ernized the ISC event location and magnitude computation procedures. We are working on the project of re-building the entire ISC Bulletin (1960-2010) by re-computing the hypocenters and magnitudes with the new location algorithm using ak135 velocity model, identifying and filling the gaps in data, correcting known errors and introducing essential additional bulletin data from temporary deployments. The ISC takes a leading role in compiling the GEM Instrumental Seismic Catalogue (1900-2009) where more reliable and consistent magnitudes and hypocentre parameters will be provided for large earthquakes using considerable volumes of newly obtained parametric data. The ISC is also running the CTBTO-Link where the ISC Bulletin data are provided to the monitoring community as a historical perspective into current recordings by the IMS network as well as making a link to current data of non-IMS networks.

Relationship between Seismicity and Oil Production

KERIMOV, I. H. A., Scientific Center of Seismology, Baku, Azerbaijan, scseismo@azdata.net; KERIMOV, S. I., Seismotech Globe BV, Keln, Nordrhein-Westfalen, Germany, seymourki@web.de

The analyses of different aspects of negative impacts to environment have proved that any repeated industrial activity with even low scale impacts should be controlled to avoid triggering disturbances of natural balance, significant ecological and economical damage and occurrence of earthquakes by them. Non-controlled industrial activity on the territory with high tense sensitivity leads to activation of tectonic processes, amplification in a stress state of the medium and changes in seismicity.

The problem is related to understanding the medium as a dynamic object with constantly changing parameters and to the fact that high power events can appear even in areas that earlier were considered as low-seismic or even aseismic. This allowed working out criteria for medium's state diagnostic and solving the wide range of problems, concerning protection of the environment on a new methodical basis.

The studies of the "Starogrozny" oil fields have revealed the existence of some threshold for acceptable pressure differences in the medium, crossing which led to elastic or nonlinear deformation processes, appearance of vibration fields, etc and all together to the destruction of fields and drops in production.

We analyzed one of such impacts to medium by method of hydraulic fracturing, fracking, widely used in oil industry, and negative aftermaths caused by them. An additional energy which also causes the emergence of earthquakes is accumulated in the medium. For example, weak seismicity increased tenfold since the commencement of the "Guneshli" oil field development.

These negative effects revealed as a consequence of the same uncontrolled development of oil fields them and damaging mediums by using fracking method to a large degree in various regions of the world: Kaliningrad, Grozny and Saberia regions in Russia; Azerbaijan section of the Caspian Sea; Gulf of Mexico; Arkansas, Texas and other states in the USA; Blackpool in England.

Earthquakes and Tsunamis at Coastal Archaeological Sites

Oral Session · Thursday 1:30 PM, 19 April · Pacific Salon 6&7
Session Chairs: Manuel Sintubin, Beverly N. Goodman Tchernov, and Tina M. Niemi

The First Description of a Tsunami in 479 BC by Herodotus: Sedimentary Evidence in the Thermaikos Gulf (Greece)

REICHERTER, K., Inst. of Neotectonics, RWTH Aachen University, Aachen, Germany, k.reicherter@nug.rwth-aachen.de; PAPANIKOLAOU, I. D., Lab. of Mineralogy & Geology, Department of Geological Sciences, Athens, Greece, i.papanikolaou@ucl.ac.uk; MATHES-SCHMIDT, M., Inst. of Neotectonics, RWTH Aachen University, Aachen, Germany, m.mathes@nug.rwth-aachen.de

The Herodotus Histories (Urania, Book 8, 129) report on a series of large waves and sea withdrawals occurring in winter 479 BC during the Persian-Greek war. Large portions of the Persian troops perished by drowning near Potidaea, western Chalkidiki peninsula (Greece), while sieging the Greek village. Therefore, Herodotus's report is regarded and interpreted as the first description of a historical tsunami.

The ancient Mende situated on the Possidi peninsula of Kassandra was a quite important city in the classic Hellenistic period, already founded in the 13th cent. BC. However, the youngest parts of the city are situated close to the seaside (proasteion of the 6-5th cent. BC). Within the excavation of the proasteion, a high-energy layer has been encountered. Besides a vast amount of ceramics, the layer also contains shells of Acanthocardia sp. These have been dated as c. 2500 a BP (14C, taking into account a reservoir effect of 400 a). More evidence has been found on the Possidi penisula where we drilled shallow cores (up to 10 m). In the cores we found sedimentary evidence for high-energy events. Also, the last cult building of the Poseidon sanctuary has an age of mid-5th cent. BC. Modelling of the tsunami potential along the western tip of the North Anatolian Fault Zone in the North Aegean Basin revealed the possibility of high waves induced by seismicity (Reicherter *et al.*, 2010). This area was not included in the ten "tsunami" regions of Greece, data presented in this paper clearly show that the Thermaikos Gulf should be included in the areas of tsunami hazards. This is a densely populated area, where the second biggest city of Greece and several holiday resorts do exist.

Reicherter, K., Papanikolaou, I., Roger, J., Mathes-Schmidt, M., Papanikolaou, D., Rössler, S., Grützner, C., Stamatis, G., 2010. Holocene tsunamigenic sediments and tsunami modeling in the Thermaikos Gulf area (northern Greece). Zeitschrift für Geomorphologie N.F. Suppl. 54/3: 99-126.

Evidence for a Potential Tsunami on the Shelf of the Northern Gulf of Aqaba, Dead Sea Transform

GALLOWAY, J., UMKC, Kansas City, MO, julielgalloway@yahoo.com; NIEMI, T. M., UMKC, Kansas City, MO, niemit@umkc.edu; GOODMAN TCHERNOV, B., University of Haifa, Haifa, Israel, goodmanbeverly@gmail.com; BEN-AVRAHAM, Z., University of Tel Aviv, Tel Aviv, Isreal, zviba@tau.ac.il; AL-ZOUBI, A., Al Balqa' Applied University, Salt, Jordan, aalzoubi@go.com.jo; TIBOR, G., Israel Oceanographic and Limnologic Research, Haifa, Israel, tiborg@ocean.org.il

As part of a collaborative geophysical and coring campaign to study the seismic hazard potential of submarine faults in the northern Gulf of Aqaba, a 4.3 m core extracted from 25 m water depth on the shelf of the northern Gulf of Aqaba was studied in detail. Analyses of foraminiferan assemblages, grain-size distribution, sediment characterization, and five radiocarbon dates on Amphistegina lessonii forams reveal evidence for alternating paleoenvironmental conditions over the past ~4000 yr B.P. The upper 50 cm of the core dating to the past 1100 yrs indicates significant dewatering compaction in the core, an interval of foram abundance, and relatively coarse sediment. Between 50 and 250 cm core depth, the sediment is fine grained and dominated by Miliolina forams. Within this zone, two foraminifera-barren layers at 170 and 190 cm depth in the core correlate to a grain size anomaly at that depth. The well-sorted, subangular quartz and feldspar dominated sediments, the lack of foraminifera and other marine biota suggests significant terrestrial input. A tsunami wave generated ~2200 yr B.P. is one possible explanation for this occurrence. Because this region is earthquake prone, it is reasonable to assume that earthquake triggered tsunamis have affected this area in the past. Earthquake catalogs document at least one account of a large sea wave in the Gulf of Aqaba associated with an earthquake in A.D. 1068. The late 12th century author, Ibn al-Jauzi, states that Aila (the present day city Aqaba, Jordan) was completely destroyed, leaving only 12 surviving inhabitants and mentions "the withdrawal and return of the sea" (Ambraseys, 2009 p. 274). Tsunamis can occur as an indirect response to seismic activity. Multibeam sonar mapping of the gulf seafloor (Tibor *et al.*, 2010) shows large detached blocks, collapsed walls, and submarine slumping that may also be tsunamigenic. Further research is needed to determine the origin of the foram-barren zone.

Evaluating the Impact of Earthquakes on Minoan Coastal Settlements: An Example from the Archaeological Site of Sissi, North-Eastern Crete (Greece)

JUSSERET, S., Universite catholique de Louvain, Katholieke Universiteit Leuven, Louvain-la-Neuve, Leuven, Belgium, Simon.Jusseret@uclouvain.be; LANGOHR, C., Universite catholique de Louvain, Louvain-la-Neuve, Belgium, Charlotte.Langohr@uclouvain.be; SINTUBIN, M., Katholieke Universiteit Leuven, Leuven, Belgium, Manuel.Sintubin@ees.kuleuven.be

According to the traditional view, seismic events played an important role in the history of Bronze Age (Minoan) Crete (ca. 3000-1200 BC): catastrophic earthquakes repeatedly destroyed settlements, shaped religious beliefs and influenced the political geography of the island. The lack of strong, supportive archaeological evidence for such effects has, however, progressively led archaeologists to disregard the Bronze Age seismicity of Crete. Moreover, the vision of Minoan society as a passive victim of ancient earthquakes is clearly at odds with current efforts to reconsider such conventional versions of Minoan history. It is suggested that any attempt to reach a more elaborate understanding of the relationship between earthquakes and Minoan society will necessitate a better grasp of the effects of seismic events on archaeological stratigraphical records. This is particularly true for coastal archaeological sites where destructive agents such as tsunamis, storms, and seaborne attacks can obscure earthquake damage patterns. A territorial approach testing the existence of synchronous and regional damage is brought forward as a way to identify ancient earthquake effects. In this perspective, and

in contexts where radiocarbon chronology is not available, ceramic analyses provide an invaluable tool for assessing the temporal relationship between damage events. They also allow shedding light on the processes having led to the formation of archaeological destruction layers. These perspectives are discussed in the Late Minoan IIIB (ca.1300-1200 BC) context at the archaeological site of Sissi, an ancient harbour excavated in 2007-2011 by the Belgian School at Athens and located on the north-eastern coast of the island.

Did a Major Environmental Event Lead to the Late Bronze Age Abandonment of the Ancient Harbor City of Hala Sultan Tekke? Unraveling the Sedimentary Record of the Larnaca Salt Lake, Cyprus

HEYVAERT, V. M. A., Geological Survey of Belgium; Vrije Universiteit Brussel, Belgium, Vanessa.heyvaert@naturalsciences.be; SINTUBIN, M., Katholieke Universiteit Leuven, Leuven, Belgium, manuel.sintubin@ees.kuleuven.be; VERSTRAETEN, G., Katholieke Universiteit Leuven, Leuven, Belgium, gert.verstraeten@ees.kuleuven.be; KANIEWSKI, D., Ecolab, Université Paul Dabatier, Toulouse, Belgium, david.kaniewski@ees.kuleuven.be; NYS, K., Vrije Universiteit Brussel, Brussel, Belgium, karin.nys@vub.ac.be

A complex of salt lakes, fringing the Mediterranean Sea between Larnaca and Cape Kiti, marks the Larnaca coastal plain in Eastern Cyprus. The ancient city of Hala Sultan Tekke is situated directly to the west of the main salt lake, and has been abandoned at the end of the Late Bronze Age (LBA; ~1200 BC). Several hypotheses circulate with respect to the LBA societal collapse in the Eastern Mediterranean: from the invasion by the 'sea people', climate change to an earthquake or even the Thera tsunami catastrophe. Nearby the archaeological site, the salt lake is protected from the Mediterranean Sea by a Pleistocene sandstone barrier.A second middle to late Holocene ridge separates the salt lakes completely from the Mediterranean Sea. Three faults, trending nearly perpendicular to the present-day coastline, are identified near the salt lakes.

Human-environmental interactions that may have led to the abandonment of the ancient city of Hala Sultan Tekke are investigated by studying the sedimentary record of the Larnaca salt lakes in great detail. Hand-operated augering took place in the main salt lake as well as in the southernmost lake (Menoui beach). The sedimentary sequence is subdivided into Pliocene bedrock, open marine (rich in Posidonia Oceanica), lagoon, salt lake and coastal ridge deposits. It is suggested that during the Early Holocene the Larnaca Bay was open, but protected; its floor being built up behind a sublittoral Posidonia meadow. Close to the Hala Sultan Tekke site, the succession reflects a confined marine embayment protected by the Pleistocene barrier. This embayment gradually evolved into lagoon, coastal marsh and finally into an enclosed salt lake due to the development of a Middle to Late Holocene coastal ridge along the present-day shoreline. To date no indications are found in the sedimentary record of events, due to tectonic movements or tsunamis, or of abrupt climate changes.

Searching for Tsunamigenic Signatures in the Coastal Deposits of Caesarea Maritima

GOODMAN TCHERNOV, B. N., University of Haifa, Mt. Carmel, Israel, goodmanbeverly@gmail.com; DEY, H. W., Hunter College: City University of New York, New York, NY, USA, hdey@hunter.cuny.edu; LOPÉZ, G. I., University of Haifa, Mt. Carmel, Israel, lopezgi.phd@gmail.com; SHARVIT, J., Israel Antiquities Authority, Jerusalem, Israel, koby@israntique.org.il

Today, the roman harbor of Caesarea Maritima lies between 3 and 6 meters below the waterline. Until recently, the state of the harbor was primarily ascribed to earthquake activity combined with related liquefaction and gradual demise, while the impact of tsunamis was largely discounted despite numerous descriptions of tsunamis in textual sources. Sedimentological evidence of tsunamigenic deposits discovered offshore from the ancient harbor in the past ten years, however, has cast a new light on the factors that led to the harbor's deterioration. Recent studies conducted by the Caesarea Coastal Archaeological Project have therefore focused on identifying and documenting the signature of tsunami deposits in the archaeological record at Caesarea, particularly in the intermediate harbor, where earlier excavators working in the 1990s described thick deposits of rubble attributed to episodes of destruction or deliberate deposition in the Byzantine and early Umayyad periods (4th-8th centuries CE). Preliminary results from two seasons of fieldwork suggest the possibility of differentiating between two tsunami events spaced within 200 years of one another, based on carefully-controlled excavations and sedimentologically-based stratigraphic descriptions, coupled with chronological markers furnished by C14, OSL, and ceramic dating methods. Curiously, there are no published claims of tsunami-derived deposits in terrestrial contexts at Caesarea, though past excavation reports strongly suggest the presence of such deposits that went unrecognized by the excavators. This is not entirely unexpected given that a) agreement over the character of tsunami deposits is even debated within the tsunami research community, b) most of these excavations were not conducted in direct collaboration with a sedimentologist or geologist, and c) Caesarea's continuous history of occupation has led to the transformation or disappearance of much of whatever deposits may have once existed.

Rotations in Strong-motion Seismology

Oral Session · Thursday 8:30 AM, 19 April · Pacific Salon 4&5
Session Chairs: Vladimir Graizer and Maria Todorovska

Differential and Rotational Excitation of Structures

TRIFUNAC, M. D. T., Univ. Southern California, Los Angeles, CA, trifunac@usc.edu

Traditional earthquake engineering has evolved based on consideration of only horizontal components of strong earthquake ground motion and on the vibrational formulation of the response in terms of the response spectrum superposition. This approach has become the standard starting point of most modern earthquake resistant design procedures. However, except for structures which have small plan dimensions, this representation can lead to serious underestimates of the response. More realistic representations of ground motion, which include rotations and differential components of motion, will require more degrees of freedom and will render the simple response spectrum method unacceptable. When the wave lengths of the strong motion waves are longer that the characteristic length of the foundation(s), simple extensions and generalizations of the response spectrum method can lead to realistic yet simple design procedures, provided the shape of the response spectrum has been modified to include those additional effects. The purpose of this review will be to show how the simple spectral modifications can be introduced to extend its validity well beyond its original definition.

Status of Rotational Instrumentation for Earthquakes

EVANS, J. R., U.S. Geological Survey, Menlo Park, CA, jrevans@usgs.gov; HUTT, C. R., U.S. Geological Survey, Albuquerque, NM, bhutt@usgs.gov; NIGBOR, R. L., Univ. of Calif., Los Angeles, Los Angeles, CA, nigbor@ucla.edu

Rotational-motion seismometers for earthquake engineering and seismology are in a rapid, early development stage. We review their present status and uses.

We are unaware of a rotational sensor with ideal properties and cost for these applications. Those designed for inertial navigation are noisy or less sensitive than needed, while low-noise high-sensitivity sensors are either costly or have performance issues. Navigation sensors include Coriolis MEMS devices, ring-laser and fiber-optic gyros, and magnetohydrodynamic sensors. Seismology-specific devices include large ring-laser and electrodynamic sensors and several in development using various methods.

In recent years the Albuquerque Seismological Laboratory of the USGS has developed facilities for measuring transfer functions, linearity, clip, and self-noise levels of rotational seismometers, particularly of strong-motion devices. These facilities include rotational and translational shake tables, a thermal chamber, regular nearby explosive sources, a quiet deep vault, and computational facilities. Academia Sinica, Taiwan, Technische Universität München, Germany, and several others have some of these capabilities.

Several deployments to record earthquakes and explosions are complete or underway, including TAIGER explosion tests and permanent stations in Taiwan (including in Taiwan 101); NEES test structures; large explosions, southern California; huddle tests at The Geysers, northern California; explosion recording in New Mexico; and broadband ring-lasers in Germany, New Zealand, California, and Arkansas.

The ability to test rotational instruments in detail, developments by existing and new manufacturers, a growing set of field and laboratory recordings of natural and artificial sources, and growing appreciation for the value of recording rotational motions have led to a renaissance of rotational earthquake engineering and seismology and the growing availability of appropriate sensors.

Parametric Analysis of Horizontal Surface Rotations from Body Waves Reflections

ZEMBATY, Z., Opole University of Technology, Opole, Poland, z.zembaty@po.opole.pl

The lecture proposed for the "SSA 2012 Meeting" deals with the problem of deriving rocking component of ground motion (rotation about horizontal axis) from wave decomposition of respective horizontal translational ground motions, using the "solid-free surface" reflection coefficients [1]. The approach proposed in the landmark paper of Trifunac [2] and developed later in numerous papers including the very recent one [3], is re-visited and reformulated to include diverse