Program and Short Abstracts
7th PATA Days, 2016

The 7th International INQUA Workshop on

Paleoseismology, Active Tectonics and Archaeoseismology

30 May-3 June 2016

Crestone, Colorado USA

Program and Short Abstracts of the 7th International INQUA Workshop on Paleoseismology, Active Tectonics and Archaeoseismology ("PATA Days")

30 May- 3 June 2016

Crestone, Colorado, USA

Editors
James P. McCalpin
Christoph Gruetzner

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Edited by
James P. McCalpin
GEO-HAZ Consulting, Inc.
Crestone, CO USA
&
Christoph Grutzner
Department of Earth Sciences, University of Cambridge
United Kingdom

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PROCEEDINGS VOLUMES OF PATA DAYS:

Vol. 7: Proceeding of the 7th International INQUA Meeting on Paleoseismology, Active Tectonics and Archeoseismology (*J.P. McCalpin & C. Gruetzner, eds*.). ISBN 978-0-9974355-2-8, 2016. Published digitally by the Crestone Science Center, Crestone, CO 81131 USA, Guidebook No. 12; 7th International INQUA Meeting on Paleoseismology, Active Tectonics and Archeoseismology, Crestone (USA).

Vol. 6: Abstracts Volume, 6th International INQUA Meeting on Paleoseismology, Active Tectonics and Archeoseismology (*Blumetti, A.M., Cinti, F.R., De Martini, P.M., Galadini, F., Guerrieri, L., Michetti, A,M., Pantosti, D. and Vittori, E., eds.)*, 19-24 April 2015, Pescina, Fucsino Basin, Italy: Miscellanea INGV, Anno 2015_ Numero 27, ISSN 2039-6651, printed in Italy by Instituto Nazionale di Geofisica e Volcanologia, Rome, Italy, 545 p.

Vol. 5: Proceeding of the 5th International INQUA Meeting on Paleoseismology, Active Tectonics and Archeoseismology (*C. Grutzner, J.-H. Choi, P. Edwards & Y.-S. Kim, eds*.). ISBN 9791195344109 93450. Printed in Korea, 2014. 5th International INQUA Meeting on Paleoseismology, Active Tectonics and Archeoseismology, Busan (Korea).

Vol. 4: Seismic Hazard, Critical Facilities and Slow Active Faults (*C. Grutzner, A. Rudersdorf, R. Perez-Lopez & K. Reicherter, eds.*). ISBN 978-3-00-0427-96-1. Printed in Germany, 2013. 4th International INQUA Meeting on Paleoseismology, Active Tectonics and Archeoseismology, Aachen (Germany).

Vol. 3: Earthquake Geology and Archeoseismology: Society and Seismic Hazard (*R. Perez-Lopez, P.G. Silva, M.A. Rodriguez Pascua, V.H. Garduno Monroy, G. Suarez & K. Reicherter, eds*.) Printed in Mexico, 2012. 3rd INQUA-IGCP 567 International Workshop on Earthquake Geology, Paleoseismology and Archeoseismology, Morelia (Mexico).

Vol. 2: Earthquake Geology and Archeoseismology: Society and Seismic Hazard (*C. Grutzner, R. Perez-Lopez, T. Fernandez-Steeger, I. Papanikolaou, K. Reicherter, P.G. Silva & A. Vott, eds.*) ISBN: 978-960-466-093-3. Printed in Greece, 2011. 2nd INQUA-IGCP 567 International Workshop, Corinth (Greece).

Vol. 1: Archaeoseismology and Paleoseismology in the Alpine-Himalayan Collisional Zone (*R. Perez-Lopez, C. Grutzner, J. Lario, K. Reicherter & P.G. Silva, eds.*) ISBN: 978-84-7484-217-3. Printed in Spain, 2009. 1st INQUA-IGCP 567 International Workshop, Baelo Claudia, Cadiz (Spain).

Preface [I]

Dear friends and colleagues,
Seven years ago, a hundred geoscientists assembled in sunny southern Spain for what can be seen as the birth of the PATA Days conference series. Klaus Reicherter who initiated and actively supported these meetings decided that we need more time for discussions and interaction both in conference halls and in the field. The huge AGU and EGU type of meetings leave no time or space for both. Therefore these regular topical workshops have been set up, providing enough time for discussions, fieldtrips, socialising and student focused summer schools. The high attendance and the planned future meetings testify for their success.

In 2009, after having studied the active faults of the Strait of Gibraltar, the tsunami deposits along the beautiful coast, and the earthquake damage at the ruins of Baelo Claudia, the meeting moved to Corinth, Greece, in 2011. This place is probably the best laboratory on Earth to study fast continental extension and it is also the birthplace of archaeoseismology. In 2012 the PATA Days were held in Morelia, Mexico, commemorating the centenary of the November 19, 1912 Acambay Earthquake (M~7). Active faulting in the Acambay Graben and the seismic hazard in Mexico were brought to the attention of the paleoseismology community. The extremely slowly deforming region of Western Germany was the topic of the 2013 meeting in Aachen. Although the ongoing extension in the Lower Rhine Graben is so low that it cannot even be measured with geodesy in the time span that is covered by modern techniques, strong earthquakes happened here in the past and left their traces in the sedimentological and archaeological record. The 2014 PATA Days led us to Busan, South Korea, and we focussed much on the issue of slow faults and hazard to critical facilities like nuclear power plants. Plus, we enjoyed the excellent South Korean food and landscape. In 1915, the strongest earthquake on record in Italy reduced the Fucino area to rubble. We visited the Fucino plain one hundred years later in 2015 to learn about the state of the art of paleoseismology in Italy and to visit L'Aquila, the city that was so badly stricken by a strong earthquake in 2009and which made it to international news with the convict of seismologists.

Now, in 2016, we are very happy to have the PATA Days in the United States for the first time. Here is the cradle of paleoseismology, here are some of the most spectacular and best-studied surface ruptures in the world, and here in Crestone, CO, is where Jim McCalpin wrote his 'bible' of paleoseismology. Here is earthquake country. We are happy that Jim is the lead organiser of this meeting.

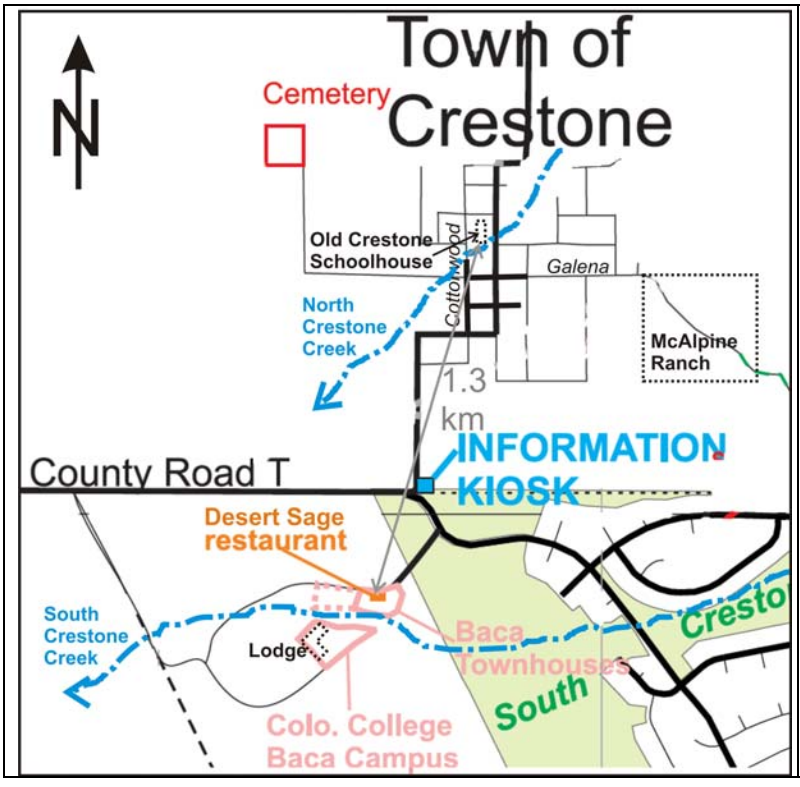
The last decades have brought us an immense new toolbox of geoscience methods. With permanent GPS and latest DInSAR technology we are now able to observe the deformation of the crust almost in real-time and to detect phenomena that we weren't even aware of a few years ago. Dense seismic networks, broadband stations, and strong motion instruments allow us to examine the anatomy of large earthquakes in many parts of the world. Stereo satellite imagery, LiDAR, and photogrammetry help us to create the most precise digital elevation models which are used to trace the surface expression of active faulting. Cosmogenic isotope dating and other advanced dating techniques offer unprecedented temporal resolution. Turbidity paleoseismology and interdisciplinary tsunami studies gave us invaluable insights into coastal hazards. But it is not only the methodology that improved, it is also the increasing co-operation with scientists from neighbouring or even more distant disciplines that helped to advance the study of paleoseismology, active tectonics, earthquake geology, and archaeoseismology.

Fostering co-operation among scientists and supporting early career researchers (ECRs) is the main aim of our new INQUA Focus Group 'Earthquake Geology and Seismic Hazards -

EGSHaz'. With the INQUA congress in Nagoya in 2015, the old structure ceased to exist and something new was born. Active tectonic studies were hitherto supported by our former focus group PALACTE (Paleoseismology and Active Tectonics) within the TERPRO Commission (Terrestrial Processes) of INQUA. The PALACTE leaders Pablo Silva, Klaus Reicherter and Luca Guerrieri stepped back after having done a fantastic job during the past years- the current group has now 445 members from 54 countries. They established the EEE catalogue of environmental earthquake effects and supported countless ECRs to participate in our activities. Now the new focus group EGSHaz will support networking and the exchange of ideas during the ongoing intercongress period 2015-2019. We are happy to have the support of the TERPRO (INQUA's Commission on Terrestrial Processes, Deposits and History) president Alessandro M. Michetti who also served as a past leader of the group. The group is now led by Ioannis Papanikolaou, Petra Štěpančíková, and Christoph Grützner, with support from Yael Braun, Beau Whitney, and Jakub Stemberk.
For the upcoming years we have established two main projects that will form the focus of our work: 'SURfaceFAulting Catalogue – Earthquakes (SURFACE)' coordinated by Stéphane Baize and 'Geological Earthquake Mapping of recent, historical and paleoseismic events; Quaternary Geology for Seismic Hazard Analyses (GEMAP)' coordinated by Ioannis Papanikolaou. We are currently establishing a new focus group website, which will contain all information about our ongoing work, collaborators, scientific reports, and meetings: www.earthquakegeology.org. For regular updates, news and announcements follow the blog over at www.paleoseismicity.org and find us on Twitter and Facebook.

We wish you an exciting and wonderful conference and we thank Jim for the amazing job he has done.

Ioannis Papanikolaou (leader), *Petra Štěpančíková* (co-leader), *Christoph Grützner* (co-leader)



MAP OF VENUE (Colorado College, Baca Campus) and its location relative to:

-the Desert Sage Restaurant (100 m to the North)

- the Town of Crestone, and Old Schoolhouse (1.3 km to the North)

-the McAlpine Ranch (2.7 km to North and East) via roads through Town of Crestone (East Galena Avenue)

Preface [II]

The 7th International Workshop on Paleoseismology, Active Tectonics and Archeoseismology (7th PATA Days) is being held in Crestone, Colorado, USA from 30-May through 3-June, 2016. The Workshop was preceded by the 1st PATA Road Trip, "*Faults of the Wild West*", a 2000-km, 6-day, limited attendance field trip led by Jim McCalpin to classic faults of the western USA. The "Wild West" theme continues with our 2016 venue of Crestone, a small former gold-mining town on the eastern margin of the Neogene Rio Grande rift zone. Crestone lies on the rift valley floor at 2500 m elevation, nestled at the base of the 4000+-meter mountains of the rift-flank uplift.

This is the first PATA Days meeting in the USA, and the second in North America (after Morelia, Mexico in 2012). However, unlike the Morelia and Fucino (2015) workshops, this one does not celebrate the anniversary of a damaging historic earthquake, for the simple reason that the rift-bounding faults in Colorado have been seismically quiescent throughout historic time (1850-present). The Rift is thus similar to the larger Basin and Range Province, having many late Pleistocene and Holocene fault scarps, but very few surface-rupturing earthquakes in our short 150-year written history. When paleoseismology was beginning in the 1970s in the USA, the conventional wisdom in Colorado and New Mexico was that the rift had developed in the Miocene and Pliocene, and that rift faults were no longer active and posed no seismic risk. Like much of the Western USA outside of California, these large extensional regions had low historic & instrumental seismicity and were shown on national/regional seismic hazard maps as having very low seismic risk. Yet studies in the 1970s began to document recent geologic evidence (fault scarps) for M>7 earthquakes in the Holocene, on the faults that were supposedly inactive! To some of us in graduate school at that time, it seemed that the contribution of paleoseismology was even more critical in these regions, than in the more seismically active areas (such as California) where seismic risk was already accepted as high. This story of rift paleoseismology will unfold on the Pre-Meeting, Intra-Meeting, and Post-Meeting Field Trips.

The 2016 Workshop will include a 4 days with keynote lectures, talks and posters in seven sessions spanning these topics: Earthquake Geology, Paleoseismology, Archeoseismology, Secondary Effects
of Earthquakes, Remote Sensing & Geomorphology, and Seismic Hazard Assessment. More than 50 scientific papers from 23 countries will be presented, as well as about 20 posters. And if you do not go to the Poster Sessions, you will not get any coffee.

In addition, 3 field trips are occurring before, during, and after the meeting. The Pre-and Post-Meeting Field Trips provide a convenient way for attendees to travel from Denver to Crestone and return, while learning about the neotectonic development of Colorado.

The meeting is organized by the Crestone Science Center (www.crestonescience.org) and GEO-HAZ Consulting, Inc. (www.geohaz.com) of Crestone. We appreciate the assistance of the INQUA Focus Group 'Earthquake Geology and Seismic Hazards' for their support for young scientists and students. We
also acknowledge for the support of The Colorado College (www.coloradocollege.edu).

On behalf of the Organizing Committee
James P. McCalpin

We gratefully acknowledge for the help and work of:

Organizing Committee:
James McCalpin (USA)
Rich Koehler (USA)
Kathy Haller (USA)
Ed Nissen (USA)
Alan Nelson (USA)
Christoph Gruetzner (UK))

Scientific Committee:
James McCalpin (USA),
Rich Koehler (USA)
Tony Crone (USA)
Ramon Arrowsmith (USA)
Eldon Gath (USA)
Christoph Gruetzner (UK)
Young-Seog Kim (KOR)
Rob Langridge (NZ)
Luca Guerreri (ITAL)
Yael Braun (ISR)
Beau Whitney (AUS)

Keynote Speakers:
Vince Matthews (USA)
Koji Okumura (JPN)
Ruben Tatevossian (RUS)
James McCalpin (USA)
Takashi Azuma (JPN)
Christoph Gruetzner (UK)
Victor Garduno-Monroy (MEX)

Invited Speakers:
Vince Matthews (USA)
Tom Rockwell (USA),
Takashi Azuma (JPN)

Program

Before the Conference (limited attendance)
The 1st PATA Road Trip; "Faults of the Wild West"
24-29 May 2016; led by James McCalpin

29 May (SUNDAY)
Arrival in Denver, Colorado and Icebreaker Party
Attendees arrive in Denver throughout the day
19:00 Icebreaker Party at the Sporting News Grill, in the Holiday Inn Airport hotel, Tower Road; this is SW and across the street from the Best Western Plus-DIA hotel

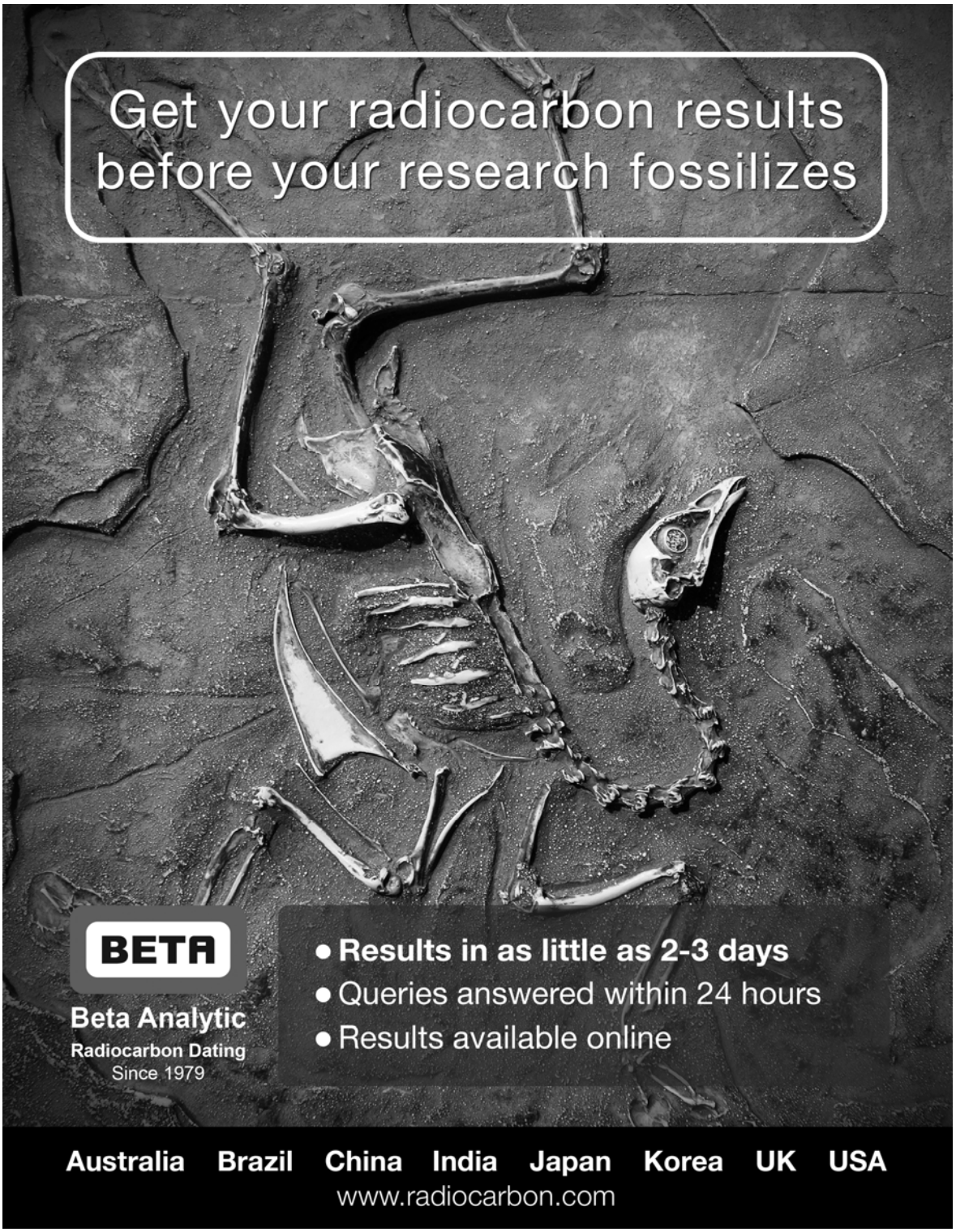
30 May (MONDAY, morning)
Pre-Meeting Field Trip (8 am-1 pm)
6:30 - 8:00 Breakfast; check out of hotel, transfer luggage to the bus
8:00- board bus at Best Western Plus-DIA hotel, 7020 Tower Road, Denver; depart Denver Airport hotels
8:00-13:00- field trip bus travels on highways I-70W, C-470, US 285, and CO 17 to Moffat, CO, then CR "T" to Crestone
13:00- arrive at the Desert Sage Restaurant

30 May (MONDAY, afternoon)
Opening Ceremony, Keynote Lectures, Poster Session 1, Dinner at Desert Sage
13:00-14:00 Lunch
14:00 - 15:00 Check -In
15:00 Opening ceremony:
- 15:00-15:10 - Organization of the workshop: James McCalpin
- 15:10-15:20 - INQUA TERPRO in the Inter-Congress Period 2015-2019; Advisory Board Member Takashi Azuma
- 15:20-15:30 - INQUA Focus Group 'Earthquake Geology and Seismic Hazards – EGSHaz';Christoph Gruetzner
- 15:30-15:40 -INQUA 'SURFACE' Project: Stephane Baize

15:40 – 16:50 Key notes, Poster Session 1, talks & wine

30 May Monday afternoon	Session 1: Keynotes	Chaired by: Robert Kirkham
(1) 15:40-16:00	Vincent MATTHEWS	Neogene Tectonism in Colorado
(2) 16:00-16:20	Koji OKUMURA	The Kumamoto, JAPAN earthquakes of April 2016
(3) 16:20-16:40	Ruben TATEVOSSIAN	Scarps associated with non-tectonic activity
(4) 16:40-17:00	James MCCALPIN	Paleoseismology of the Sangre de Cristo fault

17:00 – 17:30; set up Posters
17:30-20:00 Poster Session 1 (2.5 hours)
20:00 Dinner at the Desert Sage Restaurant; drinks afterward



31 May (TUESDAY) - Technical Talks, Keynote Lectures, Poster Sessions 2 and 3, Dinner at Old Crestone Schoolhouse

7:00 - 8:30 Breakfast
9:00 - 11:00 Key note lectures and talks

31 May Tuesday morning	Session 2: Paleoseismology-Strike Slip Faults	Chaired by: Young-Seog KIM
(5) 9:00-9:15	Sean BEMIS	The Elizabeth Lake paleoseismic site: Rupture pattern constraints for the past ~800 years for the Mojave section of the south-central San Andreas Fault
(6) 9:15-9:30	Kate SCHARER	Testing geomorphology-derived rupture histories against the paleoseismic record of the southern San Andreas Fault
(7) 9:30-9:45	Glenn BIASI	Does paleoseismology forecast the historic rates of large earthquakes on the San Andreas Fault system?
(8) 9:45-10:00	Tom ROCKWELL	Is the Southern San Andreas Fault Really Overdue For a Large Earthquake or Just Late in the Cycle?
(9) 10:00-10:20	Takashi AZUMA KEYNOTE	Paleoseismological surveys and studies of active faults in Japan

10:20-11:00 break (40 minutes)
11:00- 12:30 key note lectures, talks

31 May Tuesday morning	Session 2: Paleoseismology-Strike Slip Faults	Chaired by: Young-Seog KIM
(10) 11:00-11:15	Eldon GATH	Tectonic geomorphic and paleoseismic investigation of the Gatún fault in central PANAMA
(11) 11:15-11:30	Stephane BAIZE	Earthquake fault segmentation in the Central Andes, ECUADOR
(12) 11:30-11:45	Laurence AUDIN	Neotectonic activity in Ecuador and Peru, from geomorphic to geodetic data, focus around Andean megapoles
(13) 11:45-12:00	Sung-Il CHO	Geological evolution of Quaternary fault at Dangu-ri, Gyeong-ju area, SE Korea
(14) 12:00-12:15	Jinhyun LEE	Seismic activity in SE Korea based on a trench survey(Dangu fault) and historical earthquake data around the Yangsan fault

12:15- 13:00 Posters (45 minutes)
13:00 - 14:00 Lunch
14:00 - 15:00 poster session (1 hour)

31 May Tuesday afternoon	Session 3: Paleoseismology-Reverse Faults and Stable Continental	Chaired by: Tina NIEMI

	Interiors	
(15) 15:00-15:20 KEYNOTE	Christoph GRUETZNER	Paleoseismological challenges in Central Asia
(16) 15:20-15:35	*Paula FIGUEIREDO*	Late Pleistocene deformation at Aljezur fault system, SW Portugal: Seismicity triggering within a slow tectonic rate setting and relationships with sea-level rise (speaker- Tom Rockwell)
(17) 15:35-15:50	Colby SMITH	Holocene paleo-seismicity of the Bollnäs fault derived from terrestrial and hydroacoustical records
(18) 15:50--16:05	Gabriel VARGAS-EASTON	The San Ramon thrust fault at the eastern border of Santiago city, Chile: Paleoseismological implications from the linkage between piedmont units and fluvial terraces
(19) 16:05-16:20	Yukari MIYASHITA	Paleoseismic investigation of the Yunodake fault, Fukushima Prefecture, Japan
(20) 16:20-16:35	Reed BURGETTE	Late Quaternary Offset of Alluvial Fan Surfaces along the Central Sierra Madre Fault, Southern California

16:35 - 17:15 break (40 minutes)
17:15 - 18:30 talks

30 May Tuesday evening	Session 3: Paleoseismology-Reverse Faults and Stable Continental Interiors	Chaired by: Tina NIEMI
(21) 17:15-17:30	R. SUTINEN	Postglacial faults and paleolandslides in western Finnish Lapland
(22) 17:30-17:45	Sarah BOULTON	When did the Moroccan High Atlas Mountains get high? Constraints on neo- and active tectonics from fluvial geomorphology and palaealtimetry
(23) 17:45-18:00	C. Goswami INDIA	On Linkage between Present Geomorphology and Substrate Geology in a Tectonically Active Terrain along the North Eastern Himalayan Foothills
(24) 18:00-18:15	Javed MALIK	Surface rupture of a Great Himalayan 1905 Kangra earthquake (Mw7.8), NW Himalaya, India
(25) 18:15-18:30	Biju JOHN	Issues pertaining to active fault identification in cratonic regions: example from Peninsular India

18:30-20:00 free time and posters (1.5 hours)

20:00 evening dinner at the Old Crestone Schoolhouse , 240 North Cottonwood Street (NE corner of Cottonwood Street and Carbonate Avenue); (**but sorry, no alcohol**); after dinner, attendees can walk 2 blocks south to the Crestone Brewery, 187 West Silver Avenue)

1 June (WEDNESDAY) - Technical Talks, Intra-Meeting Field Trip, Dinner at McAlpine Ranch

7:00 - 8:30 Breakfast
9:00 - 11:00 talks

1 June Wednesday morning	Session 4: Paleoseismology-Normal Faults	Chaired by: Klaus REICHERTER
(26) 9:00-9:15	Martha GOMEZ	Paleoearthquake history and extension rates of the Waihi and Poutu faults in the Tongariro Volcanic Centre, New Zealand
(27) 9:15-9:30	Gabriel GONZALEZ	Quaternary deformation in the Atacama Fault System in northern Chile: new discoveries from trenching and OSL dating of colluvial wedges
(28) 9:30-9:45	Lorenzo LO SARDO	Paleoseismological techniques applied to different surface rupturing morpho-tectonic processes: case studies from tectonically active areas of the Abruzzi Region, central Apennines, Italy
(29) 9:45--10:00	Dean OSTENAA	Updates to the Seismic Hazard Characterization of the Cheraw Fault, Southeast Colorado
(30) 10:00-10:15	Rich KOEHLER	Reconnaissance geologic observations along the Petersen Mountain fault zone northwest of Reno, Nevada, U.S.A.
(31) 10:15-10:30	Stefano PUCCI	Structural complexity and Quaternary evolution of the 2009 L'Aquila earthquake causative fault system (Abruzzi Apennines, Italy): a three-dimensional image supported by deep ERT, ground TDEM and seismic noise surveys

10:30 - 11:15 break (45 minutes)
11:15-- 13:00 talks

1 June Wednesday morning	Session 5: Paleoseismology-Subduction Zones and Coasts	Chaired by: Yoshi KINUGASA
(32) 11:15-11:30	Sascha SCHNEIDERWIND	The Geometry of Tidal Notches – What do they reveal about historic coastal tectonics?
(33) 11:30-11:45	Jose GONZALEZ-ALFARO	Accelerated upper crustal uplift since MIS3 at the southern edge of the northern Chile megathrust seismic gap
(34) 11:45-12:00	Angelo VILLALOBOS	New evidences of the cortical origin of the seismic crisis of 2007 in the Aysén Region, Southern Chile
(35) 12:00-12:15	Beth ARCOS	Interaction of tsunamis with inland sediment sources: implications for interpreting deposits
(36) 12:15-12:30	Beau WHITNEY	Seismic source characterization in the Western Australia Shear Zone using 2D seismic data: the Dampier fault.
(37) 12:30-12:45	Daniel GARCES	Geomorphologic and Stratigraphic relationships as indicators of Quaternary climate change and Tsunami Hazard, central coast of Ecuador
(38) 12:45-	Daniel GARCES	Geological effects of the 16-April-2016 Pedernales

13:00		earthquake (M7.8), Ecuador

13:00 - 14:00 Lunch

14:00 - 18:30 Intra-Meeting Field Trip

20:00 Western BBQ dinner at the McAlpine Ranch, 600 East Galena Avenue, Crestone; (719) 256-5227; (719) 588-4279

2 June (THURSDAY) - Technical Talks, Student Training Sessions, Dinner at Desert Sage

7:00 - 8:30 Breakfast
9:00 - 11:00 Key note lectures and talks

2 June Thursday morning	Session 6: Seismites & Neotectonics	Chaired by: Tom VAN LOON
(39) 9:00-9:20 KEYNOTE	Victor GARDUNO-MONROY	Coseismical strartigraphy; A concept useful in the study of active tectonics in Mexico
(40) 9:20-9:35	Greg BROOKS	Paleoseismic assessment of multi-MTD event horizons preserved within the deposits of glacial Lake Ojibway, near Rouyn-Noranda, northwestern Quebec, Canada
(41) 9:35-9:50	Gosia PISARSKA-JAMROZY	Earthquake-induced versus periglacially-induced load structures in clastic sediments
(42) 9:50-10:05	Oxana LUNINA	Clastic dikes induced by strong earthquakes in southern Siberia and their paleoseismic significance
(43) 10:05-10:20	Petra JAMSEK RUPNIK	Fault characterization field campaign related to probabilistic seismic hazard assessment for nuclear infrastructure in the Krško Basin, Slovenia
(44) 10:20-10:35	Jakub STEMBERK	Valley evolution of the Biala Lądecka drainage network during late Cenozoic, Lower Silesia, Poland

10:35- 11:15 break [40 minutes]
11:15- 13:00 talks

2 June Thursday morning	Session 7: Seismic Hazard, Remote Sensing, Geophysics	Chaired by: Gerry STIREWALT
(45) 11:15-11:30	Edward CUSHING	Close to the lair of Odysseus Cyclops : the SINAPS@ postseismic campaign and accelerometric network installation on Kefalonia island – Site effect characterization experiment
(46) 11:30-11:45	Jure ATANCKOV	Database of active faults in Slovenia
(47) 11:45-	M. Logan CLINE	Tectonic geomorphology supporting a probabilistic seismic

12:00		hazard analysis in the Krško Basin, Slovenia: implications for critical infrastructure
(48) 12:00-12:15	Rob LANGRIDGE	Assembling lidar swaths along the distributed South Island plate boundary, NZ: The South Island 'b4' project
(49) 12:15-12:30	Thomas LEGE	Integrated InSAR Based Corpernicus Ground Motion Service for Germany - Paleoseismic aspects
(50) 12:30-12:45	Rob LANGRIDGE	Preview of 2017 PATA Days—New Zealand

13:00 - 14:00 Lunch
14:00 - 18:30 Student Training Sessions; ~1 hours in Baca Campus auditorium, remainder in field sites north of Crestone (bus trip)
14:00 - 18:30 Free time for attendees not at Training Session. Possible activities include:
0-INQUA Business Meeting
1-all afternoon bus trip to Great Sand Dunes National Park; play in Medano Creek, unique surging stream; hike the high dune (600 ft high); look at Holo fault scarps and range-front landslide formed by backsliding on a valleyward-dipping old thrust fault
2- in Crestone; 2-3 hour hike to the crest of terminal moraine complex of Willow Creek; drop down into old lake bed, now a meadow; lakebed was cored in 1979 with C14 dates on postglacial sequence of mud vs peat beds
3-in Crestone; Western horseback trail ride at the Baca Grande Stables
4-on-your-own nudist experience at Valley View Hot Springs
5-stop at Recreational Marijuana store in Moffat, 12 mi W of Crestone

20:00 dinner at the Desert Sage

Poster Sessions (Monday, May 30, 5:30-8:00 pm; Tuesday, May 31, 2:00-3:00 pm; 6:30-8:00 pm)

No.	Author	Title
1	Robyn DANIELS	Developing a paleoseismic age model for large-magnitude earthquakes on fault segments of the Himalayan Frontal Thrust in India
2	James DUNAHUE	Paleoliquefaction and possible surface deformation along New Madrid Seismic Zone in Yarbro, Arkansas
3	Francisco GOMEZ	Re-evaluation of late Quaternary deformation in the northern Wind River Basin, Wyoming
4	Chandreyee GOSWAMI	Manabhum Anticline: An apparent key to the genesis of the Eastern Himalayan Syntaxial Zone
5	Brian GRAY	Seamless Photomosaic Trench Logging Using Trench-Based Photogrammetry Methods: Workflow and Case-Studies
6	Christoph GRUETZNER	Large strike-slip faults in a convergent continental setting - the Dzhungarian Fault in the Northern Tien Shan
7	Keene KARLSSON	Paleoseismicity of the Laguna Salada fault, northern Baja California
8	Oksana LUNINA	Style of deformations in the Mondy active fault zone investigated with ground-penetrating radar and structural observations (southern

		East Siberia)
9	Genaro MARTINEZ	Investigation of uplifted marine and fluvial terraces in the Santa Rosalía basin of central Baja California, México
10	Alan NELSON	AMS 14C tests of correlations of great earthquakes along the Cascadia Subduction Zone, coastal Oregon
11	Christine REGALLA	Evidence for late Quaternary surface rupture along the Leech River fault near Victoria, British Columbia, Canada
12	Sascha SCHNEIDERWIND	Numerical modelling of tidal notch sequences on rocky coasts
13	Thomas SPIES	Establishment of an up-to-date database for seismic hazard assessment in Germany and Central Europe using paleoseismic, neotectonic and historical evidence
14	Petra STEPANCIKOVA	Applicability of complex geophysical surveying in paleoseismic studies: three case studies from Bohemian Massif
15	Jessica THOMAS	Towards an active fault assessment in the southern Upper Rhine Graben
16	Neta WECHSLER	On the accuracy of topographic models derived from UAV photography
17	Alana WILLIAMS	Shorter and variable recurrence intervals along the Cholame segment of the San Andreas Fault
18	Asmita MOHANTY	Tectonic geomorphology of Late Pleistocene-Holocene landscape evolution and drainage migration, NW Himalaya, India
19	Shao YANXIU	Fault slip behavior of North Danghe Nanshan Thrust (NDNT) from high resolution topography data and paleoearthquakes

3 June (FRIDAY) - Post-Meeting Field Trip (8 am-6 pm)

7:00 - 8:00 Breakfast; drop off room keys at Desert Sage Restaurant
8:00- board buses for field trip and depart Crestone
8:00-18:00- field trip travels north from Crestone to the Upper Arkansas Valley of the Rio Grande Rift; includes multiple (~10) field stops
18:00 to 19:00- bus arrives at Best Western Plus-DIA hotel, 7020 Tower Road, Denver; **END OF 7th PATA DAYS!!**

4 June (SATURDAY) – attendees return home

6:30 - 8:00? Breakfast; check out of hotels
Attendees take airport shuttle buses or taxis to Denver International Airport for departure home

ON THE FOLLOWING PAGES ARE THE 4-Page Extended Abstracts, ARRANGED ALPHABETICALLY BY LAST NAME OF THE AUTHOR

ARCOS, BETH
Interaction of tsunamis with inland sediment sources: implications for interpreting deposits

Maria E.M. Arcos, Amec Foster Wheeler, 180 Grand Avenue, Suite 1100, Oakland, CA 94612 USA

Tsunami deposits are increasingly being used to interpret various characteristics of tsunami wave flow including inundation and velocity. The simple model of tsunami deposition involves the erosion of sediment near the coast and then deposition from suspension as the water flows inland. Locations where tsunamis entrain new sediment a kilometer or more inland can aid in interpreting the development of the tsunami flow as it travels inland. Here we examine a modern record of the 2004 Indian Ocean tsunami in Thailand and paleotsunami deposits in the Puget lowland to the extent of influence of inland sediment sources on deposit thickness and grain size distribution. For the Thailand case, spoils from tin mining on Phra Thong Island were eroded and deposited landward, with sedimentary structures indicating a component of bedload transport. In the Puget Lowland case, deposits of a 1,000 year old tsunami thicken in several locations indicating the addition of new sediment, probably from sand blows. As expected, these deposits indicate the slowing of the tsunami flow as it extends inland. In the case of the Thailand deposit, where the grain size of the inland sediment source is known, the grainsize analysis can put upper and lower bounds on the flow speed. Tsunami deposits with inland sediment sources can help refine how tsunamis evolve as they flow inland.

ATANACKOV, JURE
Database of active faults in Slovenia

Jure Atanackov1, Petra Jamšek Rupnik1, Jernej Jež1, Blaž Milanič1, Bogomir Celarc1, Matevž Novak1, Anže Markelj1& Miloš Bavec1
1 Geological survey of Slovenia.Dimičevaulica 14.SI-1000 Ljubljana, Slovenia.jure.atanackov@geo-zs.si

Slovenia is characterized by moderate seismic activity caused by faulting at the contact of the Adriatic microplate and the European plate. Active faults form five zones: a) South Alpine thrust zone, b) Istria-Friuli thrust zone, c) Dinaric strike-slip fault zone, d) Periadriatic strike-slip fault zoneand e) Zagreb Mid-Hungarian shear zone. Also a number of damaging to devastating historical earthquakes have occurredin the area (M 6.8 Idrija 1511, M 6.4 Villach 1348, M 6.1 Ljubljana 1895, M 5.9 Villach 1690, M 5.7 Brežice 1917, M 5.7 Bovec 1998).

To provide an improved basis for assessment of earthquake hazard, active and potentially active faults have now been systematically mapped and seismotectonically parametrized into a single database. Surface trace definition and seismotectonic parametrization was based on the compilation and critical synthesis of available geologic, paleoseismic, geodynamic, geophysical, geodetic and seismological data. Active faults with surface traces longer than 5 km were included. The SHARE- Seismic Hazard Harmonization in Europe project database format was used, with each fault and its individual segments described with: fault name, type, strike, dip, rake, depth, length, width, area, segmentation type, slip rate and possible maximum earthquake magnitude(Basili et al., 2013). Quality designators were assigned to each parameter. In addition to providing a basis for future assessments of seismic hazard, the database also produced a number of potential paleoseismic trenching sites on a severalmajor active faults. The map and database contains 89 faults and 217 segments.

AUDIN, LAURENCE
NEOTECTONIC ACTIVITY IN ECUADOR AND PERU, from GEOMORPHIC to GEODETIC data, FOCUS AROUND ANDEAN MEGAPOLES

Audin Laurence– IRD, ISTERRE, Grenoble, France; Benavente Carlos– INGEMMET, Lima, Peru; Alvarado Alexandra– IG-EPN, Quito, Ecuador; Zerathe Swann– IRD, ISTERRE, Grenoble, France; Champenois Johann– CEA, Bruyères-le-Chatel, France; Baize Stéphane– IRSN, Fontenay-aux-Roses, France; Robert Xavier– IRD, ISTERRE, Grenoble, France

The Andean range stretches for thousands of kilometers from Patagonia to Venezuela and its recent tectonic evolution results from the ongoing subduction of the Nazca plate. Since the Pre Incaic period, several major earthquakes did affect the Andean human settlements. Although neglected in terms of archaeoseismic or neotectonic studies, these regions display exponentially growing megacities, highly exposed to seismic hazards. As a result, shallow crustal earthquakes that occur in the vicinity of megacities today will kill many more than they did in the past. In this study, we thus focus on investigating crustal deformation along newly described fault systems, seismically active in urban setting (in Peru and Ecuador). High resolution satellite images, geodetic data, georadar and field studies provide striking examples and evidences of the ongoing tectonic deformation that can be cross-correlated with the longer-term Quaternary geomorphic record. We focus on Quito and Ibarra regions in northern Ecuador, and on Arequipa and Cuzco regions in southern Peru. The proximity of active tectonic structures to the densely populated regions reveals the crucial need for additional tectonic studies to generate further hazard assessments. In northern Ecuador, the Quito Fault extends over 60 km along the Interandean Depression. GPS and PSInsar data indicate active shortening rates for Quito blind thrust up to 4 mm/yr. In the same region, the fault that produced the Ibarra historic earthquake source remains unknown (M~7), while it fully destroyed Ibarra and caused up to 70,000 casualties around Quito. A newly mapped fault trace highlights the probable source of the 1868 'lost' seismic event. Similarly in southern Peru, several crustal active faults extend between the forearc and the upper Altiplano in southern Peru. As an example, new direct 10Be dating of the Purgatorio fault scarp suggest at least 2 Mw7eventsin the last 1kyr, and ~2mm/yrof mean vertical slip rate on this transpressive fault.

AZUMA, TAKASHI
Paleoseismological surveys and studies of active faults in Japan
Takashi AZUMA (GSJ/AIST), Site Central 7, 1-1-1, Higashi, Tsukuba, Ibaraki, Japan, 3058567

After 1995 Kobe Earthquake, Japanese government founded "Headquarters for Earthquake Research Promotion" and conducted paleoseismological survey of major active faults in Japan as well as other seismological observations. As a result, they published reports on the long-term evaluation of active faults and the probabilistic seismic hazard map of Japan based on huge data of active faults, subsurface structures and seismological data. But still we have some problems for active fault studies, such as smaller earthquakes on active faults and its effect to the characteristic events, and lager earthquakes caused by multi-segment ruptures. I will review the active fault surveys and studies in Japan through the earthquakes we experienced for 20 years.

BAIZE, STEPHANE
Earthquake fault segmentation in the central Andes, Ecuador

S. BAIZE - IRSN, Fontenay-aux-Roses, France; L. AUDIN - IRD, Campus ISTERRE, Grenoble, France; A. ALVARADO - IG-EPN, Quito, Ecuador; H. JOMARD - IRSN, Fontenay-aux-Roses, France; J. CHAMPENOIS - CEA, Bruyères-le-Chatel, France

Relative motion between the North Andean Sliver and the South American Plate is accommodated along a large fault zone at 8 mm/yr rate. The Pallatanga Fault (PF), that crosses the entire Western Cordillera, is suspected to have hosted large historical (1797, 1911) and prehistorical earthquakes. Its surface trace is quite well known over 65 km, from Juan de Velasco (SW) to the Cajabamba area (NE) where 3 trenches were excavated. North of this, towards the Cosanga Fault (CF) in the Cordillera Real, the fault map was much less constrained and a morphological continuation was however assumed.

Our recent efforts focused on documenting the active fault map in this transition area between PF and CF. We aim both at characterizing the fault long-term activity, which are potential sources of future earthquakes, and at evidencing recent historical surface ruptures. These two topics are a relevant first step in order to constraint the rupture segmentation during large past events and to contribute to a better assessment of seismic hazard. Further investigations will have to grab information in future paleoseismic trenches.

During the last two field campaigns, we characterized many fault strands that continue the PF north of Cajabamba, then defining a large fault capable to trigger large events. This is confirmed by the presence of historical scarps with well-preserved free faces (1797 M7.6 Riobamba event) disrupting the Igualata volcano (IV). However, we could not yet evidence any structural continuity between the PF (IV) and the CF (mapped in the Huisla volcano, HV) to the NE, then defining a 5-10 km left-stepping step-over which seems to have blocked the 1797 rupture. Finally, a surface rupture has been recently discovered during the M5 Pisayambo event along the Cosanga segment, with uncommon surface rupture length and displacement. From the few unearthed evidences, we estimate at a first glance that the mean slip rate along the Pallatanga and Cosanga segments is similar and in the 1-1.5 mm/yr range.

BEMIS, SEAN
The Elizabeth Lake paleoseismic site: Rupture pattern constraints for the past ~800 years for the Mojave section of the south-central San Andreas Fault

Bemis, Sean P., Dept. of Earth & Environmental Sciences, University of Kentucky, Lexington, KY 40506; Scharer, Kate, U.S. Geological Survey; Dolan, James, University of Southern California; Rhodes, Ed, University of California Los Angeles and University of Sheffield

The extent and variability of latest Holocene paleo-ruptures along the south-central San Andreas Fault has been the focus of numerous paleoseismologic studies which have resulted in both key constraints on the patterns of prehistoric earthquakes and highlighted where critical 'gaps' in data remain. We developed the Elizabeth Lake paleoseismic site in the center of the Mojave section of the south-central San Andreas Fault, near the middle of the 100 km span between the Frazier Mountain and Pallett Creek sites, to fill a gap in the understanding of paleoearthquake extent along the SAF. We completed three field campaigns at the site, documenting 10 trenches that span portions of an elongate (~40x350 m) geomorphic depression formed by a bedrock-cored shutter ridge on the NW (downhill) side. Radiocarbon dates establish that the excavations expose >2000 years of stratigraphy deformed by a relatively narrow fault zone. The best stratigraphic resolution occurs within the past ~800 years where we have documented evidence for 4-5 earthquakes. We have good evidence for the 1857 event and another earthquake after the mid 1700s. We have strong evidence for two more events during the preceding 500 years. The stratigraphic position (relative age) of a possible fifth paleoearthquake is unclear due to lateral slip and fault overprinting; this event will be dated using luminescence (pIR IRSL). Comparison to adjacent paleoseismic records permits only one ~300-km-long, 1857-like rupture during the past 800 years. Our ongoing efforts focus on improving age control within the upper stratigraphic section (<1250 cal AD) and finalizing our catalog of evidence for each event. Radiocarbon age control illustrates a significant detrital component to charcoal ages, with up to 500 year variability for samples from the same layer. New pIR IRSL ages from key stratigraphic horizons improve our age constraints on the timing of the latest Holocene paleoearthquakes.

BIASI, GLENN
Does paleoseismology forecast the historic rates of large earthquakes on the San Andreas Fault system?

BIASI, G., University of Nevada, Reno, NV, glenn@seismo.unr.edu; SCHARER, K.M., US Geological Survey, Pasadena, CA, kscharer@usgs.gov; WELDON, R. J., University of Oregon, Eugene, OR, ray@uoregon.edu;
DAWSON, T.E., California Geological Survey, Menlo Park, CA, Timothy.Dawson@conservation.ca.gov.

We use the UCERF3 paleoseismic database (Weldon et al., 2013) to test the hypothesis that the historic rate of significant ground-rupturing earthquakes (SGRE) on the San Andreas Fault system is inconsistent with the paleoseismic rate. Specifically, we investigate a set of 12 well-studied paleoseismic sites on the San Andreas, San Jacinto, Hayward, Elsinore,Garlock, Green Valley, Rodgers Creek, Calaveras, Compton, Puente Hills and Little Salmon faults (Jackson et al., 2015) and find that the rate of SGRE in the 700 years before the start of the historic period (1770 AD) is identical to the rate of 0.04 SGRE/ year during the historic period on these faults (30/700 and 8/200, respectively). The lack of SGRE since 1906

is in marked contrast to the eight SGRE that occurred between 1812 and 1906 and leads to the impression that the past 100 years of quiescence is somehow unique. Rather, in the prehistoric period we identify four 100-yr intervals (centered on 1160, 1400, 1600, and 1760) that have only zero or one SGRE and two 100-yr intervals (centered on 1320 and 1510) that have more than seven SGRE. From thisdataset, we conclude that a 100-yr interval with either zero or as many as eight earthquakes isnot particularly unlikely. Given dating uncertainties, the ~1000 year record is too short to determine if there is any pattern in the rate of SGRE for this set of fault sections (much less the entire system), but it leaves little doubt that the number of SGRE in 100 years in a highly active system like the San Andreas varies by almost an order of magnitude. Given these variations and the brevity of the historic period, paleoseismic data remain the only way to quantify the average rate and variability of major earthquakes.

BOULTON, SARAH
When did the Moroccan High Atlas Mountains get high? Constraints on neo- and active tectonics from fluvial geomorphology and palaeoaltimetry

Sarah J. Boulton1, Martin Stokes1, Justin H. VanDeVelde1, Anne E. Mather1
(1) School of Geography, Earth and Environmental Sciences, Plymouth University, Plymouth, U.K.
sarah.boulton@plymouth.ac.uk

The surface uplift of mountain belts can have profound effects on precipitation patterns and moisture distribution, potentially resulting in the development of orographic rain shadows and aridification. Within Africa, the Moroccan High Atlas Mountains are the highest (2-4km elevation) topographic relief formed by Alpine tectonics. However, the uplift history of the Moroccan High Atlas has been a matter of debate for many years. New palaeoaltimetry data from Late Miocene lacustrine limestones that suggest that the High Atlas had a mean altitude of 1200 ± 500 m through the Middle-Late Miocene. While geomorphic data (river long profiles and river terrace data) support models that propose ~1000 m of elevation have been gained during the Plio-Quaternary. These new data provide independent constraints on the timing and magnitude of orogenic development in the High Atlas that is driven by mantle upwelling and fault reactivation.

BROOKS, GREG
Paleoseismic assessment of multi-mass transport deposit signatures preserved within the deposits of glacial Lake Ojibway, northwestern Quebec, Canada

Gregory R. Brooks, Geological Survey of Canada, Natural Resources Canada, 601 Booth Street, Ottawa, Ontario, Canada, K1A0E8; greg.brooks@canada.ca

High-density sub-bottom profiles were surveyed within a study area at Lac Dasserat, near Rouyn-Noranda, northwestern Quebec. Mapping of the upper portion of the sub-bottom sediments identified eight event horizons interpreted to comprise of 74 separate mass transport deposits (MTDs). Five of the event horizons (H-D) are intercalated within glaciolacustrine deposits of glacial LakeOjibway, the other three (C-A) are at the interface of the glaciolacustrine-lacustrine deposits. Event horizons H, G and E exhibit multi-event MTD signatures, containing 11, 13 and 21 MTDs, respectively. Rhythmites inferred to be annual varve deposits overlying the event horizons were recovered at six coring sites using a Livingstone corer. The varves were correlated to the regional Timiskaming varve series, allowing varve ages of 1267, 1324 and 1483 to be interpreted for horizons H, G and E, respectively (the varve ages are with respect to the ~2100 varve-yr-long regional Timiskaming varve series). Within the deep water, glacial lake environmental setting that was present at the study area when horizons H, G and E aggraded, the grounding of icebergs, wave actions, draw-down events, and the oversteepening-overloading of slopes were assessed as possible aseismic mechanisms. None are considered likely mechanisms that account for the multi-MTD signatures. Comparison of the varve ages of the three horizons to published logs of glacial Lake Ojibway varve deposits revealed that “disturbed” deposits with minimum varve ages of 1483 to1489, 1323 and 1325, and 1263 are present at nine, two and one sites,

respectively, located 20 to 85 km from LacDasserat. Horizons E, G and H are each interpreted to be the product of a paleoearthquake with high, medium, and medium levels of probable occurrence, respectively, based on the relative strength of the multi-MTD signatures, the regional occurrence of similarly-aged disturbed deposits, and the lack of alternative aseismic interpretations.

BURGETTE, REED
Late Quaternary Offset of Alluvial Fan Surfaces along the Central Sierra Madre Fault, Southern California

Burgette, R. (1), Hanson, A. (1), Scharer, K. (2), and Midttun, N. (2)
(1) Dept. of Geological Sciences, New Mexico State University, PO Box 30001, MSC 3AB, Las Cruces, NM 88003; (2) U.S. Geological Survey Pasadena Field Office, 525 South Wilson Ave., Pasadena, CA 91106

The Sierra Madre fault (SMF) is an east-west trending reverse fault system along the southern flank of the San Gabriel Mountains near Los Angeles, California. The ~140 km long SMF is separated into four segments, we focus on the multi-stranded, ~60 km long Central Sierra Madre fault (CSMF; W118.3-W117.7) as it lacks a well-characterized long-term geologic slip rate. We combine 1-m lidar DEM with geologic and geomorphic mapping to correlate alluvial fan surfaces along strike and across the fault strands in order to derive fault slip rates that cross the CSMF. We have refined mapping on two sets of terraces described by Crook et al. (1987) and references therein: a flight of Q3 surfaces in Arroyo Seco with distinct terraces ~30 m, ~40 m, ~50 m, and ~55 m above the modern stream, and Q3 and Q2 surfaces in Pickens Canyon with heights ~35 m and ~25 m above the modern stream, respectively. Relative degrees of clast weathering and soil development are consistent with geomorphic relationships. A scarp in the Q3 surface at Arroyo Seco has a vertical offset of ~16 m and a scarp in the Q3 at Pickens Canyon has a vertical offset of ~14 m, while the Q2 surface is not faulted. Our Quaternary dating strategy is focused on dating suites of terraces offset along CSMF scarps in order to provide broader stratigraphic context for the cosmogenic radionuclide and luminescence dating. We will present cosmogenic radionuclide depth profiles from the Q3 surfaces. A better-constrained slip rate for the CSMF will improve earthquake hazard assessment for the Los Angeles area and help clarify the tectonic role of the SMF in the broader plate boundary system. Additionally, the fan chronology will provide information about the timing of alluvial fan aggradation and incision in the western Transverse Ranges.

CHO, SUNG-IL
Geological evolution of Quaternary faultatDangu-ri, Gyeong-ju area, SE Korea

Sung-il Cho1, Weon-hack Choi1, Daiei Inoue2, Young-Seog Kim3; (1) Central Research Institute, Korea Hydro & Nuclear Power Co., Ltd., Daejeon 305-343, Korea; (2) Department of Oversea, Tokyo Electric Power Services Co., Ltd., Tokyo 135-0062, Japan; (3) Department of Earth & Environmental Sciences, Pukyong National University, Busan 608-737, Korea

Rezaei, S. et al. (2015) and Lee, J-H.et al. (2015) reported the latest and penultimate activity of Quaternary fault at Dangu-ri around the northern part of the Yangsan fault, SE Korea. We evaluated the age of the latest activity and the return period by adding age data in the overburden layers at the same site.

The Dangu-ri area is located in the alluvial plain, which is developed at the western side of the main river running from the east to the west. Geological distribution of Quaternary deposits near the trench area is mainly controlled by the river flow direction. They mainly consisted of river bed sediments such as silt, sand and several sizes of gravels. There are some large sizes of angular cobbles and pebbles provided during instantaneous floods. The Quaternary sediments at the trench site are classified into eight layers from the lowest such as 6, 1, 2, 3, 4, 4', 5, 7 based on their texture and composition. The layers from 1 to 5 are distributed in the westernblock of the fault; the layer 6 and 4' are distributed in the easternblock of fault. The layer 7 is distributed all over this trench site as flood loam. The age of the layers1 ~ 4 is assumed to be 25 ~ 35 ka B.P., the age of layer is 4,809±30, 3,990±40 and 2,145±40, and the layer 7 is 1,132±24, 1,000±40 and 247±31y B.P. by means of14C dating. The dating materials in the

layer 7 were charcoal, so probably they were not deposited at the real place, but flowed during flood. Therefore the layer 7 may be very young sediment.

We can identify three events from this trench site. The latest event is the F1 fault, this fault cut the layer 4' and covered by the layer 7. This event occurred between 15th century and 2,145y B.P. The penultimate fault event in recognized based on F2 fault trace. The F2 fault is several centimeters away to the west from the F1 fault. The F2 fault cut the layers 1 ~ 4 and terminated in the layer 4. The timing of this fault may be later than 24,440±110y B.P.. The older penultimate event is estimated by the deformation of the layers 1 and 2. Therefore, the timing of fault event may be later than 25,480±110 y B.P. The return period of the Quaternary fault at the Dangu-ri may be 10 ~ 15 ka B.P., considering from the three events.

CHUNGA, KERVIN

Geomorphologic and Stratigraphic relationships as indicators of Quaternary climate change and Tsunami Hazard, central coast of Ecuador (presented by DANIEL GRACES)

Kervin CHUNGA 1, Maurizio MULAS 1, Ma. Fernanda QUIÑONEZ 2, Daniel GARCES 1
1-Escuela Superior PolitécnicadelLitoral, FICT, Guayaquil, Ecuador. kchunga@espol.edu.ec
2-Secretaría de Gestión de Riesgos, Dirección de Análisis de Riesgos, Guayaquil, Ecuador.

Geomorphic, stratigraphic and radiometric dating techniques applied to Quaternary sedimentary sequences located on the Jaramijo site (Ecuador's central coast, South America), have allowed the recognition of Pleistocene upper to the Holocene marine terraces, from bottom to the top, T1 at an altitude of 20 meters (1.190 ± 30 BP to 1.030 ± 30 BP), T2 terrace at an altitude between 30 meters (43.245 ± 460 B.P.) and T3 at an altitude between 43 to 57 m.s.n.m. (120.000 years). It's important to note that this last terrace is considered by Pedoja et al. (2006) [1], and that our research has outlined two new terraces (referred to T1 and T2) which mostly are covered by volcanic-ash and lahar deposits. This paleogeographic reconstruction is associated with the continental margin active tectonic and glacial and interglacial stages, referred to in literature as MIS1 to MIS 3 (Marine Isotope Stages). T2 terrace is referred to the EJ-02 sample, where the EJ-02E lithologic unit composed of medium sand with plentiful bivalve molluscs indicate a sublittoral zone, where sediments probably were deposited in a water column from 0 to 30 meters deep, the radiocarbon age of this unit is cal. BC 41.295 to 40.140 years (cal. BP 43.245 to 42.090 years); δ 18O analyses and -1 to -1.5 o/oo values can be associated with a short interstadial stage within the glacial period MIS 3, associated to a rapid sea level rise reached - 10 to -20 m bellow of current level.

Geological sampling stations of EJ-01 and EJ-03 were obtained at T1 terrace, where the main geomorphologic features are a wave-cut beach platform permanently exposed at the lowest tides and an 18 m-high coastal cliff retreat with a rate estimated at ca. 1.5 to 2.5 meters/year [2]. This terrace is composed by Late Holocene sequences of sand and clay sediments intercalated with loose to weakly consolidated volcanic-ash layers. One of the most remarkable geoarchaeological findings in this outcrop (EJ-01E sample) is the identification of human bones of the Manteña culture integration period, within a 8 to 25 cm-thick volcanic ash layer [3] (radiocarbon dating of 1.190 ± 30 B.P.). The EJ-01D unit is one of the most important sedimentary levels that provide tsunami hazard information, this layer is an erosive contact with chaotic deposition of medium to fine-grained sand and presence of Melonissphaerodis foraminifera of bathyal environment, that indicates a possible tsunami deposit with run-up height of ca. 6.3 meters above sea level (estimated age of ca. 1.200 ± 30 B.P.).

All of these stratigraphic and palaeoseismologic features will allow us to understand the catastrophic geological events that abruptly shaped the landscape (such as subduction earthquakes, local tsunami, and volcanic lahar-ash landslides), at that, the tectonic uplift rate established for the Jaramijo site, of ca. 0.5 to 0.98 mm/year, have allow to preserve well distinguished marine terraces outcropping in central coast of Ecuador.

CLINE, M. LOGAN
Tectonic geomorphology and geochronology supporting a probabilistic seismic hazard analysis in the Krško Basin, Slovenia: implications for a critical infrastructure

Cline, M. Logan (1), K. Michael Cline, (1), Petra Jamšek Rupnik, (2), Jure Atanackov(2), Miloš Bavec(2), Sally Lowick(3)
(1) Rizzo Associates. 500 Penn Center Boulevard, Pittsburgh, PA 15214, USA
mlogan.cline@rizzoassoc.com
(2) Geological Survey of Slovenia. Dimičeva ulica 14. SI-1000 Ljubljana, Slovenia.
(3) Institute of Geological Sciences, Universität Bern. Baltzerstrasse 1+3 CH-3012 Bern, Switzerland

Krško Basin in southeastern Slovenia is being investigated as a potential site for a new nuclear power plant. The basin is in a region of low to moderate tectonic activity. The post-Miocene Krško Syncline defines the basin's axis, which has been driven by generally N-S convergence of the Adriatic Microplate and the European Plate. Three major obstacles have precluded accurate assessments of fault deformation rates in the region: 1) the sparse chronometric data; 2) The geochronology that exists is biased toward the latest Pleistocene and Holocene due to the inherent limitations of methods applied in the past; and 3) the lack of outcrop or near-surface evidence of deformed Quaternary sediments due to relatively low strain rates. To overcome these impediments we are utilizing methods in tectonic geomorphic analysis of LIDAR data and multiple age dating methods to develop a robust geochronology that targets the Neogene-Quaternary.

CUSHING, EDWARD MARC
Close to the lair of Odysseus Cyclops : The SINAPS@ postseismic campaign and accelerometric network installation on Kefalonia island – Site effect characterization experiment.

Edward Marc Cushing*, FabriceHollender**, Cedric Guyonet-Benaize**, Vincent Perron*,**, AfifaImtiaz***, AngkearaSvay****, Armand Mariscal**, Pierre-Yves Bard*****, Régis Cottereau****, Fernando Lopez Caballero****,NikolaosTheodoulidis******, Denis Moiriat*, Céline Gélis*; *IRSN, Fontenay-aux-Roses, France; ** CEA Cadarache, St Paul-lez-Durance, France; *** BRGM, Orléans France; **** MSSMat, CNRS, CentraleSupélec, Université Paris-Saclay, 92290 Châtenay-Malabry, France; *****Univ. Grenoble Alpes, ISTerre / IFSTTAR, Grenoble, France; ******ITSAK, Thessalonique, Grèce

Northwestern Greece is one of the main active tectonics area of the Mediterranean region and has the highest seismic activity in Europe. Located at the boundary of the Eurasian/African plates, the convergence rate is up to few centimeters per year. In the Kephalonia area, this limit is constituted by the northwestern end of the Aeagean subduction frontal thrust linked to the dextral Kephalonia Transform Fault (CTF west of Kephalonia). This major fault plays the role of a transition zone between the African subducting plate and the continental Apulian plate. Since the mean slip rate and the CTF length are large, seismic hazard is high in terms of frequency and magnitude. This was the cause of the major 1953, Mw 7.2 earthquake and provoked about 0,5 to 1 meter uplift of a great part of the Kephalonia island. Previously, two events occurred in 1915 (Mw ~ 6.6 & 6.7) in Kephalonia island. This major structure is associated with secondary ones which are the source of more recent, lower but significant earthquakes (e.g. Mw 6.2 Levkas, 2003, Lixourion doublet - Mw 6.0 and 6.1, 2014, Mw ~6.4 Levkas, 2015). The Plio-Quaternary Koutavos basin is located in the Argostoli area and characterized by sub-cylindrical structure of west verging thrust and folds with a strongly deformed and asymmetric anticline on its western part. The Koutavos-Argostoli site was selected within the French Research Agency (ANR) PIA SINAPS@ project (www.institut-seism.fr/projets/sinaps/) to host a vertical accelerometric array. We will present the site and its geodynamical, geological and seismological backgrounds, the borehole instrumentation and the associated geotechnical informations, the first results of the post-seismic campaign organized following the seismic sequence of January-February 2014 including two M6 + shocks and numerous aftershocks and recent accelerometric records performed during the last Levkas Earthquake. The long term goal is to validate 3D nonlinear numerical simulation codes in order to assess site specific amplifications and non-linearities in the framework of seismic hazard assessment for nuclear installations.

DANIELS, ROBYN
Developing a paleoseismic age model forlarge-magnitude earthquakes on fault segments of the Himalayan Frontal Thrust in India

R.L. Daniels1, R. Jayangondaperumal2, T.M. Niemi1; 1-University of Missouri – Kansas City, 5110 Rockhill Rd, Flarsheim Hall 420, Kansas City, MO, 64110; 2-Wadia Institute of Himalayan Geology, #33 GMS Road, Dehradun 248001, India.

Crustal collision at the boundary between Eurasia and the Indian subcontinent has produced a system of transverse, thrust faults which accommodate a share of the strain associated with convergence and the concomitant uplift of the Himalayan mountain range. The foremost of these faults is the Himalayan Frontal Thrust (HFT), which impels depositional units of an earlier foreland basin over those of the Indo-Gangetic Plain. Throughout the last two centuries, the HFT has produced numerous, large-magnitude earthquakes along discrete segments of the fault, which are well-constrained through instrumental and historical records. Paleoseismic studies conducted along the HFT have aimed to establish comparable spatial and temporal constraints for the penultimate ruptures of the fault. Of particular interest is the segment of the fault which lies between the areas affected by the 1905 A.D. and 1934 A.D. earthquakes, due to an apparent long-term quiescence that suggests the potential for impending large-scale rupture. Establishing the timing of earthquakes along this segment of the HFT, known as the Central Seismic Gap (CSG), is critical in assessing seismic risks for areas proximal to the fault with large populations and inadequate infrastructures. While several paleoseismic trenching studies have been conducted along the CSG, a comprehensive age model incorporating the results of this research has yet to be developed. Accordingly, the object of this study is to provide improved temporal constraint for large-magnitude ruptures along the CSG by compiling recent, paleoseismic findings into a coherent age model using the OxCal software program. The model presented in this study includes radiocarbon age data from seven published trench sites, and our results indicate two events along the CSG corresponding to historical accounts of earthquakes in 1344 A.D. and 1430 A.D. Limitations and uncertainties of the model originating from the published field data on which it is based are also discussed.

DUNAHUE, JAMES
Paleoliquefaction and possible surface deformation along New Madrid Seismic Zone in Yarbro, Arkansas

1Dunahue, J. C.; 1Niemi, Tina M.; 2Tuttle, M. P.; 3Haynes, M.; 4Anderson, N. L., and 4Torgashov, E. V.; 1-Department of Geosciences, University of Missouri – Kansas City, Kansas City, MO 64110. 2-M. Tuttle & Associates, Georgetown, ME 04548. 3-Department of Geological Sciences & Engineering, Missouri University of Science and Technology, Rolla, MO 65409.

From interpretation of historical aerial photography and LiDAR imagery of northeast Arkansas, we identified a northeast-striking topographic lineament coincident with the trend of modern seismicity along the New Madrid Seismic Zone. The linear ridge extends at least 7.0 km across the landscape, is approximately 1 – 2 m higher than the topography to the east and west, and has en echelon trending segments. The anomalous topography appears to crosscut scroll bars, meander loops, and other geomorphic features along this portion of the Mississippi floodplain. This study sought to determine whether the lineament was of depositional, co-seismic, or tectonic origin. We collected geophysical data including electrical resistivity (ERT), ground-penetrating radar, magnetics, and seismic refraction across the ridge at three locations in order to image the subsurface structure of the ridge. ERT data show an abrupt discontinuity between higher and lower resistivity at depth beneath the western margin of the ridge suggesting a possible fault. Paleoseismic trenches excavated across the western side of the ridge revealed both a large, linear graben and a large linear sand blow with multiple depositional units. The graben is 6.5 m wide and 1.0 m deep, and is filled with an organic-rich clay plug with many fractures along which sand dikes have intruded and root casts have formed. The large linear compound sand blow overlies a buried soil and is connected to a 1.8-m-wide feeder dike as well as several smaller subsidiary dikes. These data suggest that the linear graben, subparallel sand blow and related dikes along the western flank of the ridge may be either evidence for lateral spreading related to earthquake – induced

liquefaction or for an active fault. It is possible that the graben and the sand blow may both reveal and mask the presence of an active fault.

FIGUEIREDO, PAULA

Late Pleistocene deformation at Aljezur fault system, SW Portugal: Seismicity triggering within a slow tectonic rate setting and relationships with sea-level rise (presented by TOM ROCKWELL)

Paula M. Figueiredo 1, 2 Thomas K. Rockwell 3, João Cabral 1; 1-Instituto Dom Luiz, Lisbon University, Portugal; 2-Now at Quaternary and Anthropocene Research Group, University of Cincinnati, USA; 3-San Diego State University, USA

The southwest of Portugal is simultaneously the southwestern section of Iberia as well as the southwestern corner of Europe. Located along the Gulf of Cadiz and the West Iberian continental margin, the plate boundary of Eurasia – Nubia converges obliquely with a NW-SE direction at an average rate of 4-6 mm/yr. Inland, several active structures with slow tectonic rates (< 0.5 mm /yr) accommodate the ongoing deformation.

The Aljezur-São Teotónio – Sinceira Fault system (STASFS) is a 50 km long left-lateral strike-slip fault system, trending NNE-SSW, approximately parallel to the SW Portuguese coastline and located about 5 km from it. Detailed morphotectonic studies, field surveys and fault trenching along STASFS yield evidence for the en-echelon geometry of this fault system and allowed the identification of three active segments. A Quaternary horizontal slip rate of 0.16 mm/y has been estimated based upon the interpretation of displaced geomorphic features. Based upon fault length and other characteristics, the presence of distinct segments, and assumptions about failure scenarios, we estimate a maximum expectable earthquake on this fault system to be in the range of Mw 6.0 to 7.1, with average displacements per event smaller than 1 m, and average recurrence intervals ranging from 8 to 18 ka.

Several paleoseismological trenches exposed evidence for Pleistocene seismic activity, however Holocene surface ruptures have not been recognized. Recent trenching of the Alfambras segment revealed deformation within weathered alluvial fan sediments, covered by a younger alluvial fan sediments sequence. Carbon 14 dating of detrital charcoal recovered from the base of this younger sequence yielded uncorrected ages of 13930 ± 610 yr and 13320 ± 180yr, supporting the absence of Holocene surface ruptures for this strand of the fault system.

Recent studies, demonstrated that STASFS fault segments may have been subjected to an increase in Coulomb stress during periods of sea level rise. We suggest that Late Pleistocene seismicity along STASFS might be related to periods of rapid sea-level rise, such as the one that occurred immediately after the Last Glacial Maximum, thereby releasing accumulated strain and allowing for ~15 ka of inactivity.

GARDUÑO-MONROY, VICTOR

Coseismical stratigraphy: A concept useful in the study of active tectonics in Mexico

Garduo-Monroy V.H1., Soria-Caballero D2and Vázquez-Bucio M.M3; 1-INICIT-UMSNH-MGPT-vhgardunom@gmail.com; 2-Postgraduate in Earth Sciences-UNAM; 3-Postgraduate of the CIGA-UNAM

Currently, the record of evidences of shallow deformations associated to earthquakes in diverse global sectors has experienced a remarkable advance. However, most of the works in scientific meetings focused on studies of shallow coseismical ruptures which can be associated to known seismic movements in space and time.

However, paleoseismic studies in active volcanic areas, such as the central part of the Trans-Mexican Volcanic Belt become more complex. This is due to the fact that in the region occur several fault systems and volcanism with historical activity that have been more or less documented hindering the study of particular coseismic ruptures. In central Mexico there isa series of paleobasins and lake basins whose origin and evolution have been influenced directly or indirectly by the regional tectonic activity. The age, permanence and continuous record of the sediment properties have become a major element of paleo-environmental and anthropological studies. These studies have been effective to record >5 magnitude earthquakes by analyzing syn-sedimentary faults, secondary effects (e.g. liquefaction,

underwater landslides, landslides of slopes, etc.) (McCalpin, 2009), and changes in the geometry of the basin and/or the sedimentary sequence. On the basis of a review of previous works performed in these Central Mexico basins, detailed stratigraphy, and pioneer paleoseismology studies we propose a new concept for the study of lacustrine sequences influenced by active tectonics. These studies have helped us to discern the causes of the variations in the sedimentary record (climatic effects, anthropogenic or seismic), to improve the paleoenvironmental interpretations and to strengthen paleoseismic studies made with traditional methodologies. Therefore, we proposed the term of "coseismic stratigraphy" to be regarded as a branch of the stratigraphy a science that could defined the directions of the study of lacustrine sequences, marine or fluvial environments where primary and secondary effects of an earthquake have modified the original facies (e.g. erosion rates and sedimentation) and in some cases, even the geometry of the lacustrine basin center.

GATH, ELDON
Tectonic geomorphic and paleoseismic investigation of the Gatún fault in central Panamá

Gath, Eldon (1), Tania Gonzalez (1), Thomas Rockwell (1), and Pastora Franceschi (2)
(1) Earth Consultants International, 1642 E. 4th St., Santa Ana, CA 92701, USA; gath@earthconsultants.com; (2) Autoridad del Canal de Panama, Department of GeotechnicalEngineering, Bldg 721, Corozal, Panamá

The Gatún fault, a primary east-west structural feature in central Panama, has a strong geomorphic signature that can be readily observed in aerial photographs and digital elevation models. The fault forms an abrupt southern margin to the Sierra Maestra Mountains, and all rivers and streams that cross the fault are affected at the fault crossing. Most large rivers are left-laterally deflected, and all streams that cross the fault have a 1- to 2-meter, and locally as high as 5-meter near-vertical nickpoint at or immediately upstream of the fault. Paleoseismic trenching of the Gatún fault east of Gatún Lake has shown that this fault has experienced at least two, and possibly three, surface-rupturing earthquakes since 1490 AD. Based on 3-D trenching of a 3 ka channel thalweg that is offset 19-20 m, the left-lateral slip rate on the Gatún fault is 6-9 mm/yr with a maximum of 20% north-side up normal slip, and the most recent earthquake (possibly in 1849 AD) generated at least 0.7+0.2 meters of left-lateral surface offset that apparently went unnoticed at the time. Our best estimate is that this 40 km segment of the Gatún fault has a recurrence interval of ~M6.8 earthquakes every 100-170 years based on the last three events, but if the fault is capable of multi-segment, less-frequent ruptures, the earthquakes could potentially be as large as M7.4 if the entire 120 km fault were to rupture. We suspect, but cannot prove, that triggered slip resulted in soil fracturing on the Gatún fault during the 1991 M7.6 earthquake on the North Panama Deformed Belt off of Bocas del Toro. These findings are important for the seismic stability analysis of the AD 1913 Gatún Dam across the Chagres River, one of the most critical structures in the Panamá Canal.

GOMEZ, MARTHA
Paleoearthquake history and extension rates of the Waihi and Poutu faults in the Tongariro Volcanic Centre, New Zealand.

Martha Gabriela Gómez-Vasconcelos1*, Pilar Villamor2, Jon Procter1, Alan Palmer1, Shane Cronin3, Clel Wallace1.; 1-Volcanic Risk Solutions, Institute of Agriculture and Environment, Soil and Earth Sciences, Massey University, Private Bag 11 222, Palmerston North 4442,New Zealand; 2-GNS Science, PO Box 30-368, TePūAo Lower Hutt, New Zealand; 3-School of Environment, The University of Auckland, Private Bag 92019,Auckland 1142, New Zealand.
*G.Gomez@massey.ac.nz, (+64) 0211779076

At the central North Island of New Zealand lies the intra-arc Taupo Rift (Acocella et al., 2003), where extension is achieved through a combination of dike intrusion and normal faulting (Rowland et al., 2010; Villamor et al., 2006).In the southern Taupo Volcanic Zone, at the Tongariro Graben axis, the Tongariro Volcanic Complex is surrounded by two regional NNE-oriented active normal fault sets, to the west the

Waihi Fault zone and to the east the Poutu Fault zone. These faults are creating a narrower graben at the axis of the rift, parallel to the volcanic vent complex, showing uniaxial extension.

The 42 km-long Waihi Fault zonecomprises19 fault strands and 1 antithetic fault west from the Tongariro Graben axis. The most frequent trend for Waihi is 012 and the mean trend is 055. The 32 km-long Poutu Fault zone comprises 23 fault strands, 11 of them are antithetic and form a graben-like structure east of the Tongariro Graben axis. The most frequent trends are 025 and 055 and the mean trend is 041.

Our paleoseismology reconstruction shows movement on the Waihi and Poutu faults between 200 and 1.72 kyr. We evaluated their earthquake history with vertical fault displacements measured by geomorphic surfaces over 226 strands and field exposures. Changes in displacement rates suggest an apparent interdependence with all fault strands within the rift. Steepness of fault dips, en-echelon geometry of fault traces, horsetail fault splaying and non-parallel fault strands have traditionally been used to suggest oblique extension, but no strike-slip component was found. Their paleoearthquake history seems to be linked to higher regional extensional periods and/or volcanic activity in the region. A better understanding of the kinematics and evolution of these faults may have important implications for the seismic and volcanic hazard assessment in the Tongariro Volcanic Centre.

GOMEZ, FRANCISCO

Re-evaluation of late Quaternary deformation in the northern Wind River Basin, Wyoming

Francisco Gomez, Eric Sandvol, &Alzubair Abousaif, Department of Geological Sciences, University of Missouri, Columbia, MO 65211 USA; fgomez@missouri.edu

The Stagner Creek fault, bounding the southern Owl Creek Mountains and northern Wind River Basin, is one of several east-west striking Quaternary faults in central Wyoming that may correspond with scattered, present-day, intraplate seismicity. In an effort to understand the structural context of this fault, this study combines a preliminary reassessment of the morphology of the Stagner Creek scarp along with an initial view of the shallow subsurface structure beneath it. The scarp affects 4 late Quaternary surfaces, for which prior studies provide soil-based correlation ages. New geomorphic analyses were facilitated by micro-topographic surveying using RTK GPS. The resulting data provides higher resolution constraints on the scarp morphology, as well as documenting possible knickpoints within the alluvial surfaces upstream from the scarp. Scarp heights range from 0.4 to 3.5 meters, and scarp faces depict relatively shallow slopes of 2 – 7 degrees. Apparent correlation of scarp slope and relative age suggests that the scarp results from folding, rather than surface faulting. Based on this interpretation, rates of surface warping are approximately 0.05 – 0.15 deg./kyr., and uplift rates range from 0.01 to 0.03 mm/yr. The estimated uplift for a single deformation event (based on the youngest surface) is approximately 0.4 meter. A shallow seismic reflection profile acquired across the scarp imaged structure to depths of about 500 meters. The profile suggests a steep, north-dipping fault coincident with the surface scarp. Throw across the fault is approximately 10-15 meters, and the tip line of the fault is at 60-100 meters depth. Although these new results do not significantly change previous estimates of moderate earthquake potential for the Stagner Creek fault, the new evidence of surface warping and the steep, northward dip suggest a new tectonic scenario involving possible reactivation of an inherited, Laramide-age structure as a reverse or a wrench fault.

GONZALEZ, GABRIEL

Quaternary deformation in the Atacama Fault System in northern Chile: new discoveries from trenching and OSL dating of colluvial wedges

Gabriel González, Luis Astudillo, Ian del Rio, Isabel Santibañez, Steve Binnie, José Cembrano and Ruth Robinson; Universidad Catolica del Norte, Antofagasta, CHILE; ggonzale@ucn.cl

The Atacama Fault System (AFS) in northern Chile exerts a strong control on the morphology of the Coastal Cordillera near Antofagasta city (24° Latitude S). This control is primary expressed by kilometer-long mountain fronts limited by large subsiding alluvial basins. Long-term fault displacements have

produced cumulative vertical offsets of up to 500 m.Miocene and Pliocene ages from volcanic ash layers interbedded in the alluvial infill of the structurally controlled basins attest to a prolonged period of faulting. NS-striking sharp fault scarps affecting Quaternary alluvial fans are common in the piedmont of the mountain fronts. These fault scarps show the most recent reactivation features of the faults.The age of the latest Quaternary fault displacements have been constrained in a general way by using Ne21surface dating (González et al., 2005). Direct dating of single event along these faults is still needed. In this contribution we presented the results of a detailed geological analysis of two main faults of the Atacama Fault System, including the main branch of the AFS, which is the Salar del Carmen Fault, and the Mititus Fault. In our analysis we use the paleoseismological mapping of 24 trenches excavated along these two faults. In order to characterize fault scarp morphology we used 2 cm resolution digital elevation models generated by UAV-based photogrammetry. We resolved the following geological problems: 1) the temporal relationship between previously documented reverse and normal faulting along these faults, 2) the age of the latest fault displacement on the Salar del Carmen Fault and 3) the paleoseismological significance of the late fault reactivation of the AFS.

GONZALEZ-ALFARO, JOSE

Accelerated upper crustal uplift since MIS3 at the southern edge of the northern Chile megathrust seismic gap

José González-Alfaro. Departamento de Geología, Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile, Plaza Ercilla 803, Santiago, Chile.

Mejillones Peninsula – Located at the continental active margin, in the external fore-arc of the Central Andes, northern Chile – is a first order characteristic feature because it is a continental shelf area which has been upraised according to conspicuous Pleistocene marine terraces and beach ridges. Northern Mejillones Peninsula marine deposits, previously dated 100 ka BP through U-Pb series, have been redated in 31 – 46 ka corresponding to Marine Isotope Stage 3 (MIS 3) – Globally defined between 60 and 25ka – based on radiocarbon and Optically Stimulated Luminescence (OSL) analysis. Consequently, for the last 40 ka, the calculated uplift rate is 2.1 ± 0.7 m/ka which shows an acceleration of the Mejillones Peninsula uprising considering the 0.5 m/ka mean uplift rate of the last 400 ka. The uprising acceleration would be produced by co-seismic vertical deformation and rupture propagation which breaks beneath the northern Mejillones Peninsula along the subduction zone during megathrust earthquakes. Each earthquake would keep a great positive differential uprising unlike other nearby seismic gap segments.

GOSWAMI, CHANDREYEE

On Linkage between Present Geomorphology and Substrate Geology in a Tectonically Active Terrain along the North Eastern Himalayan Foothills.

Chandreyee ChakrabartiGoswami 1*, B C Poddar2, Shayan Sarkar1; 1-Department of Geology, University of Calcutta; 2- BE-367, Salt Lake City Kolkata 700064 *Corresponding Author: chandreyee.goswami75@gmail.com

Explosive urbanisation in geologically unstable terrains is a potentially risky endeavour which is amply demonstrated in unbridled growth of Itanagar-Naharlagun Capital Complex (INCC) of Arunachal Pradesh, India, anchored in neotectonically active foothills of Eastern Himalayas. Presently, urban settlements with concurrent road buildings are growing at a frenetic speed defacing the pristine landscape, questioning its sustainability. We have attempted to document and analyse the geomorphic framework and geology of the substrate with particular reference to interaction of episodic deep-seated tectonic processes and surficial fluvial activity during the Neogene and Quaternary and continue in the Holocene-Anthropocene. Our objective is to unravel the hidden and subtle linkages between geological nuances and present geomorphology. Our preliminary analysis of satellite imageries, DEMs and extensive field study reveals that the terrain is underlain by a system of thrust-controlled asymmetric folds involving incipiently lithified fluvial sediments comprising sandstone, siltstone and polymictic conglomerate of unclassified late Neogene Siwaliks. These are unconformably overlain by a stratum of Quaternary sequence of unlithified

and poorly sorted boulder clay (possibly a product of paleo-land slide), polymictic gravel and sand deposited by rivers on multiple strath terraces and extant flood plains. The Quaternary sequence has also been affected by post-Siwalik tectonic activity demonstrating instability of the geological substrate. The Siwaliks are thrusted over the Quaternaries along parallel E-W trending faults, both affected by some prominent transverse faults too, together creating the landslide prone areas in INCC. Surficial, fluvial and slope processes (controlled by climatic factors), coupled with the deep-seated episodic tectonic activity, are acting in tandem and intensively sculpting the inherited legacy of the geological past. Superimposed on this natural matrix is the impact of human intervention in the form of rapid and haphazard urban growth. The unfolding scenario of the INCC is the product of intertwined activity of Nature and Man.

GOSWAMI, CHANDREYEE

Manabhum Anticline: An Apparent Key to the Genesis of the Eastern Himalayan Syntaxial Zone

Chandreyee Chakrabarti Goswami (1), Somhrita Bhattacharjee (1); (1) Department of Geology, University of Calcutta, 35 Ballygunge Circular Road, Kolkata 700019, India; Email: chandreyee.goswami75@gmail.com

The geologically complex and logistically hostile terrain of the Assam–Arakan basin near fore deep of the Himalayan foot hills is one of the key factors to understand the Himalayan tectonics in its eastern extremity. The spectacular anticlinal structure, the Manabhum anticline in this region which is flanked by the Himalaya, the Mismi Hills and the Naga Schuppen belts on three sides and upper Assam basin on one side has been studied An effort has been given to document the geomorphological and geological features from the remotely sensed data and subsequent detailed field mapping. The accumulated data have been analysed to understand the tectonic scenario which has contributed to the morphological evidences of this area in recent past.

GRAY, BRIAN

Seamless Photomosaic Trench Logging Using Trench-Based Photogrammetry Methods: Workflow and Case-Studies

Brian Gray,Nicholas Graehl, Serkan Bozkurt, John Baldwin, and Kevin Clahan; Lettis Consultants International, Inc; 1981 N. Broadway, Suite 330, Walnut Creek, CA

Modern photo-logging methods of paleoseismic trench exposures include Structure-from-Motion (SfM) and Image-Based Modeling (IBM) techniques that reconstruct 3D surfaces to create seamless, high-resolution photomosaics designed for in-situ trench photo logging. Given the often large expense and time-critical nature of paleoseismic investigations, efficient and accurate production of seamless photomosaic trench logs is an essential component to modern paleoseismic investigations. We present our field-tested workflow herein; from photo acquisition techniques to software reconstruction and post-processing methods. Results from two case-studies are illustrated to demonstrate our workflow on various types of trench excavations in remote field settings using basic equipment. Our workflow builds on experience using SfM methods in more than 25 paleoseismic trenches in various tectonic settings, trench styles, and site conditions.

The goal of any photomosaic trench logging exercise is to develop an accurate, archive-quality, orthorectified image of the exposure. Efficient generation of a photomosaic log requires four basic steps: (1) trench excavation and grid preparation, (2) photography, (3) model generation, and (4) final log rectification and printing. Our workflow emphasizes efficiency and log accuracy from careful excavation planning, systematic photography, and a GIS-based approach to final log rectification to produce high-quality photomosaic trench logs.

In addition to outlining the basic workflow, we addresses common photomosaic log production issues that can result in significant delays and lost field time. These issues include long processing times, patching in trench updates (such as after shore moves, additional excavation, and re-flagging), production of logs in trenches with multiple bends, and rectification/referencing of logs in the absence of survey control.

GREUTZNER, CHRISTOPH
Large strike-slip faults in a convergent continental setting - the Dzhungarian Fault in the Northern Tien Shan

Grützner, Christoph (1) , Austin Elliott (2), Richard Walker (2), Kanatbek Abdrakhmatov (3), Grace Campbell (1); 1-COMET; Department of Earth Sciences, University of Cambridge, Madingley Rise, Madingley Road, CB3 0EZ Cambridge, UK, chg39@cam.ac.uk; 2-Department of Earth Sciences, University of Oxford, South Parks Road, OX1 3AN Oxford, UK; 3-Kyrgyz Seismological Institute, Academy of Sciences of the Kyrgyz Republic, Asanbay str. 52/1, 720060 Bishkek, Kyrgyz Republic

Large strike-slip faults are a characteristic feature of Tien Shan tectonics. Yet little is known about their role in accommodating the shortening between India and Eurasia, and in most cases slip rates are only estimates from satellite geodesy and GPS. We present results from our field work at the Dzhungarian Fault, which marks the border between the northernmost Tian Shan and the Kazakh platform in East Kazakhstan and West China. This right-lateral strike-slip fault is several hundreds of kilometres in length. An impressive scarp is visible on satellite imagery and in the field, stretching for more than 30 km in the central part of the fault. Few data exists on the fault slip rate (most likely in the order of 2-3 mm/yr), and the earthquake history is completely unknown. We surveyed offset morphological markers like terrace risers and river terraces with DGPS and drone/balloon surveys in order to produce high-resolution digital elevation models using Structure-from-Motion (SfM). We dated abandoned surface to get an idea on the timing of the last large earthquake and to measure slip rates at various places. Dating was performed using radiocarbon, OSL/IRSL on loess, and U-Th series on carbonate rinds that formed due to soil formation after surface stabilization. We show that the fault ruptures in a complex pattern and in great earthquakes, probably with large stress drops. We highlight that folding contributes to the overall deformation and we discuss challenges in dating methods and geomorphological analyses in the arid intracontinental setting.

GRUETZNER, CHRISTOPH
Paleoseismological challenges in Central Asia

Grützner, Christoph (1), Richard Walker (2), Austin Elliott (2), Eleanor Ainscoe (2), Kanatbek Abdrakhmatov (3); 1-COMET; Department of Earth Sciences, University of Cambridge, Madingley Rise, Madingley Road, CB3 0EZ Cambridge, UK, chg39@cam.ac.uk; 2-Department of Earth Sciences, University of Oxford, South Parks Road, OX1 3AN Oxford, UK; 3-Kyrgyz Seismological Institute, Academy of Sciences of the Kyrgyz Republic, Asanbay str. 52/1, 720060 Bishkek, Kyrgyz Republic

This paper is concerned with paleoseismological investigations in the Tien Shan. We use two case studies to illustrate problems that can come along with research on active faults and seismic hazard. The Tien Shan in Central Asia accommodates around one quarter of the total convergence between India and Eurasia. Large E-W striking thrust faults and conjugate strike-slip faults take up the distributed shortening. Many of them are characterized by rather long recurrence intervals. Combined with major landscape modifications caused by Late Quaternary climatic changes, this makes the identification of active faults challenging. In our first case study from the Ili Basin in Kazakhstan we show how the geomorphological fingerprint of large, surface rupturing earthquakes can be obliterated by erosional events. In our second example we focus on a site in Kyrgyzstan where a MW7.2 earthquake produced discontinuous surface ruptures in 1992. We discuss the rupture pattern and show how shortening might be accommodated by a complex pattern of faulting and folding. Paleoseismological data reveal that surface ruptures on this very fault are much more complicated than thought, posing a challenge not only to understanding the active deformation, but also to evaluating seismic and surface-rupturing hazard.

JAMSEK-RUPNIK, PETRA
Fault characterization field campaign related to probabilistic seismic hazard assessment for nuclear infrastructure in the Krško Basin, Slovenia

Petra Jamšek Rupnik1,Jure Atanackov1, M. Logan Cline2, K. Michael Cline2, Miloš Bavec1
1 Geological survey of Slovenia.Dimičevaulica 14.SI-1000 Ljubljana, Slovenia.petra.jamsek@geo-zs.si; 2 Rizzo Associates. 500 Penn Center Boulevard, Pittsburgh, PA 15214, USA.

The Krško Basin hosts critical infrastructure and is being investigated as a potential site for several projects including a new NPP and a low and intermediate level radioactive waste repository. The Basin lies at the transition between two structural domains:the Sava Foldsto the NW and theMid-Hungarian Shear Zone in the SE. The basin generally coincides with the post-Miocene Krško Syncline, the southernmost part of the Sava Folds.It trends WSW-ENE and comprises folded Neogene and Plio-Quaternary sediments overlaying sedimentary Mesozoic basement rocks. Large scale N-S compression, driven by convergence between the Adriatic microplate and European plate,and complex interaction between different crustal block had led to a generally transpressional setting of the Krško Basin. Focal mechanisms from moderate and dispersed seismic activity demonstrate reverse to strike-slip fault motion. The strongest historical earthquake in the basin wasthe Mw 5.7 Brežice event in 1917, (Imax VIII EMS-98), while the strongest event in the region (epicenter 40 km SE)was the 1880 Zagreb earthquake, which had an estimated Mw 6.0 (Imax IX EMS-98).

In the northern limb of the Krško Syncline (also southern limb of the Orlica Anticline), two structures seem to exhibit the youngest, post-Miocene faulting: the Orlica Fault Zone and the Artiče Structure. These are a particular focus of a field campaign designed to characterize faults for a probabilistic seismic hazard analysis that will becarried for proposed NPP. Building upon numerous previous studies, we performed morphotectonic analysis based on LiDAR data, field reconnaissance mapping, HRS survey, borings and shallow geophysical surveys. Our results suggest the Orlica Fault Zone is a highly segmented zone running mostly within the Orlica Hills, which consists of numerous SW-NE-striking left-lateral faults, and WSW-ENE-striking reverse faults. The longest fault segment at the surface is 3 km long. The HRS survey confirmed the Artiče Structure is a WSW-ENE-striking north dipping reverse fault. Morphotectonic mapping and shallow geophysical profiling (ERT, VES and SRT) identified several sites appropriate for paleoseismic trenching, which is planned for the spring of this year.

JOHN, BIJU
Issues pertaining to active fault identification in cratonic regions: example from Peninsular India

Biju John, National Institute of Rock Mechanics, INDIA; b_johnp@yahoo.co.in

Identification and evaluation of active faults is integral part of site evaluation studies for suitability of nuclear establishments. Considered as seismically more stable, the cratonic regions are most suitable for such establishments. However due to the long return period of earthquake events in such regions, geological investigations are imperative to extend the earthquake catalogue. The nuclear establishment guidelines suggest that fault movement within the present stress regime should be considered as active.

The geological studies subsequent to 1994 Wadakkancheri earthquake (M4.3) identified an active fault that changed the course of one of the biggest rivers in the region. Morphometric studies identified the subtle topographic adjustments induced by the fault movement. The ~30 km long NW-SE trending fault is exposed in a quarry section. Multiple gouge generation and fluid activity were identified in this fault zone through cross cutting relationship. The repeated ruptures in this fault zone indicate cyclic behavior of this fault having co-seismic ruptures alternating with inter-seismic periods, which is characterized by the sealed fractures and consolidated gouge. The fault zone shows a minimum accumulated dip/oblique slip of 2.1 m in the reverse direction, based in the dislocations of pegmatite veins across it , with a possible characteristic slip of 52 cm (for each event). The thickness of the gouge is also considered for the estimation of displacement. The empirical relationships between fault length and slip show that this fault might have generated events of M≥6. The ESR dating of fault gouge indicates that the deformation zone recorded a major event in the Middle Quaternary. Trench investigations in the hanging wall side of the fault, identified evidence of paleoliquefaction in the form of sand dikes within the recent sediments. The

observations from this region remind of critical seismotectonic evaluation of all proposed nuclear establishments in similar cratonic regions.

KARLSSON, KEENE
Paleoseismicity of the Laguna Salada fault, northern Baja California

Keene Karlsson, Thomas Rockwell, and John Fletcher; Dept. of Geological Sciences, MC-1020
San Diego State University, 5500 Campanile Dr., San Diego, CA 92182-1020

The Laguna Salada fault is one of several major transtensional oblique-slip faults that traverse the Sierra Cucapah and Sierra Mayor mountain ranges in northern Baja California, Mexico. Known collectively as the Cucapah fault array, two of the faults have ruptured historically in moderately large earthquakes. In 2010, the southernmost Laguna Salada fault nucleated theMw7.2 Cucapah-El Mayor earthquake, with rupture along multiple faults within the array, including the Laguna Salada, Pescaderos, Borrego, and Paso Superior faults. Previous studies have shown that the northern Laguna Salada fault ruptured in a Mw7.2 earthquake in 1892 (Mueller and Rockwell, 1995), and produced 55 km of surface rupture (Rockwell et al., 2015). Of note, the central to southern half of the Laguna Salada fault did not sustain significant rupture in either the 1892 or 2010 earthquakes, although field reconnaissance demonstrates late Quaternary scarps along its length with mostly strike-slip displacement. My study is to resolve the late Pleistocene and Holocene rupture history of this major element of the Cucapah fault array, and understand why both historical earthquakes bypassed this fault strand. One possibility is that it had sustained another late Holocene surface rupture, although preliminary fieldwork suggests an earlier Holocene age for the most recent event.

KOEHLER, RICH
Reconnaissance geologic observations along the Petersen Mountain fault zone northwest of Reno, Nevada, U.S.A.

Rich D. Koehler, Nevada Bureau of Mines and Geology, Mackay School of Earth Sciences and Engineering, University of Nevada, Reno, 1664 N. Virginia St., MS 178, Reno, NV 89557

The Petersen Mountain fault zone is a Quaternary active, 25-km-long, normal fault system that bounds the eastern side of Petersen Mountain between Cold Springs Valley and Red Rock Valley northwest of Reno, Nevada, U.S.A., an area locally known as the “North Valleys”. These relatively small fault-bounded valleys extend between the normal oblique North Peavine Peak fault and the dextral Honey Lake fault and accommodate extension between the Sierra Nevada frontal fault system and the Walker Lane. Quaternary deformation along the Petersen Mountain fault zone has generated over 500 m of relief. Previous mapping efforts have documented late Quaternary deformation including offset alluvial surfaces, lacustrine deposits, and piedmont surfaces, as well as abrupt range-front escarpments however detailed studies have not been conducted and geologic information on recurrence and slip rate are not available.The fault has been identified by the Nevada Bureau of Mines and Geology and the U.S. Geological Survey as a priority fault for detailed investigation, however, despite thegeneral lack of geologic information the fault was included in the 2014 update of the National Seismic Hazard Map (NSHM) based on modelled slip rates.

This paper describes reconnaissance geologic observations of the overall geomorphic expression, continuity of scarps, and age of faulted surficial deposits along the Petersen Mountain fault zone. The observations are being compiled as part of a regional multi-year effort to identify data gaps, better characterize faults in the “North Valleys” area, and refine seismic hazard models.

LANGRIDGE, ROB
Assembling lidar swaths along the distributed South Island plate boundary, NZ: The South Island 'b4' project

Langridge, R.M., Ries, W.F., Barth, N.C., Howarth, J.D., Quigley, M., Pettinga, Farrier, T.

Strain release on the active South Island plate boundary is dominated by from large to great (Mw 7 to >8) earthquakes on the transcurrent Alpine Fault and faults of the Marlborough Fault System. In recent years the adoption of airborne lidar as a viable technology for scanning the New Zealand landscape has led to the bit-by-bit development of a burgeoning South Island-wide plate boundary lidar swath dataset. Components of this dataset have been acquired from NZ and externally-funded research grants, and from local government surveys aimed at mitigating various natural hazards. The lidar swaths collected thus far are typically long, thin (1-2 km wide) strips that span a length of c. 400 km along the Alpine, Hope, Kelly, Clarence, Awatere and Wairau faults to form the South Island 'b4' dataset. Acquiring and collating such lidar datasets have uses for current and future active fault studies, mapping to define surface rupture hazard, and in future to assess the differential ground movement from before (b4) and after large surface-rupturing earthquakes. For example, five separate swaths along the Alpine Fault funded by NZ NHRP total ~125 km, while four separate swaths funded by the US NSF, NZ EQC and Marlborough District Council total ~86 km (82%) of coverage along the Wairau Fault, the northeasternmost extension of the Alpine Fault. These datasets are being used to re-map active faults for inclusion in the NZ Active Faults Database (Langridge et al. 2016), and to redefine the surface rupture hazard buffers ('fault avoidance zones'). Lidar swaths are also being used to improve the records of Holocene slip rate and displacement history, and to locate suitable sites for paleoseismic excavations. The conditional probability of a major earthquake on the central Alpine Fault has recently been re-estimated at ~50% in the next 50 years. This provides the wider research community with a clear goal to acquire comprehensive coverage along the main faults of the South Island plate boundary so that the total surface effects of near-field co-seismic deformation can be detected post-event. The purpose of this paper is to introduce this collaborative approach to building a plate boundary-scale dataset by highlighting some of its emerging examples of tectonic geomorphology and neotectonic results.

LEE, JINHYUN
Seismic activity in SE Korea based on a trench survey(Dangu fault) and historical earthquake data around the Yangsan fault

Jinhyun Lee (1), Sowreh Rezaei (1), Yeji Hong (1) Jin-Hyuck Choi (2), Jeong-Heon Choi (3), Weon-Hack Choi (4), Kun-Woo Rhee (5), Young-Seog Kim (1); (1) Department of Earth & Environmental Sciences, Pukyong National University, Busan 48513, Korea. Email: godgocogo@gmail.com; (2) Institute de Physique de Globe de Paris, 1 Rue Jussieu, 75005 Paris, France; (3) Geochronology Group, Korea Basic Science Institute, Chungbuk 28119, Korea; (4) Central Research Institute, Korea Hydro and Nuclear Power Co., Daejeon 34101, Korea; (5) Department of History, Humanities and Social Sciences & Business Administration, Pukyong National University, Busan 8513, Korea.

Most Quaternary faults have been reported around the Yangsan and Ulsan Fault System in SE Korea. The Dangu fault, excavated in the trench, is located in the northern part of the Yansan Fault and a dextral oblique slip fault with some reverse slip component. Attitude of the fault and slickenlines on the fault surface are N15°E/79°SE, 015°/15°, respectively. Three gouge bands with different colors developed along the fault indicate at least three faulting events. We obtained OSL and radiocarbon ages of about 7.5±0.3 ka and 3990±40 B.P in layer C. , respectively. Based on the analysis of seismic data from history, many earthquakes occurred in the Gyeongsang-do region, including several big earthquakes around Gyeongju area. Especially, some earthquakes are big enough to generate surface ruptures, although surface ruptures have not reported yet in Korea. Based on the trench survey and historical earthquake data, Gyeongju area is seismically active and more detailed seismic and paleoseismic research is required in this area. Therefore, the Dangu fault is relatively young fault in Korean peninsula and several big historical earthquakes are reported in Gyeongju area and more detailed seismic research is required in this area.

LEGE, THOMAS
Integrated InSAR Based Corpernicus Ground Motion Service for Germany - Paleoseismic aspects

Thomas Lege, Michaela Frei, Andre Kalial: Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) (Federal Institute for Geosciences and Natural Resources), Stilleweg 2, D-30655 Hannover, Germany; thomas.lege@bgr.de; michaela.frei@bgr.de; andre.kalia@bgr.de

Though the beneficial use of InSAR methods in tectonics, earthquake analysis and other geologic and geophysical branches is widespread in the scientific community it is still almost nonexistent in the day-to-day business of federal, state and municipal work and planning. Therefore and due to considerably expressed demand from user panels the German government entrusted BGR (Federal Institute for Geosciences and Natural Resources) to keenly foster the integration of national space data together with scientific developments from the InSAR-community in every-day work of German administrative bodies and thus also in small and medium enterprises (SME).

In extensive reconcilement of demands and interests of concurrent technical, administrative, business and juristic responsibilities (e.g. Ministries, Mining Authorities, Geological Surveys, Geodetic Surveys and Environmental Agencies on federal and state level, SMEs, German Aerospace Center, …) BGR developed the concept of the InSAR based National Ground Motion Service. An important backbone is the so-called Wide Area Product (WAP), developed with grants of German and European research funds.

With special respect to paleoseismic aspects one of the successful implementations of the concept, a study in the area of the Northern-German gas province will be presented. The calibration of the WAP dataset is among others based on the integration of geologic and tec-tonic knowledge. Tectonically Northern Germany is regarded to be stable, but it turned out that there might be recent slow movements along faults that are generally assumed non active nowadays. Recent slow movements became evident through the longtime measurements of the regional GNSS-Network and calculative considerations of the trace of the so called Aller-Valley-Fault-Zone in the processing of the WAP. The interpretation of the Aller-Valley-Fault-Zone as a still active tectonic structure is supported by geological hints of paleoseismic activities in gravel pits and reports of earthquakes during the last historically documented centuries.

LO SARDO, LORENZO
Paleoseismological techniques applied to different surface rupturing morpho-tectonic processes: case studies from tectonically active areas of the Abruzzi Region, central Apennines, Italy.

Lo Sardo L.1 , Falcucci E.2, Gori S.2; Saroli M.1; Moro M.2, Fubelli G.3, Lancia M.1 and Galadini F.2; (1) University of Cassino and Southern Lazio, Department of Civil and Mechanical Engineering, Via G. Di Biasio 43, 03043, Cassino, Italy. E-mail: l.losardo@unicas.it; (2) National Institute of Geophysics and Volcanology, National Earthquake Center, Via di Vigna Murata 605, 00143, Rome, Italy; (3) University of Turin - Department of Earth Sciences, Via Valperga Caluso, 35 - 10125 Turin, Italy.

We tested the effectiveness of classical paleoseismological trenching to compare and thus achieve a better comprehension of morpho-tectonic features related to different and “tricky” geological processes able to displace the surface. We selected three study areas from central Italy: the Fucino basin (i), the Prata D'Ansidonia area (ii) and the S. Stefano di Sessanio area (iii).

As for case (i), we studied the southern segment of the active Fucino normal fault, responsible for the 1915 Marsica earthquake (Mw7), namely the San Benedetto-Gioia dei Marsi fault, by means of two trenches as well as a by the analysis of the walls of two quarries. Refined structural/archaeological data allowed to better constrain the late Holocene surface faulting events.

As for case (ii), we investigated a linear scarps carved onto Quaternary alluvial conglomerates, up to 3 m high and 1.5 km long, that borders a closed narrow, depression, filled by recent colluvial deposits. Paleoseismological trenching and geophysical survey (GPR, ERT and microgravimetry) defined the genesis of the scarps as related to tectono-karstic processes, able to produce surface rupture.

As for case (iii), we investigated one of the few-km-long and hundred-metres-large closed depressions bounded by fault scarps carved onto the Mesozoic-Cenozoic carbonate bedrock and, subordinately, onto early Quaternary slope deposits, and affecting the south-western slope of the Gran Sasso Range. The fault planes are exposed at the base of the scarps. A paleoseismological trench has been dug across the investigated scarp, defining the activity of the shear plane in recent times. Our ongoing analyses seem to be in agreement with the recent interpretation of the origin of these shear planes, being the surface expression of Quaternary extensional structures that root at about 2-3 km depth on the presently inactive thrust plane that structured the Gran Sasso front during the Pliocene.

LUNINA, OKSANA

Clastic dikes induced by strong earthquakes in southern Siberia and their paleoseismic significance

Oksana, Lunina (1, 2), Andrei, Gladkov (1); (1) Institute of the Earth's Crust, Siberian Branch of Russian Academy of Sciences, Lermontova street 128, Irkutsk 664033, Russia, lounina@crust.irk.ru; (2) Institute of Marine Geology and Geophysics, Far East Branch of Russian Academy of Sciences, Nauki Street 1B, Yuzhno-Sakhalinsk 693022, Russia

We studied clastic dikes formed by earthquakes in southern Siberia that were historically mentioned or monitored by instruments. They are the most common among all liquefaction-induced soft-sediment deformation structures (SSDSs) in the epicentral areas of the Chuya, Mondy, Middle Baikal and Thagan seismic events. They are also the most reliable paleoseismic indicators in regions where cryogenic processes are intense. In addition to the commonly accepted criteria for the recognition of SSDSs, we suggest seven criteria that may be useful to separate the seismogenic clastic dikes from non-seismogenic SSDSs in a single outcrop: (1) pushed up sedimentary blocks within the dike body; (2) regular distorted contacts of dike with host sediments, reflecting cyclic loading during propagation of seismic waves; (3) turned up layers of host deposits on contacts with a dike; (4) displacement along dike contacts usually in the form of a normal fault caused by subsidence that compensates for the removed sediment; (5) a dike structure like a diapir; (6) filling of a clastic dike with coarser material than the host sediments; and (7) a sediment layer extruded on the surface or between the strata, similar in composition to the dike; in the extruded sandy-gravel-pebble layer rock fragments show upward grading (from large to small clasts). Fractures in the same outcrop may indirectly also indicate the seismogenic genesis of liquefaction-induced SSDSs. Due to the close spatial relationship of dikes with the fault structure of the investigated areas, they can be used to identify the responsible seismogenic fault, and their size can help to estimate of the lower-bound magnitude/intensity of paleoearthquakes.

LUNINA, OKSANA

Style of deformations in the Mondy active fault zone investigated with ground-penetrating radar and structural observations (southern East Siberia)

Oksana, Lunina (1, 2), Andrei, Gladkov (1); (1) Institute of the Earth's Crust, Siberian Branch of Russian Academy of Sciences, Lermontova street 128, Irkutsk 664033, Russia, lounina@crust.irk.ru; (2) Institute of Marine Geology and Geophysics, Far East Branch of Russian Academy of Sciences, Nauki Street 1B, Yuzhno-Sakhalinsk 693022, Russia

We investigated the surface deformations in the Mondy fault zone which triggered one of the strongest earthquakes in southern East Siberia occurred on April 04, 1950. The active fault connects the E–W trending Tunka basin and the N–S trending Khubsugul basin on the south-western flank of the Baikal rift zone where the geodynamic regime is quite complex. Based on the GPR and structural data, we determined the dip direction and inclination of the single faults, types and value of vertical offsets, as well as the widths of fault zones, which change from 2.5 to 17 m. The widths significantly vary along the fault strikes and decrease with depth within first meters that is typical of seismogenic ruptures. Many of them did not reach the surface but they manifested by the sinkholes concentrated in the hanging wall of the ruptures. In addition to known sinistral displacements, we established that normal fault offsets occurred along the nearly E–W and NW–SE trending ruptures. They formed negative flower structures in the

subsurface part of the earth crust. The normal fault offsets determined by analysis of the radargrams are different in the GPR profiles and reach the maximum value of 3.4 m near the village of Mondy. It can be a result of several seismic events. We suggest that a Yaminshinsky fault trending NW–SE affected the style of deformations in the Mondy fault zone. The results of modeling carried out by polarization-optical method show that when striking compression to NE–SW, like in strike-slip focal mechanism of the 1950, Mw=6.9 Mondy earthquake (Delouis et al., 2002), local change of stress field occurs in the junction of the two faults. As a result the sinistral strike-slip with the extension occurs on the Yaminshinsky and Mondy faults within the area of Russia.

MALIK, JAVED
Surface rupture of a Great Himalayan 1905 Kangra earthquake (Mw7.8), NW Himalaya, India

Javed N Malik1, Santiswarup Sahoo2, Asmita Mohanty3, Sambit P. Naik3 and Koji Okumura4; 1-Department of Earth Sciences, Indian Institute of Technology Kanpur. Kanpur 208016. Ph. +91-512-2597723. Email: javed@iitk.ac.in
2-Department of Geology, Utkal University, Odisha. Email: sahoosantiswarup@gmail.com; 3-Department of Civil Engineering, Indian Institute of Technology Kanpur. Kanpur 208016. Email: masmita@iitk.ac.in; 3Department of Civil Engineering, Indian Institute of Technology Kanpur. Kanpur 208016. Email: psambit@iitk.ac.in; 4-Department of Geography, Faculty of Letters. Hiroshima University. Higashi-Hiroshima. Hiroshima 739-8522. Japan. Email: kojiok@hiroshima-u.ac.jp

The 04 April 1905 Kangra earthquake (Mw 7.8) killed more than 20,000 people, caused total damage to the towns of Kangra and Dharamsala in NW Himalaya. In spite of its large magnitude with a maximum intensity X recorded in the epicentral area, no surface rupture was reported, and no focal mechanism is available. Our finding reveals that the 1905 Kangra earthquake occurred along a newly identified the "Kangra Valley Fault" (KVF) with prominent right lateral strike-slip movement. KVF striking WNW-ESE and E-W extends for ~60 km, cutting through the Kangra and Sihunta valleys. This fault is capable of producing Mw≥7.2 earthquakes. Existence of the KVF in the Kangra Re-Entrant is indicative of oblique convergence and slip partitioning between thrust namely Main Boundary Thrust (MBT) in north and Jawalamukhi Thrust (JMT) in the south and strike-slip fault in the NW Himalaya. Paleoseismic investigations revealed evidence of at least four earthquakes on KVF. Event-I (oldest) occurred before BC 900 or between BC 900-2500; Event-II between BC 100-80; penultimate Event-III occurred around AD 800-1000; and Most Recent Event (MRE) Event-IV after AD 1620 and before AD 1940, and is likely the 1905 Kangra earthquake (Mw7.8). Our findings suggest that inter-seismic strain accumulated south of the fault ramp under the Higher Himalayas was not only released periodically along the Himalayan Frontal Thrust (HFT) during large magnitude earthquakes, but also along the active faults in the hinterland. Since the strain during 1905 Kangra earthquake was released along the KVF, potential for large magnitude earthquakes in NW Himalaya along the HFT still remains.

MARTINEZ-GUTIERREZ, GENARO
Investigation of uplifted marine and fluvial terraces in the Santa Rosalía basin of central Baja California, México

Martínez Gutiérrez, G.1, Antinao Rojas, J.L.2, Camacho Antuna, D.A.1, Hartke, S.3, Pugh, A.4, and Niemi, T.M.5; 1-Department of Earth Sciences, UABCS, México; 2-DRI-Division of Earth and Ecosystems Sciences, Reno, NV; 3-Department of Geosciences, University of Texas, Dallas, TX; 4-Dept. of Geological Sciences and Engineering, University of Nevada, Reno, NV; 5-Department of Geosciences, UMKC, Kansas City, MO

The Santa Rosalía basin in México's central Baja California peninsula records the sedimentary record of Gulf of California rifting and subsequent tectonic uplift of the basin. Gravel and calcareous fossiliferous conglomerate and sandstone defined as Santa Rosalía formation were deposited unconformably on the In- fierno, Gloria, and Boleo formations. The Santa Rosa Rosalía formation lies on the remnants of a broad uplifted terrace, called the "Mesa", that is found at elevations from 90 m to >300 m across the

region. This dramatic shift in sedimentation indicates a pronounce change in the tectonic history of the region that is not well documented. In January 2016, we initiated a study of the uplifted marine and fluvial terrace that are found along the arroyos and shoreline of the Santa Rosalía basin and of the undifferentiated Tertiary- Quaternary terrestrial conglomerates. We used digital imagery on field tablets to map the terrace surfaces and 3D outcrop imaging technologies using a DJI Phantom 3 drone and structure from motion software to map outcrops. We also described stratigraphic sections exposed in outcrops and in soil pits. Distinct 10 m, 25-30 m, 100, and 190 m marine terraces were identified. Four distinct fluvial terraces were observed in the Arroyos Santa Agueda, Boleo, and Providencia with deeper and better-developed soil profiles correlating with higher elevation from modern equivalents. GIS analyses of the fluvial surfaces indicate elevation breaks and fluvial incisions between marine and fluvial terraces. Deposits from the La Reforma and Tres Vírgenes volcanic complex interfinger with terrace deposits in an area that was not studied but provide stratigraphic control of the age of terraces. Furthermore, interbedded volcanic ash, provenance studies, surface age dating, and other data are likely to further our understanding of the tectonic evolution of this Santa Rosalía basin.

MATTHEWS, VINCE

Neogene Tectonism in Colorado

Vincent Matthews, Leadville Geology LLC, Leadville, CO

The dogma in Colorado during the 1960s was that the youngest deformation in the state was Laramide in age (80-40 Ma). Hence, all of the faults were considered to have been dead for 40 million years and thus there was no natural earthquake hazard in the state. In the intervening half century, an abundance of data shows that this is not accurate. Instead, Colorado is a center of active rifting with the potential for a major earthquake that could affect an under-designed building stock.

The catalogue of Quaternary faults in Colorado increased from 0 in 1969 to 87 in the latest inventory, and more than 350 faults that displace Miocene strata. Because of the large expanse of Proterozoic crystalline terrane, these figures are probably quite minimal. Neogene faulting is related to post-Laramide extension that is active today as the Rio Grande Rift. The rift trends ~N20W throughout the southern 2/3 of the state, but changes strike to N75W in the northern part of the state. GPS and stress indicators demonstrate these two fault trends are normal to extension in each area. These disparate stress orientations are consistent with a clockwise rotation of the Colorado Plateau away from the stable craton. The physiographic boundaries of the Colorado Plateau are not coincident with its structural boundaries on the east and northeast.

Distinguishing natural seismicity from triggered seismicity in Colorado has become increasingly important for seismic-hazard analysis, as well as design of oil and gas, injection operations.

MCCALPIN, JAMES

Paleoseismology of the Sangre de Cristo Fault

James McCalpin, GEO-HAZ Consulting, Inc., Crestone, CO 81131 USA; mccalpin@geohaz.com

The Sangre de Cristo fault (SCF) forms the eastern boundary of the Rio Grande rift over a length of 260 km, spanning the Colorado-New Mexico border. It is a west-side-down normal fault that separates the Sangre de Cristo Mountains (horst) from the San Luis Valley and Taos Plateau (grabens) in Colorado and New Mexico, respectively. Ruleman and Machette (2007) divide the fault into the Northern (NSCF) and Central (CSCF) Sangre de Cristo faults in Colorado (106 and 59 km long, respectively) and the Southern Sangre de Cristo fault (SSCF, 96 km long).in New Mexico. This paper describes the NSCF, which is divided into two sections (Crestone, 79 km; Zapata, 28 km) and the CSCF, divided into two sections; (Blanca, 2 km; and San Luis, 59 km). Additionally we describe the 19 km-long Villa Grove fault zone (VGF) which splays off the NSCF into the northern San Luis Valley.

In 1979-80 fault scarps were mapped from stereo aerial photographs, and 77 fault scarp profiles were measured manually in the field (McCalpin, 1982). Five trenches were dug across the NSCF in 1980, but only two of them yielded C-14 ages that closely constrained the age of the latest two faulting events.

Work on the fault resumed after a 20-year hiatus in 2001, with the establishment of the Crestone Science Center and excavation of the paleoseismic teaching trench on the Villa Grove Fault Zone. Several new trenches have been dug on the range-front Sangre de Cristo fault to test segmentation theories (Zapata section in 2003; northern Crestone section in 2003 and 2013). It now appears that the NSCF has a segment boundary near Valley View Hot Springs, defining a northern (Hayden) subsegment of the Crestone section. About 2/3 of past ruptures on the main Crestone section have broken through this boundary; the others have splayed off onto the VGF.

MOHANTY, ASMITA
Tectonic geomorphology of Late Pleistocene-Holocene landscape evolution and drainage migration, NW Himalaya, India

Asmita Mohanty1, Javed N Malik2 and Koji Okumura3; 1-Department of Earth Sciences, IITK, Kanpur, masmita@iitk.ac.in; 2-Department of Earth Sciences, IITK, Kanpur, javed@iitk.ac.in; 3-Graduate School of Letters, Hiroshima University, kojiok@hiroshima-u.ac.jp

The mighty Himalayan orogenic belt resulted due to the continent-continent collisional between Indian and Eurasian plates. The convergence between the two plates is taken up by numerous major thrust and strike-slip fault systems in Himalaya. The Himalayan Frontal Thrust (HFT) is the frontal most fault system of the Himalayan orogenic belt and is associated with a typical foreland folded structures. The present study area in the northwestern fringe of the Janauri anticline along the foothill zone of NW Himalaya Hajipur, Punjab, India revealed an excellent example of ongoing tectonic deformation. Lateral propagation of fold along the active faults has resulted into shifting/deflection of the Beas River by about 10 km towards NW. Displacements along the two parallel faults (Hajipur faults – HF1 and HF2) have uplifted the Beas River bed, resulted into formation of south facing fault scarps. To understand the tectonic evolution of this landscape we used high resolution satellite data (CARTOSAT–1 and CORONA). In total 6 terraces (T0-T5) and associated terrace risers were identified. We also demarcated 5-paleobanks suggestive of channel migration or shifting of Beas River caused by lateral propagation of fault and related folding. Three terraces (T0, T1, and T5) have been displaced along HF2 - well revealed by prominent south facing fault scarps ranging in height from 6 to 8 m. OSL ages obtained from terraces (T0 – 0.8±0.1 ka; T1 –0.98±0.07 ka; T2 – 2.78±0.15 ka and T4 – 12.44±0.7 ka) suggested the average shift of Beas River is about 40.39± 1.907 mm/yr.

MIYASHITA, YUKARI
Paleoseismic investigation of the Yunodake fault, Fukushima Prefecture, Japan

Yukari Miyashita, Institute of Earthquake and Volcano Geology, Geological Survey of Japan, AIST Central 7, Higashi 1-1-1, Tsukuba, Ibaraki 305-8567, JAPAN

On 11th March 2011, an earthquake off the Pacific coast of Tohoku occurred along the Japanese trench. The earthquake affected static stress changes to inland active faults in Northeast Japan, and induced the Fukushima-ken Hamadori earthquake (MJMA7.0) occurred on 11th April 2011. Remarkable surface ruptures appeared along the Yunodake fault and the western trace of the Itozawa fault at the induced earthquake. Although the NW-trending Yunodake fault is previously mapped with a normal down-to-the-SW sense of slip, its paleoseismic history is poorly understood. I conducted a trenching survey on the northwestern part of the Yunodake fault to reveal paleoseismic event timings. On the trench wall beneath the 2011 ruptures, a set of fissures and apparent reverse faults with positive flower structures was exposed. Detailed trench wall observation and radiocarbon dating revealed that the penultimate surface-rupturing earthquake occurred between about 1,000 and about 6,000 years ago, implying that the Yunodake fault was not activated by AD 869 Jogan earthquake which was the penultimate event of the 2011 Tohoku earthquake.

NIEMI, TINA
New paleoseismic data from the Lal Dhang trench site across the Himalayan Frontal Thrust in India

Niemi, Tina M. (1),Robyn L. Daniels (1), R. Jayangondaperumal(2); (1) Department of Geosciences, University of Missouri-Kansas City, 5100 Rockhill Road, Kansas City, MO 64110, USA. Email: niemit@umkc.edu; (2)Wadia Institute of Himalayan Geology, Dehradun, India

The Himalayan Frontal Thrust (HFT), also referred to as the Main Frontal Thrust, is the 2500 km-long fault system that marks the active southward-verging collisional boundary of the Eurasian plate with the Indian subcontinent. Defining the rupture segments for both recent and historical earthquakes have been a challenge especially in areas with long seismic gaps. In Fall 2015, a new paleoseismic trench, approximately 5-m-wide by 30-m-long and 8-m-deep, was excavated across the HFT in the Central Seismic Gap at the Lal Dhang site, where a >10-m-high fault scarp runs north-northwest along the fault. Excavation revealed evidence of faulting and folding of the depositional units of the fluvial terrace and floodplain. Two prominent, stacked, thrust faults with recumbent folded units were driven over horizontal units to the southwest. The exposed sections show heights of approximately 3-4 m for each fold, with a combined height of approximately 6.5 m, although erosion has reduced the original fold dimensions. Charcoal and OSL samples were collected from numerous locations in the trench to determine if the offsets occurred in one or more events, and to establish dates corresponding to those event(s).

NELSON, ALAN
AMS 14C Tests of correlations of great earthquakes along the Cascadia subduction zone, coastal Oregon

NELSON, Alan R., Geologic Hazards Science Center, U.S. Geological Survey, 1711 Illinois St, Golden, CO 80401, ENGELHART, Simon E., Department of Geosciences, University of Rhode Island, Woodward Hall, 9 East Alumni Avenue, Kingston, RI 02881, WITTER, Robert C., U S Geological Survey, Alaska Science Center, 4210 University Drive, Anchorage, AK 99508 and DUROSS, Christopher B., Geologic Hazards Science Center, U.S. Geological Survey, 1711 Illinois St., Golden, CO 80401, anelson@usgs.gov

After three decades of debate, consensus remains elusive about the rupture lengths and frequency of megathrust earthquakes at the Cascadia subduction zone. Radiocarbon ages for earthquake evidence from coastal wetland stratigraphic sequences generally overlap broad 14C-age intervals for the most widely correlated marine turbidites, triggered by shaking from the greatest (~M9) earthquakes rupturing much of the 1200-km-long subduction zone. But the times and number of lesser great earthquakes (~M8-8.8), which may have ruptured only a few hundred kilometers of the megathrust, are uncertain. Along-strike correlation of coastal earthquake evidence has largely relied on position in a stratigraphic sequence and maximum-limiting 14C ages with errors of decades to hundreds of years.

We consider 180 (72 unpublished) AMS 14C ages from the 12 best-dated sequences along 350 km of the Oregon coast to test along-strike correlations of stratigraphic contacts inferred to mark subsidence during great earthquakes and (or) inundation by their accompanying tsunamis during the past 2000 years. At each coastal site we selected the highest quality (least ambiguous stratigraphic context) plant macrofossils providing the closest maximum- and minimum-limiting ages for each contact predating the ~M9 AD 1700 earthquake. Comparison of OxCal-calculated age models for contacts at each site suggests three closely spaced earthquakes from 700-1200 cal yr BP, an interval previously considered to include coastal evidence for only two earthquakes. If accurate, the comparison implies incomplete stratigraphic records for some great earthquakes at some sites. Product means (with 2σ uncertainties) of OxCal age probability distribution functions yield great earthquakes at 798±55 (6 sites), 933±59 (3 sites), 1124±59 (6 sites), 1264±26 (5 sites), and 1546±23 (11 sites) cal yr BP.

OKUMURA, KOJI
Earthquake Geology of the April 14 and 16, 2016 Kumamoto Earthquakes

Koji Okumura, Graduate School of Letters, Hiroshima University, 1-2-3 Kagamiyama, 739-0045 Japan.
Email: kojiok@hiroshima-u.ac.jp

A Mw 7.0 earthquake hit west central Kyushu Island in west Japan at 01:25 JST on April 16, 2016. Reportedly 49 were killed, 1 is missing and more than thousand are injured as of April 27. 28 hours before, at 21:26 JST on April 14 another Mw 6.1 had shaken the same region severely. Intense ground shaking by two successive earthquakes caused structural damage in an extensive area. The shaking by a large number of aftershocks forced 90,000 people to evacuate from their homes no matter if the homes were damaged or not. And the extensive damage to infrastructures is making their lives more difficult.

Previously mapped and evaluated Futagawa and Hinagu fault zones are the sources of these two earthquakes. The Futagawa fault zone, the northeastern portion of the two fault zones, runs about 30 km ENE-WSW. The longest section of the NE portion is called Futagwa fault. The SSW-NNE trending Hinagu fault merges with the Futagawa near its west termination. The Futagawa fault is the source of the Mw 7.0 with 2 m+ right-lateral strike-slip at the surface. The Mw 6.1 earthquake resulted from slip on about a 15 km-long northernmost section of the Hinagu fault, but without surface rupture. Minor surface ruptures appeared in this section during the Mw 7.0 earthquake.

OSTENAA, DEAN
Updates to the Seismic Hazard Characterization of the Cheraw Fault, Southeast Colorado

Dean Ostenaa1 and Mark Zellman2; 1-Ostenaa Geologic, Dillion, CO; deano3geo@gmail.com; 2-Fugro Consultants, Inc., Lakewood,CO; m.zellman@fugro.com

The Cheraw fault is a rare, mid-continental Quaternary normal fault in North America. Crone et al., (1997) mapped a 45-km-long scarp, and based on a single trench found three surface ruptures since 20-25 ka, and suggested the prior interseismic period, extended to at least 100 ka. However, the existence of a numerous sinkholes and closed depression in the region, and Permian evaporates below the fault trace, raised questions regarding its seismogenic potential.
New constraints from mapping, shallow geophysical surveys, and boreholes, combined with interpretation of reprocessed industry 2D seismic reflection profiles, show: 1) the Cheraw fault extends an additional 15 km from its previously mapped northern termination, for a minimum total Quaternary rupture length of ~60 km, 2) offset of an early (?) Quaternary pediment along the northeast extension near the town of Haswell of ~3 m, is similar in magnitude to the post 20-25 ka offset of a late Pleistocene channel reported by Crone et al. (1997) along the main trace of the fault, 3) seven 2D seismic reflection lines show that the fault extends to depths of 2 to 3 km into lower Paleozoic strata and crystalline basement rock as a steep, discrete zone with a dip near 75□, 4) the surface fault trace is a reactivated structure, within a broader and complex zone with multiple periods of Paleozoic to late Cenozoic deformation, and 5) Quaternary surface faulting is not related to dissolution within the evaporate section. The seismic reflection data provide vertical offset estimates for early Cenozoic units that can be compared to scarp height and offset estimates for Quaternary datums along the fault. The implications of these new data for seismic hazard models, along with initial results of new trenching planned for spring 2016 will be discussed.

PISARSKA-JAMROZY, GOSIA
Earthquake-induced versus periglacially-induced load structures in clastic sediments

Pisarska-Jamroży, M.1, Van Loon, A.J. (Tom)2, Woronko, B.3; 1-Institute of Geology, Adam Mickiewicz University, Maków Polnych 16, 61-606 Poznań, Poland; pisanka@amu.edu.pl
2-Geocom Consultants, Valle del Portet 17, 03726 Benitachell, Spain; Geocom.VanLoon@gmail.com

3-Faculty of Geology, University of Warsaw, Żwirki i Wigury 93, 02-089 Warsaw, Poland; e-mail: bworonko@uw.edu.pl

The uplift of the earth crust after retreat of Pleistocene ice sheets was shock-wise, causing frequent, high-magnitude earthquakes. Earthquakes with a magnitude of at least 4.5-5 can be reflected in layers (seismites) that are characterized by abundant soft-sediment deformation structures (SSDS). Similar SSDS can, however, also be caused by a wide variety of other processes, including gravity-induced sliding or slumping, permafrost-related processes, and fluidization or liquefaction due to instable density gradients, to mention only the most common ones.

A loadcast of seismic origin can develop only if liquefaction takes place in the layer under the parent layer of the loadcast or its ultimate form, a pseudonodule. The type, size and complexity of SSDS in seismites are related to the magnitude of the earthquakes and the distance to the epicenter. The spatial distribution and lateral changes in the type, size and complexity of these SSDS can be consequently be used to locate the epicenter. In periglacial environments, pore water can induce intense deformation during temperature changes around 0°C. The freezing/thawing alternations during the Pleistocene glaciations affected many sediments, resulting in abundant SSDS.
The final morphology of SSDS resulting from liquefaction and fluidization (the most important processes during load casting) depend mainly on the initial sedimentary setting, the driving force and the duration of the deformable state, whereas the nature of the trigger mechanism seems to play a minor or negligible role. In other words, SSDS can have identical morphologies, independent of whether they originated due to a seismic shock or due to periglacial processes.

A fundamental question therefore now arises with the recently largely increased insight into the formation and characteristics of seismites: are all Pleistocene layers that contain abundant soft-sediment deformation structures and that were ascribed earlier to periglacial processes indeed due to periglacial processes, or were at least part of the deformations triggered by rebound-related seismic shocks?

PUCCI, STEFANO

Structural complexity and Quaternary evolution of the 2009 L'Aquila earthquake causative fault system (Abruzzi Apennines, Italy): a three-dimensional image supported by deep ERT, ground TDEM and seismic noise surveys

Pucci, S. (1), Villani, F. (2), Civico, R. (1), Di Naccio, D. (2), Sapia, V. (1), Di Giulio, G. (2), Vassallo, M. (2),Ricci, T. (1), Delcher, E. (3), Finizola, A. (3), Baccheschi, P. (2), Pantosti, D. (1);
(1) Istituto Nazionale di Geofisica e Vulcanologia, via di Vigna Murata 605, 00143 Roma, Italy.
(2) Istituto Nazionale di Geofisica e Vulcanologia, via dell'Arcivescovado 8, 67100 L'Aquila, Italy
(3) Laboratoire GéoSciences Réunion, Université de la Réunion, Institut de Physique du Globe de Paris, Sorbonne Paris-Cité, CNRS, UMR 7154, Saint-Denis, La Réunion, France.
Corresponding Author: Stefano Pucci, Email: stefano.pucci@ingv.it

We present results from a multidisciplinary workflow applied to image the three-dimensional architecture of the Paganica-San Demetrio (PSD) basin, epicentral area of the 2009 L'Aquila earthquake (central Italy). Field survey and LIDAR analysis yield to a new structural and Quaternary continental deposits map with an unprecedented detail for the area. Then, we collected several time domain electromagnetic soundings (TDEM), coupled with seismic noise measurements, and acquired three 2-D Deep Electrical Resistivity Tomography (ERT) transects, up to 6.36 km-long, focusing on the characterization of the bedrock/infill interface.

The surface investigations and the geophysical images allowed defining for the first time a complex basin architecture. We recognize two fault systems: (A) NNE- and WNW-trending conjugate extensional system, inherited from an ancient compressional phase; and (B) NW-trending dip-slip system. The two fault systems controlled individually a syntectonic, Quaternary deposition as evidenced by prograding and migrating alluvial bodies. The Quaternary continental infill buried under several depocentre (up to 500m deep) a dissected Mesozoic-Tertiary substratum. In general, the infill grew as the interference pattern due to the superimposition of the fault system B on A, occurred mainly at the lower Early Pleistocene.

Later, the B system prevailed in leading the sedimentary traps development and it is responsible for the present-day outline of the PSD basin. The leading faults ofB show a substantial stable long-term activity. Among them, an individual leading fault splay extends to 20 km because of a post-Early Pleistocene linkage of two smaller splays, showing an apparent interruption that originates from the inherited basin bottom morphology. Furthermore, major splays of the fault system A laterally limit the leading fault splay and now act as segment boundaries or possibly transfer faults between stepping segments. The results support repeated activity of a segment with a M6.6 maximum expected earthquake.

REGALLA, CHRISTINE
Evidence for late Quaternary surface rupture along the Leech River fault near Victoria, British Columbia, Canada

Christine Regalla1, Kristin D. Morell2, Lucinda J. Leonard2, Colin Amos3, Vic Levson2¬, Emily Rogalski1; 1-Department of Earth and Environment, Boston University, Boston, Massachusetts 02215, USA; 2-School of Earth and Ocean Sciences, University of Victoria, Victoria, British Columbia V8P 5C2, Canada; 3-Geology Department, Western Washington University, Bellingham, Washington 98225-9080, USA

We present results of new geomorphic and structural mapping of the Leech River fault that provide the first evidence for Quaternary surface ruptures along a crustal fault in southwestern British Columbia, Canada. The Leech River fault is a terrane boundary fault separating the Wrangellia Complex from basalts of the Metchosin Formation, that extends ~60 west from the capitol city of Victoria, British Columbia. The fault is not currently listed in a catalogue of active faults in Canada, and the last known slip of the fault is bracketed to the Eocene-Oligocene. However, based on new field and aerial mapping aided by2m LiDAR DEMs, we identify >60 individual, sub-parallel, linear scarps, sags and swales that occur in semi-continuous, en echelon arrays and that offset bedrock and late Pleistocene-Holocene deposits. Field surveys at three sties confirm that the identified scarps are not the result of anthropogenic, glacial or landslide processes, and in several places overly faulted bedrock with brittle fracture networks and gouge. At one site, reconstruction of fault slip across an offset post-last glacial maximum (~15 ka) colluvial surface near the center of the fault zonerequires~6 m of dip displacement of the colluvial surface, and ~4 m of displacement of intervening channels. These data argue that the Leech River fault experienced at least two ~M6 earthquakes since ~15ka.We interpret the mapped scarps to be associated with a steeply dipping fault zone that is 500-1000m wide and 30 - 60 km long, and suggest that the fault accommodates transpression across the Cascadia forearc. The Leech River fault may merge along strike with active faults in western Washington state, and is likely only one of a network of active crustal faults that may need to be considered in seismic hazard assessments for southern British Columbia.

ROCKWELL, TOM
Is the Southern San Andreas Fault Really Overdue For a Large Earthquake or Just Late in the Cycle?

Thomas K. Rockwell, Department of Geological Sciences, San Diego State University, San Diego, CA, USA; trockwell@mail.sdsu.edu

Compilation of paleoseismic data from several dozen trench sites in the southern San Andreas fault system, along with more precise dating of Lake Cahuilla sediments that cross many of these sites, allows for sequencing of the past 1100 years of large (M6.5 and larger) earthquakes for the southern 150 km of the main plate boundary system. Major faults capable of larger earthquakes include the San Andreas, San Jacinto, Elsinore, Imperial, Cerro Prieto, Laguna Salada, and possibly the Earthquake Valley faults. Displacement data have been generated for most of these faults for the past one to several events. Using these observations on timing and displacement in past large earthquakes, and assuming reasonable seismogenic thicknesses, estimates of moment release through time can be made. Based on these estimates, at least three generalizations are clear: 1) M7 and larger earthquakes account for most of the moment release in the southern San Andreas fault system over the past 1100 years; 2) large earthquakes on individual faults are quasi-periodic but display a relatively high coefficient of variation in

recurrence time, similar to most long California records; and 3) moment release has temporally varied during the past 1100 years but within potentially predictable bounds. A fourth observation is that inundation of Lake Cahuilla may have triggered some large earthquakes, as previously suggested, and that the lack of a lake in the past 300 years may partially explain the relatively long quiescence of the southern San Andreas fault system. Together, the record suggests that the southern San Andreas fault is late in the cycle but not necessarily "overdue", and that a systems level approach may be more accurate in long term earthquake forecasting than data generated from a single element of the fault system.

SCHARER, KATE
Testing geomorphology-derived rupture histories against the paleoseismic recordof the southern San Andreas Fault

Scharer, Katherine, U.S. Geological Survey, Pasadena CA 91104, kscharer@usgs.gov
Weldon, Ray, University of Oregon, Eugene, OR, ray@uoregon.edu

Evidence for the 340-km-long rupture of the 1857 Fort Tejon earthquake is found at each of the high-resolution paleoseismic sites on the southern San Andreas Fault: Bidart Fan, Frazier Mountain, Elizabeth Lake, Pallett Creek and Wrightwood. Using trenching data from these sites, we evaluate if the M7.8 rupture was typical, or presents a unique event in the last thousand years, and then compare these results to geomorphic-offset derived rupture histories. At each location, trenching investigations conclude the average interval between paleoearthquakes is ~90 to 140 years and the coefficient of variation (CV) is ~0.6 (Biasi et al., 2013). The assemblage of dated paleoearthquakes, constrained by displacements from 3D trenching where available, produces a range of rupture lengths from 50 to 350 km long with variable displacement profiles and requires >60% of ruptures are smaller than 1857. In stark contrast to this variability, reconstructions of the paleorupture lengths from preserved geomorphic offsets extracted from lidar are long (100-300 km) and flat (Zielke et al., 2011), and have repeating displacements that are more regular (CV=0.2; Zielke et al., 2014) than from a global dataset (CV=0.5; Hecker et al., 2013). Direct comparison of the two datasets shows that paleoruptures determined from geomorphic offset populations cannot be reconciled with dated paleoearthquakes on the southern San Andreas Fault. We explore two factors that influence this discrepancy: (1) a statistical approach to determining geomorphic offsets that minimizes uncertainties, (2) a saturation in displacements in ruptures greater than ~200 km that is not recognized in global rupture length versus displacement regressions. Our study concludes that the 1857 rupture was larger than average and should not be used as the template for which all past ruptures are interpreted and emphasizes the need to date geomorphic offsets so these can be tied to the paleoearthquake record.

SCHNEIDERWIND, SASCHA
The Geometry of Tidal Notches – What do they reveal about historic coastal tectonics?

Schneiderwind, Sascha (1), Kázmér, Miklos (2), Boulton, Sarah (3), Papanikolaou, Ioannis (4), Stewart, Iain (3), Reicherter, Klaus(1); 1-Neotectonics& Natural Hazards, RWTH Aachen University, Lochnerstr. 4-20, 52056 Aachen, Germany.s.schneiderwind@nug.rwth-aachen.de; 2-Department of Palaeontology, Eötvös University, H-1117 Budapest, Pázmány Péter sétány 1/c, Hungary; 3-School of Geography, Earth and Environmental Sciences, Plymouth University, Plymouth, DevonPL4 8AA, UK; 4-Laboratory Mineralogy – Geology, Agricultural University of Athens, Iera Odos 75, Athina 118 55, Greece.

Tidal notches along steep rocky calcareous coastlines have been the subject of research for many years. In the Mediterranean especially, these studies have aimed to derive information about Holocene relative land movement and coastal tectonic activity. It is generally accepted that tidal notches form at mean sea-level where the resulting notch height equals the tidal range. Therefore, when older features above or below the tidal range are offset from present-day sea-level, coastal uplift or subsidence, respectively, can be inferred. However, the extraction of quantitative information on the relative sea level change is controversial since tectonic uplift from a single seismic event, in extensional tectonic settings, is not likely to exceed several decimetres and thus the tidal range.

In order to review existing knowledge regarding notch formation, and to improve the identification of tidal notches, we applied analogue and logical modelling to investigate shape modification of notch sequences. The contributors to notch erosion are chemical, physical and biological agents. Endolithic bivalves, chitons and limpets live in galleries at mean sea-level, frequently immersed by periodic tides. Consequently, the deepest indentation at mean sea-level is also the inflection point for a symmetrically shaped notch. Arithmetically, the ideal notch shape - neglecting parameters such as lithological inhomogeneity or spray zones above high tide- follows symmetry such as those from a quadric function. A gradual build-up of a stationary model fed by empirical earthquake data indicates how overlapping former and newly created erosional zones may interact, and thus how older features get overprinted over successive events. Potentially, only minor changes in the surface curvature records older erosional bases. However, recognizing erosional remnants enables the reconstruction of a relative sea-level history, and knowing the overall erosion rate is not necessary since the tidal range defines the notch height.

SCHNEIDERWIND, SASCHA
Numerical Modelling of Tidal Notch Sequences on Rocky Coasts

Schneiderwind, Sascha (1), Kázmér, Miklos (2), Boulton, Sarah (3), Papanikolaou, Ioannis (4), Stewart, Iain (3), Reicherter, Klaus(1); 1-Neotectonics& Natural Hazards, RWTH Aachen University, Lochnerstr. 4-20, 52056 Aachen, Germany.s.schneiderwind@nug.rwth-aachen.de; 2-Department of Palaeontology, Eötvös University, H-1117 Budapest, Pázmány Péter sétány 1/c, Hungary; 3-School of Geography, Earth and Environmental Sciences, Plymouth University, Plymouth, DevonPL4 8AA, UK; 4-Laboratory Mineralogy – Geology, Agricultural University of Athens, Iera Odos 75, Athina 118 55, Greece.

The development of tidal notches at sea-level suggests these features could be compelling archives of relative land movements and coastal tectonic activity when uplifted, or subsided, relative to present-day sea-level. However, decoding a quantitative record of tectonic activity from notch profiles is an outstanding challenge. Tidal notch formation occurs within the tidal range at a given erosion rate, predominantly against limestone coasts. Therefore, a certain period of time is necessary, where eustatic sea-level rise and isostatic regional uplift appear at the same rate in order to form the famous U-/V-shaped notch profiles. The duration of this time period controls the indentation into the cliff (notch depth), while the resulting notch height is a consequence of the tidal range. Additionally, notch morphology can be modified by rapid relative movement due to seismic events. Yet in extensional tectonic settings, coseismic uplift is not likely to exceed several decimeters. Therefore, a rapid seismic event where the amount of uplift exceeds the tidal range is required to lift the former notch completely above the tidal range and place previously unaffected lower parts of the cliff in the erosional zone. However, if the rapid uplift does not exceed the tidal range the new erosional base overprints existing notches. In order to investigate successive modifications of coastal cliff morphology we developed a numerical model in MATLABTM. The software centers all requirements and makes algorithms transparent. The prototype model enables the adjustment of aforementioned input parameters and calculates gradual modifications in accordance to a chosen sea-level curve. Preliminary results show, that (I) significant notch formation occurs since 6 kyrs BP but individual shapes vary due to minor sea-level changes, and (II), dependent on the event date, the present-day notch sequence from top to sea-level is not inevitably of descending age.

SMITH, COLBY
Holocene paleo-seismicity of the Bollnäs fault derived from terrestrial and hydroacoustical records

Colby A. Smith, Martin Sundh, Johan Nyberg, Björn Bergman, and Henrik Mikko; Geological Survey of Sweden, Uppsala, Sweden

Despite the intraplate setting, Fennoscandia experienced high-magnitude seismicity during the Holocene. Following deglaciation, preexisting bedrock faults were reactivated by a combination of tectonic and isostatic stresses. These so called post-glacial faults are well-documented in the north, but recent high-resolution digital elevation data shows linear escarpments that appear to cut across glacial sediments in

central Sweden, some 400 km south of previously mapped structures. One such feature lies just west of the town of Bollnäs and has undergone extensive terrestrial and hydroacoustical investigations to determine its origin.

Three lines of evidence support the interpretation that the escarpment results from post-glacial faulting. 1) Trenches excavated across the scarp reveal faulted glacial sediments and landslides down the scarp overlain by undisturbed flat lying sediments. 2) Trenches atop an esker reveal water escape structures, interpreted to be seismites. 3) Numerous paleolandslides exist in non-susceptible deposits on low-angle slopes. The rupture dimensions suggest a paleo-seismic event of magnitude ~6.2. The stratigraphy of the trench indicates that faulting occurred shortly after deglaciation and is consistent with bog bottom dates from landslide scars that indicate sliding occurred prior to 10,200 calendar years before the present. These results are consistent with modeling results of fault instability following deglaciation.

The scarp is visible on opposite sides of Lake Voxsjön. Hydroacoustically-derived imagery show that it is traceable across the lake in the bathymetry. Additionally, sub bottom profiling indicates glacial sediments have been vertically offset by ~2-4 m and overlain by undisturbed flat lying sediments. These results are identical to those seen on land and provide a benchmark for how post-glacial faults appear in hydroacoustical data sets.

SPIES, THOMAS

Establishment of an up-to-date database for seismic hazard assessment in Germany and Central Europe using paleoseismic,neotectonic and historical evidence

Thomas Spies, Jörg Schlittenhardt, Diethelm Kaiser, Klaus Reicherter und Jochen Hürtgen,
BGR and RWTH Aachen, Germany

For reliable seismic hazard assessment an up-to-date data base must comprise historical and paleoseismic evidence and all additionally available information on the locations and properties of seismic sources, e.g. on active faults and -supplementary in areas of moderate seismicity- also models of seismotectonic zones. Paleoseismic investigations in the United States helped to refine seismicity and the locations of seismic sources in the Central and Eastern part which is a region of moderate seismicity like Central Europe. In Germany a new rule for the seismic safety of nuclear facilities demands the use of historical seismicity and of paleoseismic data as well as the use of relevant current geoscientific data to establish seismotectonic source zones. According to these demands the historical seismicity is being reviewed continuously and a data base of existing paleoseismic evidence in Central Europe was established. Looking at historical seismicity in Germany 1200 years can be overlooked but many of the events have to be re-evaluated by modern standards of historical research. The paleoseismic database obviously lacks a lot of information in Central Europe. One distinct approach of extension of data will be the detailed look at soft sediment deformation in Northern Germany which can indicate seismic events in the Quaternary as has been shown in exemplary investigations yet. Additionally a database of active faults and seismogenic structures will be compiled using current seismological, tectonical and geological data. Further on a concept for the derivation of seismotectic zoning will be developed. Up to now such models for Germany mainly relied on observed seismicity and fault patterns revealed by remote sensing. The concept will take into account the geological development of the region, the neotectonic situation and geophysical data characterizing the seismogenic zones in the crust which in Central Europe often cannot be attributed to deformation features at the surface.

STEMBERK, JAKUB

Valley evolution of the Biala Lądecka drainage network during late Cenozoic, Lower Silesia, Poland

Jakub STEMBERK1,2, Petra ŠTĚPANČÍKOVÁ2, Petr TÁBOŘÍK1,2; 1-Department of Physical Geography and Geoecology, Charles University in Prague, Albertov 6, Prague 2, 128 43, Czech Republic; kuba.stemberk@gmail.com; 2-Institute of Rock Structure and Mechanics, Academy of Sciences of the Czech Republic, Dpt. Engineering Geology, V Holešovičkách 41, Prague 8, 182 09, Czech Republic; 3-Institute of Hydrogeology, Engineering Geology and AppliedGeophysics, Charles University in Prague, Albertov 6, Prague 2, 128 43, Czech Republic

Biala Lądecka (Biala Kłodzka) river is located in Lower Silesia (Poland) and its valley separates Góry Złote Mts. (Rychlebskéhory Mts.) on the northeast from Góry Bialskie Mts. on the southwest. During last year we dealt with geomorphology research in Biala Lądecka river basin, which has a noticeably asymmetrical river basin, probably due to Quaternary tectonic activity of the Sudetic Marginal Fault. According to old research provided in this area by L. Finckh and G. Götzinger (1931), W. Walczak (1954) and A. Ivan (1966), Biala Lądecka riverused to flow across the Góry Złote Mts. directly to Oderskánížina Lowland during Pliocene; currently it flows to Nysa Kłodzka Basin. Our research was focused on analysis of all available cartographic materials (geological and topographic maps), available literature and own detail geomorphological mapping of selected landforms. Spatial distribution of these landforms such as gullies, erosion trenches, dellens, alluvial plains, alluvial fans, springs, swamps, river terraces, could potentially indicate recent tectonic activity in the studied area. Moreover, stream network parameters (based on DEM data) such as changes in erosion intensity indicated in longitudinal and cross-section profiles, slope gradient and morphometric indexes, e.g. Stream Length (SL) index (Hack 1973),for Biala Ladecka river basin were analyzed. On selected places geophysical research was also performed to discover rests of sediments of the Biala Lądecka paleoriver.

The results will also complete the research focused on tectonics in the adjacent areas, e.g. paleoseismologic studies on the SMF (Štěpančíková et al. 2010, 2011), monitoring using dilatometric gauges TM71 installed on the SMF (Stemberk et al. 2010), etc. Some of preliminary results will be presented.

ŠTĚPANČÍKOVÁ, PETRA

Applicability of complex geophysical surveying in paleoseismic studies: three case studies from Bohemian Massif

Štěpančíková Petra1), Táborík P.1, 2), Hartvich F.1), Stemberk J. jr.1, 2),Vilhelm J.2), Fischer T.2), KarousováM.2), Špaček P.3), Široký J.2), Rockwell T.4), Havaš M.5); 1)Inst. of Rock Structure and Mechanics, Czech Acad. of Sci., Prague, Czech Rep.; 2) Faculty of Science, Masaryk Univ., Brno, Czech Rep.; 3) Faculty of Science, Charles Univ., Prague, Czech Rep.; 4) Dept. of Geol. Sci., San Diego State Univ., California; 5) Faculty of Science, Ostrava University, Czech Rep.

During last decade, several faults in Bohemian Massif that were re-activated during Quaternary were studied. We present three case studies from various geological environments where extensive 2-D and 3-D geophysical survey preceded and accompanied paleoseismic trenching survey, thus the results of geophysics could be correlated with the lithology exposed in the trenches. The methods included (i) direct current (DC) geoelectrical surveying, i.e. electric resistivity tomography (ERT) and micro-scale resistivity profiling (mRP); (ii) electromagnetic (EM) surveying, i.e. ground penetrating radar (GPR) and dipole electromagnetic profiling (DEMP); and (iii) shallow seismic refraction (SSR) and seismic tomography (ST).

First trenching site is Bílá Voda, situated in the north-eastern part of the Bohemian Massif where morphologically pronounced NW- trending Sudetic Marginal fault controls the mountain front of the Sudeten mountains at the length of 140 km. Due to distinct physical rock properties on the both sides of the fault, remarkable horizontal gradient in electric resistivity clearly showed the fault position and identified more resistive crystalline bedrock juxtaposed to conductive Miocene clayey sands covered by a veneer of alluvial fan deposits. Also limit of the alluvial fan deposits and its thickness was identified, which helped in interpretation of paleoseismic survey such as sense of the movements.

The second site Brodek, situated in the Upper Morava basin, a Late Cenozoic tectonically active region located at the contact of Bohemian Massif and the Western Carpathians' orogenic front, on the Holešov fault, which controls the SE basin margin. Both 2-D and 3-D geophysical measurements clearly distinguished between two different sedimentary units and, thus, indicated the position of the studied fault.

The third site, Kopanina exposed Mariánské Lázně fault controlling the Cenozoic Cheb-Domažlice graben in the western Bohemian Massif. Trenching survey revealing Holocene activity was combined with 2-D ERT, 3-D GPR and 3-D conductometry (DEMP)in order to extent the fault properties to the depth and laterally and traced the faults as well as displaced sedimentary bodies.

The case studies showed the usefulness and suitability of an individual method depending on different geological conditions.

SUTINEN, RAIMO
Postglacial faults and paleolandslides in western Finnish Lapland

R. SUTINEN1, T. RUSKEENIEMI2 AND M. MIDDLETON1;1-Geological Survey of Finland, P.O. Box 77, 96101, Rovaniemi, FINLAND; 2-Geological Survey of Finland, P.O. Box 96, 02151, Espoo, FINLAND

High-resolution LiDAR-based digital elevation models provide an efficient tool to detedect postglacial fault (PGF) scarps and paleolandslides beneath forest canopies. The spatial distribution of these features tend to be coincidental hence suggesting that dating of landslide-buried organic materials will provide evidence on the frequency of the past earthquakes.

We percussion drilled through the paleolandslide accumulations to find buried organic materials and were able to reveal several samples for the C14 datings. In Kittilä, the Taalovuoma buried organic sediments yielded 5050 yrs cal BP. In Kolari, Lehtolaki site provided data on three different paleoslide events with following ages: 1275, 1585, 5860, 10185 yrs calBP. In addition, three basal peat samples yielded 9220, 9480 and 9510 yrs cal BP from peat bogs developed on the foot wall of the Ruokojärvi postglacial fault, just next to the fault scarp in Kolari.

Our previous finding of landslide-buried woody remnants of birch yielded 9730 yrs cal BP in Kittilä. We therefore propose that earthquakes around 9500-10200 yrs cal BP, 5000-5900 and 1200-1600 yrs cal BP occured in western Finnish Lapland. Historical earthquakes (M<4) are spatially coincidental with PGFs, yet our results suggest that the recurrence interval of major earthquakes may be of the order of 4000 years within the Fennoscandian plate.

TATEVOSSIAN, RUBEN
Scarps associated with non-tectonic activity

R.E. Tatevossian, E.A. Rogozhin, Institute of Physics of the Earth, RAS, Ul. B. Gruzinskaya, 10, Moscow, Russia, ruben@ifz.ru

The Ganges–Brahmaputra Delta (GBD), the world's largest delta, has been built from sediments eroded from the Himalayan collision. These sediments prograded the continental margin of the Indian subcontinent by ~400 km, forming a huge sediment pile that is now entering the Burma Arc subduction zone. The Rooppur NNP site is located almost in the central part of the GBD, close to Ganges River banks. Although the site is located more than 300 km away either from Indo-Burma subduction zone to the east or from Himalayan collision zone to the north, these global-scale structures govern to a great extent the seismicity and seismic hazard in the site vicinities. Regional seismic network is missing in Bangladesh; knowledge on local seismicity is poor. A local seismic network was organized; it found only diffused weak seismicity pattern in site vicinities. Some suspicious scarps were found within the site limits. They were cut by three trenches. Inclined layers of the trench walls are interpreted as an evidence of erosion effect (not tectonic) caused by fluctuations of Ganges River flow-course. Possibly, for the first time trenches across the scarp did not reveal tectonic activity.

THAKKAR, MAHESH
Review of Paleoseismic and active tectonic studies and Earthquake hazard potential in Kachchh paleo-rift basin, Western India

M. G. Thakkar, Department of Earth and Environmental Science, KSKV Kachchh University, Bhuj-Kachchh-370001, INDIA; mgthakkar@rediffmail.com

Kachchh intra-plate, pericratonic paleo-rift basin generated during the rifting of Gondwana in early Triassic, the resulted half-grabens facilitated the Mesozoic sediments. Post Indo-Eurasia collision tectonics has evolved the once subsided cratonic blocks to the recent uplifted blocks as positive topography with flat salt playa landscape. They evolved through the original weak planes that behaved normal during rift and reverse during uplift. The E-W running master faults are yet not at rest and witness major to great earthquakes in Quaternary period. The overall stress from south to north in the basin squeezes the crustal blocks upward along major basin bounding faults. The present review pertains to paleoseismic and active tectonic studies that carried out in last two decades in Kachchh. Two large magnitude earthquakes struck in last two centuries on different faults and geographic locations. Allah bund earthquake in 1819 generated a 90km long ridge across playa landscape. The 2001 Bhuj earthquake revealed atypical characteristics of large intra-plate earthquakes with innumerable liquefactions; secondary surface deformations and lateral spreads. Trench studies at 2001 instantaneous off fault features near epicenter unfold a 4000 years old event. The flexuring and faulting in Quaternary gravels resting on the active Katrol Hill Fault exhibit three events in 21ka time. The Bhuj earthquake since struck in instrumental period, stratigraphic and topographic changes prove analogous for similar earthquakes in intra-plate settings. The studies along active KMF and SWF will eventually summarize recurrence for entire basin. The liquefaction, seismic microzonation and recent seismicity with palaeoseismic characterization recapitulate earthquake hazard potential zones mostly to the east of the N-S median high axis. The other vulnerable zones away from the active fault rupture lines are tracks of alluvial cover of Samakhiyali plain. The present review suggests planning of small towns in active regions rather than the large cities.

THOMAS, JESSICA

Towards an Active Fault Assessment in the Southern Upper Rhine Graben

J. Thomas, S. Baize, J. Hürtgen, K. Reicherter; RWTH Aachen University, Aachen, Germany

A brief overview at a seismic map of the Upper Rhine Graben area (between Strasbourg and Basel) reveals that the region is seismically active. The area has been hit recently by shallow and moderate quakes but, historically, strong quakes damaged and devastated populated zones. Several authors previously suggested, through preliminary geomorphological and geophysical studies, that active faults could be traced along the eastern margin of the graben. Thus, fault-based PSHA (probabilistic seismic hazard assessment) studies should be developed.

Nevertheless, most of the input data in fault-based PSHA models are highly uncertain, based upon sparse or hypothetical data. Especially the Freiburg area located on the eastern border is missing in paleoseismic studies.In the frame of the pre-trenching survey we did geophysical measurements in that area. Both shallow ground penetrating radar profiles and electrical resistivity tomography show promising results indicating that one of the eastern boundary faults, the Rhine River Fault, was active relatively recently.

Moreover our preliminary analyses suggest that the LiDAR topography can adequately image the fault segments and, thanks to detailed geomorphological analysis, these data allow tracking cumulative fault offsets.

Because the fault models can be considered highly uncertain, our coming project for the next 3 years is to acquire and analyze these accurate topographical data, to trace the active faults and to determine slip rates through relevant features dating. We plan to find an appropriate trenching site to add paleoseismological data because this approach has been proved to be worth in the Rhine Graben, both to the North (Worms and Strasbourg) and to the South (Basel). This would be done in order to definitely prove whether the faults ruptured the ground surface during the Quaternary, and to determine key fault parameters such as magnitude and age of large events.

VARGAS-EASTON, GABRIEL
The San Ramon thrust fault at the eastern border of Santiago city, Chile: Paleoseismological implications from the linkage between piedmont units and fluvial terraces

Gabriel Vargas-Easton, Departamento de Geología, CEGA, Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile, Plaza Ercilla 803, Santiago, Chile; gvargas@ing.uchile.cl

The San Ramón fault is an active west-vergent thrust fault system located along the eastern border of Santiago, capital city of Chile, at the foot of the western slope of the main Andes Cordillera. The structural system is composed of segments on the order of 10-15 km length, evidenced by conspicuous 4-over 100 m height scarps systematically located along the fault trace that affect Quaternary piedmont units, suggesting slip rate in the order of ~0.4-0.5 mm/year. Recent observations from a paleoseismological trench excavated across a prominent 4-5 m high escarpment revealed two ruptures of estimated magnitude Mw 7.2-7.5 in the past 17,000-19,000 years, with the last large earthquake having occurred nearly 8,000 years ago.
New observations from additional trenches as well as natural outcrops and geochronological results from the youngest units along the piedmont of Santiago valley, together with subsurface geophysics, reveal the structure of the fault and support the idea of two major events in the last 16-17 ka. The geomorphology of Quaternary fluvial terraces that crosses the fault system indicates increasing incision rates toward the structural front up to ca. 1 mm/year, from which 0.4 mm/year of vertical offset from deformed and tilted terraces, in the last ca. 86 ka.
The available data demonstrate the consistency of tectonic markers along the entire fault system, supporting the Quaternary activity of this fault and its potential for generating strong earthquakes with superficial rupture along the eastern border of Santiago. From the available geochronological results it is possible to infer a probability of ca. 3% for the occurrence of a major earthquake in the next century.

VILLALOBOS-CLARAMUNT, ANGELO
New evidences of the cortical origin of the seismic crisis of 2007 in the Aysén Region, Southern Chile

Angelo Villalobos-Claramunt1*, Gabriel Vargas1, Andrei Maksymowicz2 y Galderic Lastras3;
(1) Departamento de Geología, Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile, Plaza Ercilla 803, Santiago, Chile; (2) Departamento de Geofísica, Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile, Av. Blanco Encalada 2002, Santiago, Chile; (3) Geociències Marines, Universitat de Barcelona, Barcelona E-08028, España. angelovillalobos42@ug.uchile.cl

On April 21, 2007, an earthquake magnitude 6.2 Mw hit the Aysén Region, Southern Chile. This event corresponds to the largest earthquake in a sequence (called the Seismic Aysén Crisis) that started to be perceived on January 10, 2007, with a small tremor of magnitude ML< 3 and continued until February 2008. The affected area is characterized by the presence of the Liquiñe-Ofqui Fault System (LOFS), corresponding to the main neotectonic and seismotectonic feature of Southern Chile. In this research, we present new paleoseismological and geomorphological evidences obtained using reflection seismic profiles and high-resolution bathymetry that let us to constrain the seismic source to a cortical origin. It is established that the Punta Cola Fault (PCF), a branch of the LOFS with ~NS strike and dextral kinematic, with a reverse component expressed in a positive flower geometry visible on seismic profile, was responsible for the mainshock. Furthermore this structure generated enough deformation to produce surface rupture with fault scarps on the seafloor. Finally, identifying paleo-mass removals, we propose that at least three similar cortical events have occurred in the area of the fjord since the retreat of the glacier ice cap 12 ky ago.

WECHSLER, NETA
On the accuracy of topographic models derived from UAV photography

Neta Wechsler1, Oded Katz2, Amit Mushkin2; 1. Department of Geosciences, Tel-Aviv University, Isrrael; 2. Geological Survey of Israel, Jerusalem, Israel

The use of automated photogrammetric methods to generate topographic models have become ubiquitous in recent years, the result of increasing availability of UAVs equipped with high resolution digital cameras, of commercial and open-source processing software and of increasing computing power. The cost of conducting a Structure-from-Motion DTM model is now a small fraction of the cost of Airborne Lidar (ALS) and takes considerably less time than using ground based Lidar (TLS). This allows for rapid-response mapping of geomorphic features, such as surface ruptures, extreme deposition/erosion events, etc. The accuracy of UAV mapping depends on many factors such as ground control, quality and number of images, etc. In this study we compare topographic models acquired over various terrains with a small UAV to models acquired using ALS and TLS and discuss the accuracy of UAV-based models. The first case study is located at the northern shore of the Sea of Galilee, Israel. An area of several km2 was recently devegetated by the Israel Park Service, offering a unique opportunity to map part of the Dead Sea fault which was obscured by vegetation beforehand. A UAV survey was conducted in the fall, before winter growth, in order to map the geomorphic signature of the fault. We compare the obtained DTM with the ALS-derived bare-earth model, generated prior to the denudation. The second site is along the coastal cliff at Olga beach, Israel. The cliff is monitored for rate of retreat over several years using TLS surveys, ALS being less useful for vertical cliff faces. A UAV mapping campaign was conducted along part of the cliff and the results compared with ALS and TLS topographic models. We show that in unconventional settings, UAV can perform with adequate accuracy and has the advantage of being cheap, fast and easy to utilize.

WHITNEY, BEAU

Seismic source characterization in the Western Australia Shear Zone using 2D seismic data: the Dampier fault

B.B. Whitney1 and J.V. Hengesh2; 1 Centre for Energy Geoscience, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia; 2Interface Geohazard Consulting, 20 Plumeria Pl., Lahaina, HI, 96761, USA (hengesh@gmail.com); Also at the Centre for Offshore Foundation Systems, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia; Corresponding author: Beau Whitney, beau.whitney@uwa.edu.au

The Western Australia Shear Zone (WASZ) consists of several distinct sections that each have unique structural styles. The 91 km long Dampier fault section, in the northern Carnarvon Basin, forms an 11km wide fault zone across a reactivated Mesozoic graben. The fault zone cross-cuts Quaternary age sediments producing a net down-to-the-north sense of displacement observed on 2D seismic transects. The east-west trending fault zone is oblique to the dominantly northeast trending Mesozoic structural fabric.

Fault offsets are estimated using displacements of several horizons that extend across the northern Carnarvon Basin; displacements are estimated from two way travel time (TWT) assuming a seismic velocity of 1600 m/second. From seismic line s136:136_24, the cumulative down-to-the-north vertical displacement of the 2.6 Ma horizon is 0.08 to 0.14 second TWT, or 64 to112 m. The cumulative down-to-the-north vertical displacement of the 1.0 Ma horizon is 0.04 to 0.05 second TWT, or 32 to 40 m. The cumulative down-to-the-north vertical displacement of the 0.5 Ma horizon is 0.015 to 0.02 seconds TWT, or 12 to 16 m.

The estimated vertical slip rates for the Dampier fault based on total fault displacement of the 500 ka to 2.6 Ma horizons ranges from0.02 to 0.05mm yr-1. Based on regressions between fault length and magnitude we estimate a maximum earthquake magnitude distribution on the order of Mw 7.2 to 7.5 with a range of recurrence intervals between 30,000 to 137,000 years. The estimated vertical slip rates are minimum values, yet significant with respect to an intraplate tectonic setting; any horizontal component of motion may increase the recurrence rates. These slip rate, recurrence, and Mmax estimates are similar to other seismic sources within the WASZ, which are consistently higher and larger than adjacent non-extended cratonic terranes.

WILLIAMS, ALANA
Shorter and variable recurrence intervals along the Cholame segment of the San Andreas Fault

Alana Williams, J Ramon Arrowsmith, Arizona State University, Tempe, AZ

Paleoearthquake data from the Cholame segment of the San Andreas fault (SAF) are important for testing earthquake recurrence models along the central SAF. Slip per event or few event information coupled with tightly constrained event age control is needed to build a catalog of paleoearthquakes between the Parkfield and Carrizo sections of the SAF. We excavated five exploratory fault perpendicular trenches within an abandoned gypsum mine (35.253478, -119.585675) in the southeastern portion of the Cholame segment. The trenches did not reveal adequate preservation of rupture evidence to provide estimates for recurrence interval. In summer 2016, we will expand our earthquake geology research to promising new sites in the northern central portion of the Cholame segment

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YANXIU, SHAO
Fault slip behaviour of North Danghe Nanshan Thrust (NDNT) from high resolution topography data and paleoearthquakes

Shao Yanxiu (1,2), Wang Pengtao (1), Yuan Daoyang (1), Liu-Zeng Jing (2), Wu Zhao (1)
(1) Lanzhou Institute of Seismology, China Earthquake Administration, Lanzhou, 730000, China
(2) State Key Laboratory of Earthquake Dynamics, Institute of Geology, China Earthquake Administration, Beijing, 100029, China; Email: shaoyx@geoidea.org

New surveying and mapping technology, which can acquire high resolution topography quickly, is being used to study active tectonics in recent years. The results were great for earthquake reoccurrence model of large strike slip faults. Similar studies, however, were not carried out on active thrusts. We are studying earthquake reoccurrence model of North Danghen Nanshan thrust, which has different degree scarps, under because of thrusts' destruction. Our study is based on not only high resolution topography but also paleoearthquakes. Firstly, we used small Unmanned Aerial Vehicle (sUAV) and terrestrial LiDAR to construct high resolution Digital Elevation Model (DEM), and based on which to measure scarps along fault. We employed statistical methods such as probability density function to get accumulated slip distribution along fault and peak slip values. The number of earthquakes on different degree scarps were analysed according to slip distribution and peaks. Meanwhile, we also excavated trenches across different degree scarps to attain paleoearthquakes from successive depositional walls directly. The paleoearthquakes were compared with the result inferred from slip at last. Our primary result shows that it is valid to study active fault rupture mechanics from slip distribution, and slip behaviour of this thrust coincide with characteristic earthquake mode.