Keywords: recurrence period; paleoearthquakes; Eastern Iberia; trenching

Paleoseismic studies performed in eastern Iberian Peninsula have revealed the presence of seismogenic faults characterized by slow slip-rate. Evidence of several large prehistoric earthquakes was provided along the El Camp normal fault to the NE (Catalan coastal ranges) and of the left-lateral Alhama de Murcia fault to the southeast (eastern betics) despite the complication of obtaining a long enough and continuous record in such slow-moving faults. In the former, eight trenches were analyzed and three paleo-earthquakes interpreted to be younger than 125 ka being the last possibly not older than 3000 yr. Additionally, a minimum of two pre-125 ka earthquakes (younger than 300 ka) were also detected even though their evidence is poor. Therefore, a recurrence period of 60 ka since 300 ka and of 30 ka since 125 ka is attributed to the El Camp fault. In the Alhama de Murcia fault two events were detected along four trenches in the central segment of the fault (Lorca-Totana) resulting in a recurrence period of 14 ka, and one in the southern segment (three trenches, in progress). Recurrence values, however, include a large number of uncertainties: little dating constraints, little number of evidence repeated trench to trench, non continuous record (alluvial fans), little amount of earthquakes, etc. Following these uncertainties: Are the recurrence values obtained in such slow-moving faults reliable?.

271-3 Oral Radulov, Alexander Georgiev

TRENCHING EVIDENCE FOR THREE POST-GLACIAL SURFACE-RUPTURING EARTHQUAKES PRECEDING THE 1928 RUPTURE ON CHIRPAN FAULT, SOUTHERN BULGARIA

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Keywords: paleoseismology; active fault; Bulgaria; sesmic hazard

Two of the largest earthquakes in Bulgaria in the 20th century ruptured the surface of the Upper Thracian Depression in April 1928. The April 14 earthquake (M 6.8) near Chirpan caused vertical displacements of 0.3-0.4 m on a normal fault defining the northern limit of a 10-20 km wide graben, and the subsequent April 18 earthquake (M 7.1) near Popovitsa caused surface offsets of 1.5 m on the southern fault of the graben. Despite many contemporaneous descriptions, it is not obvious to locate the fault scarps with precision and to determine the entire rupture length. We therefore conducted a paleoseismological study of Chirpan fault. From aerial photographs, a detailed DEM and topographic leveling, we identified a 12-km-long scarp. Geophysical investigation (2-D resistivity imaging, vertical electric soundings and shallow boreholes) at several sites confirmed the tectonic nature of this scarp, and showed evidence of Quaternary fault activity. In 2002, for the first time in Bulgaria, we excavated a trench to study the faulting history. The trench exposed a narrow fault zone, offsetting Plio-Pleistocene alluvial sand in the footwall from younger alluvial silt in the hanging wall. Pollen spectra indicate a Late Glacial and Holocene age for the entire, 4-m-thick hanging-wall section. The 1928 earthquake is recorded by a 0.45 m offset of the youngest soil, which is in accordance with the reported displacement. We identified three colluvial wedges next to the fault in the hanging-wall sediments, providing evidence for at least three older paleoearthquakes since the Late Glacial to Holocene transition. The penultimate event had an offset of ± 0.3 m and occurred in the last 3 ka years. The offset of the two older events cannot be determined exactly, because the affected units in the hanging wall are not represented in the footwall. Their minimum offsets, estimated from the thickness of the colluvial wedges, are similar to or larger than the 1928 event. There is indirect evidence for one more event which may have occurred between events 3 and 4, but this needs to be confirmed. Though age control is limited, we may infer a Holocene recurrence period between 1400 and 2400 years for earthquakes similar in size to the 1928 event. More trenches are needed, however, to better understand the activity of Chirpan fault and other faults in the Upper Thracian Depression, the more so as they are closely-spaced and any earthquake may trigger a nearby fault as in 1928.

271-4 Oral Meghraoui, Mustapha

STRUCTURAL CONTROL AND MULTI-SEGMENT RUPTURES ALONG MAIN CONTINENTAL FAULTS IN THE MIDDLE EAST: IMPLICATIONS FOR EARTHQUAKE RECURRENCE

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Keywords: Faulting behaviour; Paleoseismology; Structural control; Seismic hazard

Constructing models of earthquake recurrence along main continental faults in the Middle East is an important step towards a realistic seismic hazard assessment. Recent earthquake faulting studies and paleoseismic investigations along the northern section of the Dead Sea Fault (DSF) and the North Anatolian Fault (NAF) provided a wealth of field data and results on the faulting behaviour. Complex rupture zones with structural step-overs, multiple segment boundaries and variable slip distribution along strike point out for a non-characteristic component to large earthquakes. An important factor that controls the faulting behaviour is the recurrence periods of large seismic events and the rate of active deformation. The northern section of the DSF experienced sequences of large earthquakes in 1156, 1170 and 1202 and a period of quiescence during the last 8 centuries, and with 7 mm/year and left-lateral slip rate. The 1999 earthquake sequence along the NAF and related paleoseismic investigations near the Marmara Sea reveals that segment boundaries are soft and that their level of slip distribution and state of stress may allow ruptures to jump apparent segment boundaries. Although the debate continues concerning the occurrence of a (super) large earthquake in the Marmara Sea, high-resolution paleoseismic data brings new constraints in the processes of nucleation and termination of large ruptures. A straightforward result of these paleoseismic analyses is the definition of structural control of faulting through the slip-patch model. Temporal clustering of large earthquakes correlate with segment boundaries, and mutli-segment ruptures along major continental faults. The rich historical seismicity catalogue and outstanding faulting exposures provide the best conditions in estimating the likely size and probable occurrence of future large earthquakes in the Middle East.

271-5 Oral Berryman, Kelvin R

TECTONIC AND VOLCANO-TECTONIC RUPTURE CHARACTERISTICS OF THE PAEROA FAULT, A LARGE NORMAL FAULT IN THE TAUPO RIFT, NEW ZEALAND

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Keywords: active normal fault; Taupo Rift; New Zealand; volcano-tectonic; tectonic

The 27 km long Paeroa Fault is the largest fault of the modern Taupo Fault Belt in the Taupo Rift of North Island, New Zealand. Along its northern sector it forms a 2.5 km wide graben structure comprising at least 11 strands. The cumulative displacement across the fault strands on the c. 64 ka surface of the pyroclastic flow deposit known as the Earthquake Flat Breccia is c. 100 m. Many of the floors of valleys dissecting the breccia surface are displaced by 0.5-3.0m. Seven trenches from five of the eleven fault strands have been excavated in these valley floors. Twenty three rupture events have been identified in the seven trenches interpreted from progressively larger displacement of successively older airfall tephra horizons and intervening paleosols. No doubt some of these events represent the same rupture recorded in multiple trenches. Successive ruptures in individual trenches are highly variable both in size and in recurrence, but most trenches reveal three or four ruptures in the past 16 kyr. Of the 23 faulting events recognised, nine occurred during the accumulation of recognisable tephra units erupted from the Okataina rhyolite volcano, which is 12-20 km distant, and 14 occurred in between tephra depositional periods. We therefore identify, and are able to distinguish between, tectonic and volcano-tectonic faulting. At least two different fault rupture events occurred in association with the 13.8 ka Waiohau eruption, and at least one of the tectonic events appears to immediately precede the Waiohau tephra. Trenches that lie on a single transect perpendicular to fault strike capture data on about 45% of the strands of the fault and the cumulative displacement on these strands is also about 45% of the total displacement. The various events identified in each trench in this transect cluster into eight different multi-strand rupture events in the past c. 16 kyr, five of which are tectonic and three of which are volcano-tectonic. Cumulative primary displacement during each of these clustered rupture events range from c. 0.5-2.2 m, with many are about 1.0 m. There is no obvious distinction between size of tectonic and volcano-tectonic rupture events. In comparison with the 14 km long surface faulting of the 1987 Edgecumbe earthquake, the data from this sector of the Paeroa fault suggests the 27 km long Paeroa fault may rupture in association with earthquakes up to Mw 6.8, consistent with displacement of 2.2 m.

271-6 Oral Nicol, Andrew

SPATIAL AND TEMPORAL CLUSTERING OF PALEOEARTHQUAKES IN AN ACTIVE NORMAL FAULT SYSTEM

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Keywords: paleoearthquakes; normal faults; displacement accumulation

Clustering of paleoearthquakes in space and time has for a number of years been discussed in the literature and may be a widely occurring phenomenon. In many fault systems however insufficient paleoearthquake data are available to determine whether clustering is common and, if so, how it varies between faults. In the absence of constraining data, potential underlying controls on the clustering process cannot be assessed. Using data from the Taupo Rift, New Zealand, here we determine the nature and origin of the clustering of large prehistoric earthquakes on timescales of thousands to tens of thousands of years. Earthquake histories of faults in the Taupo Rift are determined from displacements of up to 11 radiometrically dated horizons (ca. 2-26 kyr in age) in 26 trenches excavated on fault traces distributed across the rift. These data record approximately 30-40% of the total extension across the rift. Older horizons in each trench generally display greater displacement, however, the relation between displacement and horizon age varies between faults. Displacement profiles range from step functions, with episodic slip accumulation, to near-linear functions with constant displacement rates. Variations in the shape of displacement profiles reflect a marked difference in the paleoearthquake histories of faults. Stepped profiles account for ca. 40% of all fault data and are consistent with the notion of temporal earthquake clustering. Time periods of rapid displacement accumulation and of little fault activity typically range from 5-10 kyr. Displacement rates on individual faults averaged over intervals of >10 kyr, which span periods of both rapid and slow displacement accumulation, are less variable and more coherent than rates measured over shorter time windows. The strong degree of temporal variability of slip events on many faults are matched by spatio-temporal variations in fault slip on adjacent faults. As a consequence, over timescales of 5-10 kyr local anomalies in displacement rate are removed when fault displacements for a given horizon are aggregated across the rift. It appears, therefore, that the key to understanding how slip accumulates on individual faults within the Taupo Rift lies in the recognition that each fault is an element of a larger kinematically coherent system. On timescales of thousands of years all faults in the rift were in communication and together accommodate stable boundary conditions.

271-7 Oral Wesnousky, Steven

EARTHQUAKE SLIP DISTRIBUTIONS, MECHANICS OF EARTHQUAKE RUPTURE, AND SEISMIC HAZARD ANALYSIS

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Keywords: earthquakes; faults; seismology

It has become standard practice during the last 35 years to map the geometry of rupture traces and assess the surface-slip distribution of large earthquakes that break the ground surface. The resulting observations have been used in development of seismic hazard methodologies and assessments, engineering design criteria for critical facilities, the development and discussion of dynamic fault models to predict strong ground motions, and efforts to predict the endpoints of future earthquake ruptures. There now exist at least 30 historical earthquakes for which investigators have put forth maps of earthquake rupture traces with data describing the coseismic slip as a function of fault length. Yet, there has been no effort to gather, analyze, and present in a systematic manner the slip distributions and geometry of the earthquake rupture traces. Here I attempt to do so and then use that data to explore issues bearing on seismic hazard analysis and fault mechanics.

271-8 Oral Awata, Yasuo

CHARACTERISTICS OF SIZE AND ACTIVITY OF THE 290 MAJOR BEHAVIORAL SEGMENTS OF ACTIVE FAULT IN JAPAN

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Keywords: active fault; fault segmentation; behavioral segment; displacement per event; recurrence interval

The Active Fault Research Center, GSJ / AIST has been constructing an active fault database to make a probabilistic evaluation of the future faulting event and earthquake occurrence on major active faults in Japan. The database consists of three sud-database, (1) sub-database on individual site, which including long-term slip and paleo-faulting data with error range and reliability, (2)