...ons, they grow at or below their closure temperatures. Dating mica growth in fault zones across an orogen or fold belt can therefore be used to constrain the timing and duration of deformation. This information when combined with either shortening estimates, measured finite strains and/or palinspastic restorations can be used to estimate both time averaged strain and fault displacement rates. Deformation of the turbidite dominated succession in the western Lachlan Orogen occurred by chevron folding and faulting over an eastward propagating decollement/melange zone. Based on Ar-Ar dates of white micas from major fault zones, deformation started at about 455 Ma in the western part and ended at about 385 Ma in the eastern part of the western Lachlan. Distinct concentrations of deformation occurred at about 440, 420 and 390 Ma. These data suggest a decollement propagation rate of about 8 mm/yr, which translates to a strain rate of about 10E-15 per second for the palinspastic separation of about 1000 km. At the scale of individual hanging wall thrust sheets dating micas from (1) bedding parallel fabrics and veins, (2) sub-vertical cleavage, and (3) cross-cutting veins on thrust faults formed after fold lock-up, defines the duration of the deformation process as about 10-15 million years.

8:30 AM White, Arthur P.

RAPID TRANSITIONS IN DEFORMATIONAL STYLE FROM CONTRACTION TO EXTENSION AT MID-CRUSTAL LEVELS

WHITE, Arthur P., HODGES, Kip V., Massachusetts Institute of Technology, Department of EAPS, Cambridge, MA 02139, apwhite@mit.edu

Young orogens such as the Himalayas provide natural laboratories for studying active fault processes in the near surface environment. However, direct observation of fault structures and their timing at depth is not possible in active orogens. Therefore, we have been conducting a detailed, multidisciplinary study of a large orogen parallel normal fault system in the East Greenland Caledonides; this orogen, once the same size and scale as the Himalayas, has been eroded and exhumed over the past 400 Ma to expose mid-crustal structural levels (10-20 km).

Field relations in the allochthonous Krummedal Sequence (KS) of metasedimentary gneisses exposed in Forsblad Fjord (72.5 lat.), show 2 generations of contractional fabrics (S1 and S2) which have been overprinted by an extensional fabric (S3). This S3 fabric is found in the footwall of the Tindern Detachment (TD) which separates the amphibolite facies KS from the weakly metamorphosed sediments of the Eleonore Bay Supergroup. Using U-Pb geochronology to constrain the formation of these fabrics, we have found a rapid transition recorded at or just after peak metamorphic conditions during which contraction (D2) was followed by extension (D3). This timing is constrained by concordant monazite dates from a leucosome which structurally pre-dates D2 (425.1±0.4 Ma) and a syn-D3 leucogranite (423.8±0.9 Ma). This leucogranite cooled rapidly from magmatic temperatures to the closure temperature for 40Ar diffusion in muscovite (~400 C) in roughly 2 million years. Additional cooling to 40Ar closure temperatures in K-feldspar (~150-350 C) took approximately 20 million years, suggesting exhumation may have ceased during this period or significantly slowed down.

These constraints demonstrate fast transitions from contraction to extension and imply periods of rapid movement on extensional structures at mid-crustal depths. Further work is under way to model a rate of exhumation along this detachment.

8:45 AM Sorkhabi, Rasoul

TIMING OF FAULT ACTIVITY AND FAULT ROCKS BY THERMOCHRONOLOGICAL TECHNIQUES

SORKHABI, Rasoul, Japan National Oil Corporation, 2-2-1 Hamada, Chiba 261-0025, Japan, rasoul@jnoc.go.jp

A quantitative appraisal of timing of fault activity and cessation is important for many fields of geology from tectonic analysis to evaluation of traps in petroleum basins. Applications of thermochronological techniques for dating of faults are based on two approaches: (1) Comparison of time-temperature pathways (cooling histories) of hangingwall and footwall rocks; (2) dating of fault rock. This paper illustrates these approaches by application of fission-track (FT) and K-Ar and $^{40}Ar/^{39}Ar$ techniques to faults in the Indian Himalaya. The Paleozoic Tethyan sedimentary rocks are juxtaposed against the Higher Himalayan crystalline complex (HHC) along the South Tibetan Detachment (STD). In the Zanskar region, mica K-Ar ages are discordant across the STD (23-18 Ma) while apatite FT ages are concordant (~10 Ma) constraining the time-span of the STD. Another case study comes from the Jhala Fault in the Garhwal region, which is a post-metamorphic brittle thrust within the HHC. The $^{40}Ar/^{39}Ar$ plateau ages of micas from rocks collected away from the fault are 18 Ma; however $^{40}Ar/^{39}Ar$ ages of biotite and muscovite from the fault gouge both give disturbed spectra with a minimum age of ~8 Ma for the first fraction of the argon release spectra, which is probably due to fault activity at that time. The Main Boundary Thrust (MBT) is a major fault boundary between the Proterozoic rocks of the Lesser Himalaya and the Siwalik molasse sediments of Himalayan foreland basin. In the Kumaun region, a Siwalik sandstone sample collected at the fault contact with the MBT belongs to the Lower Siwaliks (14-11 Ma depositional age) and has become hardened. Detrital apatites were separated and dated by the FT technique. Three analyses yielded an FT age of 5.3±0.5 Ma. The FT age is younger than the depositional age; it indicates the reheating (resetting) of the sample at least up to ~110°C probably by frictional heating along the MBT. Length measurements of fission tracks (>14 microns) indicate rapid surficial cooling of the sample and support this interpretation.

SJCF began at 11±3 Ma when the rocks were 150±15°C. The SJCF accommodated ~6.5 km uplift at long-term rates that reached as high as 2 mm/yr, but averaged 0.5-0.8 mm/yr. Continental rifting in the southern Gulf Extensional Province postdated the southward passage of the Rivera triple junction (~12 Ma), which implies driving forces were likely dominated by far field plate kinematics and coupling between the Pacific, Farallon and North America plates. This continental rifting has persisted through many inferred reconfigurations of plate motion: northward rotation of relative-motion vector (8Ma), eastward migration of the wrenching from Pacific to the Gulf (6Ma) and onset of sea-floor spreading (3.6Ma).

9:15 AM Chan, Marjorie A.

IRON AND MANGANESE MINERALIZATION, AND TIMING OF FAULT-RELATED FLUID FLOW IN JURASSIC SANDSTONES, SOUTHEASTERN UTAH

CHAN, Marjorie A., PARRY, William T., and PETERSEN, Erich U., Dept. Geology & Geophysics, Univ. Utah, 135 S. 1460 E., Salt Lake City, UT 84112-1183, machan@mines.utah.edu; HALL, Chris M., Dept. Geological Sciences, Univ. Michigan, 2534 C.C. Little Building, Ann Arbor, MI 48109-2534.

Hematite concretions (mm to tens of meters-sized), pipes, and strata-bound layers of southeastern Utah occur in the permeable Navajo, Page, and Entrada Sandstones. The diagenetic mineralization appears to be associated with fault fractures. Around Moab, Utah, field, lab, and numerical modeling studies suggest a relation to the Moab Fault. Saline brines from the Pennsylvanian Paradox Formation (with or without hydrocarbons) flowed up the Moab Fault and outward into adjacent permeable sediments carrying iron and manganese and likely bleaching some of the sandstones units. When saline brines mixed with shallow, oxygenated groundwater, iron and manganese oxides were precipitated as cements in porous sandstones. Multiple iron mineralization events and concretionary geometries are evident, suggesting episodic movement of the brine.

Localized manganese oxides with hematite are present on a small fault within the Navajo Sandstone, south of Moab at Flat Iron Mesa. Here, fluid movement likely occurred along the Moab and Lisbon Fault systems. Grains of potassium -bearing cryptomelane were isolated by magnetic separation and hand picking and then dated using 40Ar-39Ar methods. Ages near 25 million years on duplicate runs suggest Oligocene-Miocene timing for the manganese mineralization, coincident with uplift on the Colorado Plateau. Because manganese and iron must be transported by reducing solutions, the ages may represent the timing of movement of hydrocarbons or brines on the fault systems from subsurface reservoirs.

This study represents one of the few documented examples of using 40Ar-39Ar dating of cryptomelane on faults and has important implications for the timing of iron and manganese mineralization along faults and fractures in southeast Utah.

9:30 AM Knott, J. R.

QUATERNARY DISPLACEMENT ON THE BADWATER AND MORMON POINT TURTLEBACK (LOW-ANGLE NORMAL) FAULTS, DEATH VALLEY, CALIFORNIA

KNOTT, J. R., UNOCAL Environmental, 376 S. Valencia Ave., Brea, CA 92823; jrknott@unocal.com

The Death Valley turtleback faults are low-angle (15-30 NW dipping) normal faults found along the western front of the Black Mountains which are often considered part of the Death Valley fault zone. Dynamic models of low-angle normal fault formation, including the turtlebacks, propose that active high-angle faults are progressively tilted to inactive low-angle dips. Alternatively, normal faults may form at low angles. Evidence of Quaternary activity on low-angle normal faults is rare, and estimates of latest slip on the Death Valley turtleback faults have ranged from Miocene to Quaternary. Geologic mapping, tephrochronology and 40Ar/39Ar dating show that the turtleback faults at Badwater and Mormon Point have unequivocal Quaternary displacement. Both faults offset the 760 ka Bishop ash bed, but not the 120-180 ka lake gravels. Based on offset of the Bishop ash bed, one of the high-angle faults, which soles into the Mormon Point turtleback fault, has an estimated throw of 150 m and a heave of 210 m. At Mormon Point, early to middle Pleistocene lacustrine mudstones, which overlie the turtleback fault in fault contact, are generally horizontal to shallowly dipping, indicating low-angle slip in the uppermost crust and little, if any, post-slip tilting of the turtleback fault. Based on the timing of slip, and lack of post-slip tilting, I hypothesize that the Death Valley turtleback faults represent a thermally warped detachment fault system. Coincident intrusion of the 11 Ma Willow Spring gabbro/diorite, ductile deformation of the turtlebacks (8-11 Ma), and plutons derived from partial melting (9-10 Ma) suggest a locally raised the brittle-ductile transition due to high heat flow, resulting in the warped detachment, which has been subsequently exposed by post-Miocene extension.

9:45 AM Gran, Sara E.

EVIDENCE FOR RAPID, HOLOCENE DISPLACEMENT ON THE NAHEF EAST NORMAL FAULT, NORTHERN ISRAEL: A COSMOGENIC CL-36 APPROACH

GRAN, Sara E., Geology Dept., Univ. of Vermont, Burlington, VT 05405, sara.gran@alumni.carleton.edu; MATMON, Ari, Inst. of Earth Sci., Hebrew Univ., Jerusalem 91904, Israel; BIERMAN, Paul R., Geology Dept., Univ. of Vermont, Burlington, VT 05405; ENZEL, Yehouda, Inst. of Earth Sci., Hebrew Univ., Jerusalem 91904, Israel; CAFFEE, Marc, CAMS, Livermore Natl. Lab., Livermore, CA 94550.

While most of Israel outside the Dead Sea Rift zone is seismically quiescent, we document Holocene, high-magnitude, rapid normal fault displacement in northern Israel on the Nahef East fault, with as much as 7 meters of vertical displacement occurring in as few as 5000 years.

We have measured in-situ, cosmogenic Cl-36 in 42 limestone samples taken at 30-cm downdip intervals from the bedrock fault scarp of the Nahef East fault, northern Israel (300 m asl, 33 degrees latitude). By pairing the in-situ cosmogenic Cl-36 data with an interpretive numerical model, we are able to date directly the exposure of the limestone scarp as it becomes exhumed through time. The majority of fault activity occurred between 14 and 3 kya, with displacement starting slowly, reaching its peak rate between 8 and 6 ky, and then decreasing. We do not see evidence of faulting within the past 3000 years.

Based on empirical relationships between surface rupture length, maximum displacement, and earthquake moment magnitude, our data are consistent with potentially destructive earthquakes (M 5.5 to 6.5) occurring on the Nahef East fault as recently as 7000 years ago. Our evidence of recent faulting is in marked contrast with the low level of seismic activity of the region today. There is no other evidence of major Holocene tectonic activity in the near vicinity, aside from the presence of this and other young-looking fault scarps. According to our Cl-36 data, the temporal pattern of uplift on the 6-km long Nahef East fault is episodic (the entire scarp formed in a short period of time, with periods of tectonic quiescence before and after), making long-term recurrence interval calculations irrelevant and casting doubt on the existence of a characteristic earthquake for this particular fault.

10:15 AM Lee, Hee-Kwon

ESR DATING OF MULTIPLE GOUGE LAYERS IN A FAULT ZONE, KOREA

LEE, Hee-Kwon, Dept. of Geology, Kangwon National Univ., Chunchon, Kangwon-do, South Korea, 200-701, heekwon@cc.kangwon.ac.kr; CHWAE, Ueechan, Korea Institude of Geology, Mining and Materials, Kajung-dong, Yusong-Gu, Taejon, South Korea, 305-350; SCHWARCZ, Henry P. , School of Geography and Geology, McMaster Univ., Hamilton, Ontario, L8S 4M1, Canada

We tried to detect multicyclic movements within single fault rock units, using the electron spin resonance(ESR) dating method. Some fault rock zones in the Yangsan fault system of Korea were reactivated, producing well-defined bands of fault rocks. Each band generated distinct ESR ages whose sequence agrees with geological evidences for relative age. We divide fault rock bodies into four modes of faulting according to the behavior of faulting sequences. New fault rock bands next to an older host fault rock, indicative of the type I faulting mode, are found to yield younger ESR dates than their hosts. In the Type II faulting mode, the ESR ages of reactivated fault rocks exhibit younger ESR dates than those of host fault rocks. For Type III faulting mode, the whole fault rock zone is reactivated giving constant ESR ages. On the other hand, for Type IV faulting mode, new fault rock bands yielding younger ESR ages are generated in the host rock or branch off from the host fault rock zone. Local variations of deformation environments make these faulting modes vary along the given fault or during the history of fault movements. These applications of ESR dating of fault rocks, constitute an approach to studying both the evaluation of the movement history and the sequential evolution of the fault zones.

10:30 AM Ayarbe, John P.

NUMERICAL MODEL THAT COUPLES DIFFUSION MODELING OF FAULT-SCARP MORPHOLOGY TO THE ACCUMULATION OF CHLORINE-36

AYARBE, John P. (payarbe@nmt.edu), PHILLIPS, Fred M. and HARRISON, J.B.J., Earth and Environmental Sciences Department, New Mexico Institute of Mining and Technology, Socorro, NM 87801, and ELMORE, David and SHARMA, Pankaj, PRIME Lab, Purdue University, West Lafayette, IN, 47907-1396.

Determining rupture chronologies from fault scarps is important in earthquake hazard assessment. In arid environments, the low occurrence of organic matter often prevents carbon-14 dating of displacements; therefore, in these regions, diffusion modeling of fault-scarp morphology has been applied to date scarps. A drawback to this technique, however, is that the geomorphic diffusivity is often unknown and must be estimated. Because the geomorphic diffusivity of unconsolidated material can vary by three orders of magnitude a large amount of uncertainty is introduced into the calculated age of a scarp. By coupling the accumulation of chlorine-36 to a diffusion model of fault-scarp morphology, the geomorphic diffusivity can be constrained, thereby, providing better estimates of a scarp age.

The model combines geomorphic modification predicted from a diffusion model of fault-scarp morphology to chlorine-36 production and redistribution. A three-dimensional, numerical integration is used to calculate production from the spallation of K and Ca by high-energy nucleons. Thermal-neutron capture by chlorine-35 is assessed for both thermal and epithermal energy ranges. Thermal neutron fluxes for thermal and epithermal neutrons are described by two-dimensional, diffusion equations. The model accounts for radioactive decay and the redistribution of material from the footwall onto the hanging wall. The model was calibrated against measured chlorine-36 concentrations. These concentrations were analyzed from footwall and hanging wall samples collected from vertical transects near the plane of the Socorro Canyon Fault. During the calibration, the timing of ruptures and the geomorphic diffusivity were used as fitting parameters. Although the diffusion equation is non-unique when both the geomorphic diffusivity and rupture age are unknown, using chlorine-36 with diffusion modeling of fault-scarp morphology constrains the geomorphic diffusivity and allows ages to be determined. This approach provides a new means for establishing rupture chronologies. The technique also shows that cosmogenic nuclide accumulation can be combined with transport laws for geomorphic modification for assisting in geochronology.

10:45 AM Hilley, George E.

MORPHOLOGIC DATING OF TRANSPORT- AND PRODUCTION-LIMITED FAULT SCARPS

HILLEY, George E., hilley@asu.edu; AMOROSO, Lee; and ARROWSMITH, J R., Department of Geology, Arizona State University, Tempe, AZ 85287-1404

A fault's geomorphic expression contains information about the rates and timing of movement along the fault and the rates of geomorphic processes acting to redistribute sediment across the fault. Where geomorphic rates and initial landform geometries can be reconstructed or inferred, fault scarp and/or fault zone morphology may be used to estimate tectonic rates. This method provides broader temporal (10 kyr-100 kyr) coverage than detailed fault zone studies that typically focus on individual fault ruptures and events.

Analyses of the morphology of scarps to determine tectonic rates typically are limited to scarps that do not expose bedrock (transport-limited scarps). In this study, we present a model for the degradation of fault scarps dominated primarily by production-limited conditions as well as those subject to transport-limited conditions. For transport-limited scarps, we find that scarp morphology is dependent on tectonic and geomorphic transport rates. For realistic geomorphic transport rates, transport-limited scarps are sensitive to tectonic uplift rates between 2-10 mm/yr. We find that for typical bedrock weathering rates, a steady-state condition, where the surface topography of the scarp and the location of soil—bedrock interface do not vary with time is never achieved. In contrast to transport-limited scarps, production-limited scarp morphology depends primarily on the tectonic uplift and bedrock production rates. Production-limited scarps are sensitive to lower tectonic uplift rates (0.01-0.5 mm/yr). From our models, we propose the following possibilities for short and long term scarp development: 1) Scarp development will remain transport-limited for the duration of the faulting if the tectonic rates are slow, the tectonic uplift is short lived, or the thickness of transportable material is large. 2) The scarp will change from transport-limited conditions towards production-limited conditions if > 1 mm/yr tectonic uplift rates are sustained. 3) Under special circumstances where bedrock production rates are high and rock uplift rates are less than 1 mm/yr, transport-limited conditions may be preserved over long time-scales.

For typical tectonic and bedrock production rates, our analysis suggests that an equilibrium profile and soil-bedrock interface cannot persist indefinitely under transport-limited conditions. Therefore, faults slipping at rates where the rock uplift rate exceeds 1 mm/yr will usually be driven into production-limited conditions.

11:00 AM Champion, Jocasta A.

STRUCTURAL STYLE, FAULT SLIP RATES, SEISMIC MOMENT AND MAGNITUDES FOR THE LAST 2.3 KA - LAKE COUNTY UPLIFT, NEW MADRID

CHAMPION, Jocasta A., MUELLER, Karl J., Dept. of Geological Sciences, Univ. of Colorado, Boulder, CO 80309, jocasta@emarc.colorado.edu; GUCCIONE Margaret, Dept. of Geology, Univ. of Arkansas, Fayetteville, AR 72701.

Trenching, geomorphology and structural analysis of subtle, fault-related folds in the Lake County uplift (LCU) suggest uplift is accommodated mostly by fault-bend folding above the blind Reelfoot thrust. Trench exposures indicate the Reelfoot scarp is comprised of 2-3, east-facing kink-bands that dip 5-16°. These form above bends in the underlying blind thrust, collectively accommodating ~ 20-25 degrees of flattening of the thrust at the top of a ramp dipping 55° west. Seismic profiles image the scarp as a monocline comprised of overlapping kink-bands (multibend fold). Additional shortening is defined in trench excavations and seismic data as a ~4 km wide fold, that forms above a fault tip (i.e. a fault-propagation fold). Fault-related fold theory and radiocarbon dates on folded sediments allow slip rates on the thrust to be determined. The average width of kink-bands in the trenches is ~14.0 m. Limb width is equivalent to fault slip; this and the age of folded sediments (~2.3 + 0.1 ka) yields a slip rate of 5.8 + 0.7 mm/yr. Another method uses the 9.1 m of total structural relief across the Reelfoot scarp, the age of folded sediments and uplift on a 55° thrust to yield a slip rate of 4.8 + 0.2 mm/yr. Vector transformation of these rates onto the strike slip Cottonwood Grove fault (CGF) indicates slip on the CGF of 1.8 - 2.2 mm/yr. This is in conflict with recent assertions based on GPS that New Madrid is now inactive. Seismic moment and moment magnitude calculations for faults in New Madrid used fault geometry from our model, slip inferred by fold geometry and published recurrence intervals. For a period of 500 years, seismic moment for the thrust is 9.77 x 1026 dyne -cm (Mw = 7.3); for the strike slip CGF, moment is 5.0 x 1026 (Mw = 7.1). This is consistent with historical records from the 1811/12 sequence where greater shaking was felt over the LCU.

11:15 AM Guccione, M. J.

DATING DEFORMATION AND SLIP RATES ALONG REELFOOT SCARP, NEW MADRID SEISMIC ZONE USING RADIOCARBON DATES FROM AN ABANDONED MISSISSIPPI RIVER MEANDER

GUCCIONE, M. J., Dept. of Geosciences, Univ. of Arkansas, Fayetteville, AR 72701, guccione@comp.uark.edu; CHAMPION, J. and MUELLER, K. Dept. of Geological Sciences, Univ. of Colorado, Boulder, CO 80309-0399, karl@emarc.colorado.edu

The Mississippi River meander belt is folded by the Reelfoot scarp, providing a means of dating late Holocene deformation in the New Madrid seismic zone. Along the scarp of the Tiptonville dome, from near the present Mississippi River to the south edge of Reelfoot Lake, sediments deposited by a single migrating meander are deformed. Initially the moderately sinuous channel migrated from west to east across the scarp, eroding any earlier relief produced by active folding. Geomorphology and shallow stratigraphy indicate that the northern limb subsequently migrated southward, possibly within several centuries, leaving an abandoned, clay-filled secondary channel and sandy scroll bars. Because the southern meander arm was relatively stationary, the meander became more sinuous. Ultimately a neck cutoff west of Tiptonville, TN caused the meander to be abandoned. The abandoned channel infilled quickly at the cutoff, forming an oxbow lake within the present Reelfoot basin.

We have dated organics from fill within the cutoff meander to determine the maximum age of surface deformation along Reelfoot scarp. In the northern meander limb, dates from the lower channel fill range upward from 2310 ± 40, 3050 ± 110, and 830 ± 35 yrs BP. From the southern limb one date is 2240 ± 20 years BP. We conclude that the Mississippi River abandoned a very sinuous channel by a neck cutoff slightly > 2.2 -3.5 kya (calibrated). Structural relief defined in trenches across the Reelfoot scarp is 9 m, suggesting a slip rate of ~ 4.9 + 0.2 mm/yr, assuming a blind thrust dipping 55 degrees to the west.

11:30 AM Cannon, Eric C.

HOLOCENE FAULT OFFSET RATES OF THE HILINA FAULT SYSTEM, KILAUEA VOLCANO, HAWAII

CANNON, Eric C., Department of Geology, One Shields Avenue, University of California, Davis, CA, 95616, cannon@geology.ucdavis.edu; BURGMANN, Roland, Department of Geology and Geophysics, 301 McCone Hall, University of California, Berkeley, Berkeley, CA, 94720-4767, burgmann@seismo.berkeley.edu

We evaluate offset rates for the Hilina fault system, on the south flank of Kilauea Volcano, Hawaii, over the time scale of hundreds to thousands of years. Knowledge of south flank short-term deformation is limited to geodetic surveys conducted within the last approximately 100 years. We analyze Hilina fault system offsets to better understand past Kilauea south flank displacement behavior. South flank hazard assessment of seismicity and catastrophic mass movements will benefit from our long-term offset rate studies. Major south flank earthquakes (M > 7) involve slip along a subhorizontal detachment fault at approximately 10 km depth, and surface normal faulting. The 1868 Great Kau and 1975 Kalapana earthquakes both produced coastal subsidence and Hilina fault offsets of several meters. We improve our knowledge of south flank displacement behavior as far back as approximately 3000 years by analyzing surface offsets along the Hilina fault system.

We calculate fault system slip rates from surface offset measurements collected along the Hilina fault system in July 1998 and June 1999. Minimum offset rates are determined by dividing surface offset measurements by lava flow age. Surface offset measurements include fracture and piercing point offsets. Lava flow ages within the field area range from 24 years to approximately 3000 years, with prehistoric ages previously determined using paleomagnetic and/or radiocarbon methods. Using 1975 Kalapana earthquake offsets as a proxy for major south flank earthquake offset, preliminary offset analysis indicates older flows contain larger magnitude offsets than younger flows. Longer major earthquake repeat times in the past may have existed compared to the short historic earthquake repeat times for the 1868 and 1975 earthquakes.