στρώματα πυκνού νερού που βυθίζονται στον πυθμένα αντί να αναμειγνύονται με το θαλασσινό νερό. Μέχρι σήμερα, όμως, όλες οι γνωστές υποθαλάσσιες λίμνες αποτελούνταν από νερό που εμπλουτίζεται με μεγάλες ποσότητες αλατιού, οπότε γίνεται πιο πυκνό από το νερό στο γύρω περιβάλλον.

The recessed locations of the Kallisti Limnes pools did not permit sampling of their fluids with the HOV. However, in-situ mass spectrometer measurements recorded during the HOV survey of the ambient seawater one meter above the pools indicate pCO_2, dissolved methane, and dissolved oxygen concentrations ranging from 490 to 547 μatm, 28 to 44 nM, and 130 to 131 μM, respectively. The dissolved oxygen concentrations are consistent with values found at this depth in this region of the Aegean[18], but the pCO_2 concentrations were substantially elevated compared to Aegean waters at this temperature[19], and the methane concentrations were similar to levels previously measured along the lines of known fracture zones outside the caldera[20], suggesting that the pools are associated with hydrothermal activity. Therefore, a follow-up investigation was conducted to sample the pools' fluids using a remotely operated vehicle (ROV) equipped with a Niskin bottle sampler and temperature probe (Supplementary Fig. S2).

A one-hour time series recorded by the temperature probe while deployed within the pool fluids on July 22, 2012 indicates a stable elevated temperature of 21.5 °C, or approximately 5.5 °C greater than the surrounding ambient seawater at this depth (Supplementary Figs. S3 and S4). Ex-situ analysis of the pool fluids collected using the ROV Niskin sample bottles revealed a pH of 5.93, 41 PSU salinity (2 PSU greater than the ambient seawater at this depth) along with pCO_2, dissolved methane, and dissolved oxygen concentrations of 50,400 μatm, 30 nM, and 80 μM, respectively. The pool fluid's concentrations represent a pCO_2 enrichment approximately 100 fold greater than the adjacent seawater, and nearly identical dissolved methane concentration. The pool fluid's relatively minor dissolved oxygen decrease of 39% suggests, however, that it contained a mixture of seawater and hydrothermal fluids, and may substantially under-represent the CO_2 enrichment of the hydrothermal fluids.

Mats and suspended particulate material from the Kallisti Limnes are composed of iron oxyhydroxide ooze with biogenic silica debris (diatoms and other siliceous shells), minor phases such as kaolinite, glass and pumice volcanic debris, and trace amounts of K-feldspar and chlorite, but devoid of carbonate minerals. Microscopic examination of the material revealed filamentous Fe-rich and spherical Si-rich structures (Fig. 4).

Figure 4: Scanning Electron Microscope (SEM) images of Si-Fe-rich particles from mats and suspended particulate materials.



Morphologies are consistent with microbially produced structures by iron-oxidizing genera: A. Coiled (Co), curved (T) and slender sheath-like (S), filaments; helical or twisted structures resemble the stalks of *Gallionella ferruginea or Mariprofundus ferrooxydans*[26,27]. B. Irregularly twisted branching filamentous (T), and platy (P), forms; spheroid cell-like grains (G) commonly precipitate on the surface of filaments. C. Curved non-coiled sheath-like septated structures (S); diatom frustule (D) with striae are also visible.

Discussion

The Kallisti Limnes and vent mounds are in line with the Kolumbo normal fault onshore (Kolumbo Line in Fig. 1), which belongs to the CSK tectonic line[17]. This tectono-volcanic fracture zone is of predominantly right-lateral transtensional character, which extends from the Christianna volcanic group northeast to the Kolumbo volcanic chain and likely controls hydrothermal circulation pathways within the caldera. The pools and flow channels that form the Kallisti Limnes are in close proximity to a shallow magmatic intrusion within the sediments of the Santorini North Basin[15]. The locations and thermal and chemical composition of these pools suggest that they are a locus of fluid seepage from the CSK tectonic line.

The high Si content of mats (Supplementary Table S1) and suspended particulate material from the Kallisti Limnes is consistent with amorphous opal (~10 wt%), generating the pools' iridescent coloration, while high Fe content (Supplementary Table S1) associated with oxyhydroxides is indicative of a rapid upward flux of Fe(II)-rich waters derived either from sub-seafloor hydrothermal processes[20] and/or connate waters from Fe-rich sediments[21]. Outward flow of reduced Fe-rich sub-seafloor fluids is further supported by high concentrations of free Fe measured within the orange microbial mats. Low S concentration (Supplementary Table S1) and the absence of sulfide and sulfate minerals do not indicate precipitation from brine. Rare earth element distributions (Supplementary Fig. S5) exhibit negative chondrite-normalized Eu anomalies, which are consistent with low-temperature (<100 °C) acidic fluids ($pH < 4$)[22], and/or subseafloor reaction of felsic crustal rocks with low pH acid–sulfate fluids[23]. Eu/Eu*, La/Yb, and Zr/Fe ratios (Supplementary Table S1) indicate bio-detrital derived particulate matter[24].

The Fe-oxyhydroxide particles in the mats generally appear as biomorphous fine-grained aggregates with helical ribbon-like morphologies (Fig. 4) resembling the stalk of known Fe-oxidizing bacteria *Gallionella ferruginea* (previously isolated from hydrothermal sediments within the Santorini Caldera[25]), and/or*Mariprofundus ferrooxydans*[26,27]. Environmental clones within this group of Fe-oxidizing organisms have been obtained from CO_2-rich/H_2S-poor hydrothermal vent systems[26], and Fe–Si-rich precipitates in deep-sea low-temperature hydrothermal environments[27]. The dense microbial mats associated with these pools indicate that fluid seepage has persisted on a time scale sufficient to allow extensive colonization and the meandering flow channels within the microbial mats provide clear evidence of persistent low velocity, gravity-driven flow. Their inactivity during our field investigations further suggests a temporally varying flow regime.

Pycnoclinic seafloor pools exist throughout the world, including the Eastern Mediterranean[28,29], and are characteristically generated through dissolution of upward injected evaporites into younger, surficial seafloor sediments[30]. Although the salinity content of the Kallisti Limnes is only slightly elevated and not sufficient to be considered as brines, the massively elevated carbon dioxide content of the Kallisti Limnes increases the fluid density by at least 82 to 109 g·m^{-3}. Under sufficiently low energy (i.e., thermal and dispersive mixing) conditions this density increase may be adequate for stratification and gravity-driven flow[31].

The process leading to the formation of the Kallisti Limnes and their elevated CO_2content remains uncertain. Localized regions of microbial mats were observed cascading downward in areas of the slope walls directly above the highest elevation hydrothermal pool. These microbial mats appeared to initiate as point sources along specific geologic strata, providing indirect evidence of dense fluid sources seeping at low velocities along flow conduits within the volcano-sedimentary strata. Alternatively, if gaseous carbon dioxide venting occurs from the seafloor, it should in principle generate buoyancy, causing CO_2 to be driven upward through the water column. The rapid dissolution of CO_2 gas into the water column may nonetheless increase the entrained water's density to such a degree that it separates into a gravity-driven plume convecting CO_2-laden water downward[7,31,32]. Previous investigations of gaseous CO_2 venting within the nearby Kolumbo volcano identified dilute acidified benthic waters within its crater, but localized pools of CO_2 accumulations were not observed[33].

The Kallisti Limnes represent a previously unobserved but theoretically contemplated marine phenomenon: concentrated seafloor CO_2 accumulations generated by venting from a geologic reservoir[33,34]. The pools are situated below the basin's sill depth of 150 m, which presumably controls the outflow of the CO_2-rich basin water, but enrichments of dissolved methane and pCO_2 were detected in the water column directly above the pools to a depth of 25 m, indicating transport into surface waters (Fig. 2A,B,C). Although the CO_2 concentrations measured during this investigation have shown that the pool fluids are under-saturated with respect to CO_2 by approximately two orders of magnitude, further research is required to determine the CO_2 inventory of these pools and if their accumulation rate can exceed mixing and carbonate speciation rates to a degree that they present an environmental hazard[34] similar to the freshwater "killer" lakes of Cameroon[35].

Unlike evaporite brine pools, which can persist as relatively stable seafloor features, the shallow volcanic slope setting, relatively minor total inorganic carbon (C_T)-induced density difference, and carbonate system buffering suggest that the Kallisti Limnes may be ephemeral structures, oscillating between CO_2accumulation and re-emission. Their location within the caldera's slope provides clear evidence of previously unknown hydrothermal activity in close proximity to densely populated areas on Santorini. The pools may provide a new diagnostic tool for detecting localized geophysical activity (e.g., variations in the magmatic system or hydrothermal pathways) and a natural analog for studying leakage dynamics and environmental impact from subsea floor anthropogenic carbon storage sites. Further study is required to locate the CO_2 source of these pools and determine if CO_2 accumulation within the Kallisti Limnes is linked to the onset of renewed volcanic unrest. In addition to monitoring seismicity and terrestrial inflation, monitoring the size and composition of these pools may aid the archipelago's hazard preparedness by providing insight into the caldera's subsea dynamics.

Methods

Submarine Reconnaissance

Multibeam bathymetric surveys were carried out by the R/V AEGAEO using a hull-mounted SEABEAM 2120 swath system operating at 20 kHz during multiple cruises in 2001–2006 and 2012. This sonar has an angular coverage sector of 150° with 149 beams, covering a swath width from 7.5 to 11.5 times the water depth for depths from 20 m to 5 km. Initial reconnaissance dives were conducted with the Girona 500[36], a recently developed 500 m depth-rated AUV (Supplementary Fig. S1). It was equipped with conventional navigation sensors (Doppler velocity log, attitude, heading, roll, ultra-short baseline acoustic transponder, pressure, and sound velocity) as well as analytical payload sensors (profiler sonar, side scan sonar, video camera, a digital stereo still imaging system, Imagenex (DeltaT) multibeam swath microbathymetry, and TETHYS mass spectrometer[37]). AUV missions were conducted in a water column profiling mode, with the mass spectrometer autonomously recording dissolved gas distributions in-situ, principally methane (M/Z 15), dissolved oxygen (M/Z 32), and carbon dioxide (M/Z 44). The TETHYS mass spectrometer is equipped with an integrated Seabird FastCat49 conductivity, temperature, and depth (CTD) sensor. The Thetis HOV (Supplementary Fig. S1) was deployed following completion of the AUV dive missions for closer inspection of water column chemical anomalies. Thetis is a Comex Remora 2000 class HOV, capable of operating up to 610 m depth for up to nine hours mission duration. Visual survey was documented using multiple still cameras within the 2 person crew cabin (pilot and scientist). For this dive the submersible was operated in a close bottom following mode (within one meter of the seafloor) and was equipped with a TETHYS mass spectrometer and integrated Seabird FastCat49 CTD. The mass spectrometer and CTD were mounted onto the submersible's port manipulator arm and autonomously logged the previously described chemical and physical water parameters.

Physical sample collection and analysis

Two autonomous logging temperature probes provided temperature estimates of the Kallisti Limnes pool fluids. These sensors were installed in a plastic framework that was placed by the MaxRover remotely operated vehicle (ROV) (Supplementary Fig. S3). These temperature probes were left within the pool for one hour to allow for thermal equilibration. The instruments' (NKE autonomous temperature sensor and WHOI-MISO low-temperature sensor) records yielded maximum temperatures within the pool of 21.5 and 19.7 °C. We report only the highest temperature in the text of this manuscript. Fluids and suspended material were collected from the Kallisti Limnes pools using 2.5 l Niskin bottles attached to the side of the ROV frame (Supplementary Fig. S2). Kallisti Limnes pool fluid samples were collected at a depth of −235 m.

Following recovery the samples' solid phases were separated from liquid by vacuum filtration using a 0.45 μm pore filter. Solid filtrates underwent a series of geochemical analyses (ACME Labs Ltd; Vancouver, BC, Canada). Analytical portions of 0.2 g were subjected to a lithium borate fusion and dilute acid digestion. Concentrations of major elements were subsequently measured by ICP-AES while rare earths and refractory elements were measured by ICP-MS. Base metal and metalloid concentrations were analyzed by ICP-MS following an aqua regia digestion. Analytical quality was assessed by duplicate analysis and run of reference materials and was found to be within acceptable limits. Scanning Electron Microscopy was conducted on carbon-coated free surfaces of suspended particulate matter samples with a JEOL-560 instrument, equipped with an Oxford Isis 300 EDS System (National and Kapodistrian University of Athens-NKUA, Greece). The operating conditions were

20.0 kV, with a working distance of 20 mm and beam current of 0.5 nAmps.

Water sample pH was measured shipboard ex-situ, immediately following recovery of the ROV, at 23 °C using a WTW 340i, set B, pH sensor (WTW GmbH, Weilheim, Germany). The electrode was calibrated daily with three buffer solutions at pH = 4.01, 7.00 and 10.01, and was thoroughly rinsed with distilled water between each measurement. Ex-situ salinity, CO_2, methane, and oxygen measurements recorded from Niskin water and pool fluid samples were analyzed using the TETHYS mass spectrometer and its integrated FastCAT 49 CTD (Seabird Electronics, Bellevue, Washington) which was operated in the ship's science laboratory in a closed-loop circulation configuration. The recirculation system was thoroughly rinsed with distilled water between each measurement.

Laboratory-based TETHYS mass spectrometer calibrations for dissolved methane, oxygen, and pCO_2 were completed prior to deployment using ultra-high purity reference gases (SCOTTY Specialty Gas Calibration Standards, Sigma-Aldrich, Saint Louis, Missouri, USA) bubbled through Milli-Q water for 15–20 min at constant temperature. Dissolved gases were then injected in a pre-evacuated temperature and pressure controlled chamber and measured using the TETHYS mass spectrometer. Each temperature calibration was carried out across a temperature span of 2 °C to 23 °C and was performed across a pressure range of 1 to 200 bar. TETHYS dissolved oxygen calibration was verified in United States coastal waters prior to the survey operations by simultaneously measurement of seawater samples using a calibrated Aanderaa Oxygen Optode 4330F (Aanderaa Data Instruments AS, Bergen, Norway).

Estimation of pool fluid density

Ten benthic water column samples were collected using the ROV's Niskin bottles at a depth of −340 meters in the vicinity of a previously identified hydrothermal field[8,9]. These water samples were collected for the purpose of establishing baseline water column chemistry. The pH of these samples was 7.924 ± 0.044, which is statistically consistent with Eastern Mediterranean intermediate waters (−700 to −200 m depth) pH = 7.962 ± 0.021[38]. In-situ salinity measurements in this baseline area was 39.07 PSU (−340 to −235 m water depth), which is also within the range of Eastern Mediterranean intermediate waters[38]. Sea water density calculations[39] indicate that ambient water within the caldera at a depth of −235 m (15.97 °C and 39.07 PSU) has a density of 1,029,921 $g \cdot m^{-3}$. In contrast, the calculated density of the Kallisti Limnes pool fluids (−235 m depth, 21.5 °C, and 41.00 PSU) is 1,029,942 $g \cdot m^{-3}$, yielding a net density increase for the pool fluids (accounting for temperature and salinity) of 21 $g \cdot m^{-3}$.

Eastern Mediterranean intermediate water has a characteristic total inorganic carbon (C_T) content of 2293 ± 15 $nmol \cdot g^{-1}$, with a total alkalinity (A_T) of 2612 ± 5 $nmol \cdot g^{-1}$ [38]. However, if the increased salinity of the pool fluids (41 PSU) and an A_T -salinity relationship (80 $nmol \cdot g^{-1}$ per PSU[38]) are ignored in order to avoid double counting of the elevated CO_2 density effects, a conservative estimate can be made of the pools' C_T and its associated density increase. Using the ambient seawater A_T of 2612 and salinity of 39.07 PSU in combination with the pool fluids' measured minimum pH of 5.93 (recorded ex-situ at 23°C) yields a C_T of approximately 4700 $nmol \cdot g^{-1}$ [40]. The pool fluids' measured pCO_2 of 50,400 µatm (recorded ex-situ at 22.3°C), along with these ambient alkalinity and salinity values provide a second, independent C_T estimate of at least 4100 $nmol \cdot g^{-1}$ (within 13% of the pH derived value).

C_T calculations for the pool fluids indicate an enrichment of between 1800 and 2400 $nmol \cdot g^{-1}$ in excess of the ambient water column, contributing a fluid density increase of at least 82 to 109 $g \cdot m^{-3}$. This approximation is likely to underestimate the actual density increase because it does not take into account colloidal suspensions, such as iron and biogenic silica, or additional ions present in the pools which may also affect the fluid's CO_2 buffering capacity. Furthermore, the position of the Niskin bottles on the ROV prevented sampling of fluids from the bottom of the pools, making it likely that fluid samples are mixed with ambient water and under-represent the pools' actual C_T.

Additional Information

How to cite this article: Camilli, R. *et al.* The Kallisti Limnes, carbon dioxide-accumulating subsea pools. *Sci. Rep.* **5**, 12152; doi: 10.1038/srep12152 (2015).

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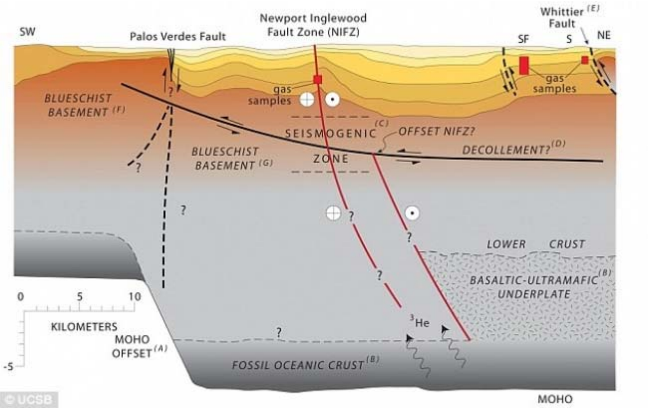
Acknowledgements

This research was supported by the Eurofleets Caldera 2012 Project (EU), a NASA Astrobiology Science & Technology for Exploring Planets grant #NNX09AB76G (USA), a CAREER Award grant #OCE-0955674 to R. Camilli from the National Science Foundation (USA), and IPGP (France). The authors wish to thank Captain Kanakaris and *AEGAEO* crew of HCMR, *Thetis* pilot Kostas Katsaros, *MaxRover* ROV crew, and citizens of the Island of Santorini for their generous assistance.

(http://www.nature.com/articles/srep12152#close)

Helium Leakage from Fault in LA Raises Fears of a Major Earthquake



A geologic cross section of the Los Angeles Basin from the southwest to northeast. This profile intersects the Newport-Inglewood Fault Zone at Long Beach

In a huge rift in the Earth's crust near Los Angeles, it is observed helium leak, and researchers believe that this finding sheds new light on the Newport-Inglewood fault in the basin of Los Angeles.

In a huge rift in the Earth's crust near Los Angeles, it is observed helium leakage, and researchers believe that this finding sheds new light on the Newport-Inglewood fault in the basin of Los Angeles. The fracture is far deeper than scientists used to believe, and an earthquake would be much more devastating than expected.

A report by the US Geological Survey has warned that the risk of 'the big hit in California' has increased dramatically. The geologist Jim Boles from UC Santa Barbara found helium leakage from the Earth's mantle at a stretch of 30 miles of Newport-Inglewood fault in the basin of Los Angeles.

The fault has a slip rate of about 0.6 mm per year and is projected to be able of a 6.0-7.4 magnitude earthquake on the Richter scale. The Newport-Inglewood fault seems to sit on a subduction zone, which is 30 million years old; subsequently it took researchers by surprise the fact that it maintains a path through the crust.

Helium (3He) is a remnant of the Big Bang, and the mantle is its only terrestrial source. Blueschist shows that the fault is an ancient subduction zone - where two tectonic plates collide.

Boles explained 'About 30 million years ago, the Pacific plate was colliding with the North American plate, which created a subduction zone at the Newport-Inglewood fault. Then somehow that intersection jumped clear over to the present San Andreas Fault, although how this occurred is really not known. This paper shows that the mantle is leaking more at the Newport-Inglewood fault zone than at the San Andreas Fault, which is a new discovery. We show that the Newport-Inglewood fault is not only deep-seated but also directly or indirectly connected with the mantle. If the décollement existed, it would have to cross the Newport-Inglewood fault zone, which isn't likely. Our findings indicate that the Newport-Inglewood fault is a lot more important than previously thought, but time will tell what the true importance of all this is.'

Source: dailymail.co.uk

(Geoengineer.org, Monday, 06 July 2015)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΠΕΡΙΒΑΛΛΟΝ

Forget asphalt: a European city is building a road made entirely out of recycled plastic

Does the sight of discarded plastic swirling in the Pacific ocean — the so-called Great Pacific Garbage Patch — haunt you every time you throw away a soda bottle?

Dutch construction company VolkerWessels has found a unique way to make you feel less guilty.

As part of a concept called PlasticRoad, VolkerWessels aims to build roads entirely from recycled plastic that has been salvaged from oceans and incineration plants.

Shortly after it was unveiled in July, the idea attracted attention from the Rotterdam city council. The Netherlands city has now offered VolkerWessels a pilot location to test PlasticRoad. The first road will actually be a bicycle path and, as The Guardian reported, building it will take three years.

According to the plan, sections of the road would be crafted in a factory and then assembled — Lego-like — at the construction site. This means that grooves for traffic sensors and light poles could be worked in even before the panels leave the factory. The design also leaves room for hollow space below the surface, making it easier to lay cables and pipelines later.

But what makes plastic a potential alternative to asphalt, the thick black sticky substance that has long been the material of choice for highway engineers?

A road fashioned out of recycled plastic, according to the company, would be able to survive temperatures as low as -40 degrees and as high as 80 degrees Celsius. In fact, the road would last three times as long as a normal road — potentially as long as 50 years. A plastic road would also be "unaffected by corrosion" and require less upkeep, which theoretically would mean fewer traffic jams.

Ditching asphalt for plastic also makes sense if you consider what the more traditional building material does to the environment. Asphalt is to blame for 1.6 million tons of CO_2 that stream into the atmosphere every year. That makes up 2% of all road transport emissions, according to The Guardian.

Once the plastic road wears out, VolkerWessels hopes to recycle it again and build a new PlasticRoad.

For now, the idea exists only on paper.

But we've already seen how it can work. The city of Jamshedpur in India has paved nearly 50 kilometers of roads partly, if not entirely, with recycled plastic. Bottles and wrappers are reportedly hauled to collection centres, shredded, and mixed with asphalt.

At the very least, the idea floated by VolkerWessels is a promising step on the road to solving the world's crippling plastic problem.

(Shivam Saini / Business Insider Australia, July 22 2015, http://www.businessinsider.com.au/a-dutch-city-is-planning-to-build-roads-from-recycled-plastic-2015-7)

The Piccalilly Line: how a disused Tube tunnel became London's first urban farm

An urban farm located in a disused London Underground tunnel has started to sell produce to the capital's markets and restaurants.

The 170 square metre carbon neutral "Growing Underground" farm is situated 33m under the south London borough of Clapham in tunnels that were last used as a bomb shelter during the Blitz.

The farm combines hydroponics, which uses a nutrient solutions rather than soil, and LED lighting to grow its crops.

The hydroponic system requires 70% less water than traditional open-field farming and also means that crops can be grown all year.

Growing Underground founders Richard Ballard and Steven Dring with Michel Roux Jr

The venture was begun by West Country entrepreneurs Richard Ballard and Steven Dring to produce a variety of vegetables and herbs, including celery, rocket, parsley, radish and mustard leaf.

Growing Underground says its produce can go from farm to fork in under four hours.

Michel Roux Jr, presenter of the BBC's Masterchef programme, said: "The quality of these ingredients is second to none; they are going to be picked and delivered practically on the day, and you can't get fresher than that."

The project was started in an attempt to bring food production back into the capital.

The tunnels used by Growing Underground could shelter 8,000 people during wartime air raids.

Watch a four minute "pitch" from Growing Underground here https://www.youtube.com/watch?v=fxTaXDxzIXE.

(Joe Quirke / GCR Global Construction Review, 3 July 2015, http://www.globalconstructionreview.com/news/piccalilly-line-h8ow-dis6us0ed-tu4b0e6-4t2un0n8el)

Ρομποτικός οικοδόμος
Εκτυπωμένο κτήριο γραφείων σχεδιάζει το Ντουμπάι

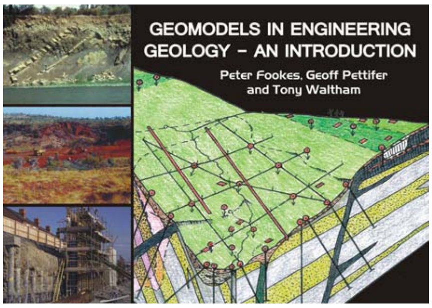
Η τεχνολογία της 3D εκτύπωσης αρχίζει πλέον να μπαίνει και στον χώρο της κατασκευής κτηρίων

Η κυβέρνηση των Ηνωμένων Αραβικών Εμιράτων ανακοίνωσε ότι προχωρά άμεσα στη δημιουργία του πρώτου οικοδομήματος που θα χρησιμοποιηθεί ως χώρος γραφείων η κατασκευή του οποίου θα γίνει με εκτυπωτή 3D. Πρόκειται για ένα οικοδόμημα που θα έχει συνολική επιφάνεια 185 τετραγωνικών μέτρων. Θα χρησιμοποιηθεί ένας 3D εκτυπωτής ύψους 7 μέτρων ο οποίος θα εκτυπώσει μια σειρά από στρώματα τα οποία στη συνέχεια θα συναρμολογηθούν για να δημιουργήσουν το εκτυπωμένο κτήριο γραφείων.

Τα υλικά που θα χρησιμοποιηθούν για την εκτύπωση του οικοδομήματος είναι ενισχυμένο τσιμέντο, και γύψος ενισχυμένος με ίνες γυαλιού και πλαστικό. Τα έπιπλα των γραφείων θα είναι επίσης προϊόν εκτύπωσης. Την εκτύπωση θα αναλάβει η κινεζική εταιρεία Winsun που ειδικεύεται στην εκτύπωση πολύ μεγάλων αντικειμένων με 3D εκτυπωτές. Το οικοδόμημα που θα βρίσκεται στο Ντουμπάι σύμφωνα με την κυβέρνηση των ΗΑΕ θα έχει κατά 50%-70% μειωμένο κόστος κατασκευής σε σχέση με ένα συμβατικό κτίριο και 50%-80% μικρότερο εργατικό κόστος.

(Θοδωρής Λαΐνας / Βήμα Science, Newsroom ΔΟΛ, 01 Ιουλ. 2015, http://news.in.gr/science-technology/article/?aid=1500009137)

ΝΕΕΣ ΕΚΔΟΣΕΙΣ ΣΤΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΠΙΣΤΗΜΕΣ



Geomodels in Engineering Geology - An Introduction

Peter Fookes, Geoff Pettifer and Tony Waltham

- **Visual guide to varied geological/geomorphological situations**
- **Profusely illustrated with over 400 photographs and diagrams**
- **The ideal first step to gain an overview of a site for investigation**

The book provides a valuable systematic guide to the evaluation and understanding of ground and worldwide environmental conditions of sites and their surrounds. This is done through a series of annotated block models and supporting photographs of common geological and geomorphological situations around the world, with basic text explanations and information on each principal block diagram and its annotated photographs.

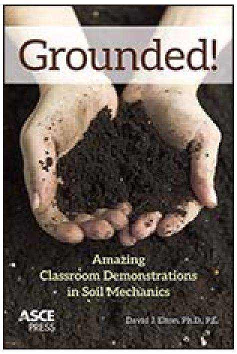
Geomodels in Engineering Geology outlines the world's climatic and morphological zones and the changes such environments bring upon the ground. It deals with fundamental aspects of surface soils and geology in relation to their engineering behaviour and guides the way that ground investigation can be developed to provide appropriate information needed for design and construction of a project - augmented by case histories and experience of practical problems.

Contents: Introduction. **Part 1**: The Underlying Factors Climate and Geology. **Part 2**: Near-surface Ground Changes. **Part 3**: Some Basic Geological Environments for Engineering. **Part 4**: Ground investigation (GI). **Part 5**: Case Histories and Some Basic Ground Characteristics and Properties. **Appendix**: Geotechnical Problems Associated with Different Types of Engineering Soils. References. Bibliography. Index

Extract from the Foreword by **Professor John Burland**, Imperial College London

… Many important engineering implications are illustrated emphasising the necessity of understanding the geological processes that form the ground profile. …this book will provide an invaluable insight into the art of unravelling the complexities of the ground.

(Whittles Publishing, September 2015)



Grounded!

Smazing Classroom Demonstrations in Soil Mechanics

David J. Elton

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Topics include: slaking, pile capacity, swelling clays, shear and compression, effective stress, capillary tension and flow, soil arching, tensile and compressive strength, soil identification, piping, liquefaction, relative density, soil filters, settlement rates, and many more.

Each demonstration includes easy-to-follow directions, illustrations, and an explanation of the engineering signifi-cance or application of the principle demonstrated. Videos of many experiments are also available.

An exciting tool for high-school and college instructors, the inexpensive and simple experiments in this book make soil mechanics fun to learn and are fascinating to even the casual science enthusiast.

David J. Elton, Ph.D., P.E, has taught civil engineering, specializing in geotechnical engineering, at Auburn University for more than 25 years. In addition, he practices as a professional engineer, has won the TRB Fred Burggraf award, and is a past-president of the North American Geosynthetics Society.

(ASCE Press, 2015)

ΕΚΤΕΛΕΣΤΙΚΗ ΕΠΙΤΡΟΠΗ ΕΕΕΕΓΜ (2012 – 2015)

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