S62B MCC: Hall C Saturday 1330h

Young Continent-Continent Collision II Posters *(joint with T)*

Presiding: **A Maggi,** Bullard Laboratories University of Cambridge**; N McQuarrie,** California Institute of Technology

S62B-1183 1330h POSTER

Implications of GPS Measurements in Iran on the Contemporary Crustal Deformation and Plate Kinematics in Middle East.

Philippe Vernant[1] (33-4-67-14-45-91; vernant@dstu.univ-montp2.fr); Faramarz Nilforoushan[2]; Frédéric Masson[1]; Denis Hatzfeld[3]; Mohamad Abbassi[4]; Christophe Vigny[5]; Farok Tavakoli[2]; Roger Bayer[1]; Joseph Martinod[3]; Mohsen Ashtiani[4]; Jean Chéry[1]

[1]Laboratoire de Géophysique, Tectonique et Sédimentologie, Université Montpellier II - CNRS, Pl. E. Bataillon, Cedex 05, Montpellier 34095, France

[2]Geodynamic Department, National Cartographic Center, Po. BOX 13185-1684, Meraj Ave, Tehran 13185-1684, Iran (Islamic Republic of)

[3]Laboratoire de Géophysique Interne et Tectonophysique, Université J. Fourrier Grenoble - CNRS, BP 53, Cedex 9, Grenoble 38041, France

[4]International Institute of Earthquake Engineering and Seismology, Farmanieh, Dibaji, Arghavan St.,N27, Tehran 19531, Iran (Islamic Republic of)

[5]Laboratoire de Géologie, Ecole Normale Supérieure - CNRS, 24 rue Lhomond, Cedex 05, Paris 75231, France

Iran is wedged up between Eurasia and Arabia. This northward convergence of the Arabian platform relative to Eurasia involves continental collision in several belts (Zagros, Alborz, Talesh, Kopet Dag), and oceanic subduction of the Gulf of Oman under the Makran accretionary wedge. All these deformation areas are surrounding relative aseismic blocks (South Caspian block, Central Iran). Some of them are bordered by great N-S strike slip faults (Lut, Helmand). As GPS is providing a precise tool to quantify the deformation, a network of 27 sites was implemented in Iran and Northern Oman to measure displacements in this part of the Alpine-Himalayan arc. Two surveys were performed in September 1999 and October 2001. We present and interpret the results.

GPS sites in Oman show northward motion of the Arabian plate relative to Eurasia (20 $\pm$ 2 mm/yr at N11° $\pm 5^{\circ}$ E) slower than the NUVEL-1A estimates (31 mm/yr at N13°E). This convergence is distributed in several orogens in western Iran. Like Alborz mountain range, Zagros thrust and fold belt is accommodating 8 $\pm$ 2 mm/yr at the longitude of the Caspian Sea. The shortening accommodated by the Zagros is decreasing toward the north-west until a rate of 3 $\pm$ 2 mm/yr near the western Iranian border. If we assume a partitioning in the NW Zagros between shortening in the fold and thrust belt and right lateral displacement along the Main Recent Fault, then the dextral motion (3 $\pm$ 2 mm/yr) along this part of Arabian plate border is very low compare to the rate suggested by several authors. However dextral motion (7 $\pm$ 2 mm/yr) occur in the north-western part of the country along a NW-SE fault network which seems to be more or less connected to the North Anatolian Fault. This right lateral displacement involves extrusion and overthrusting of the NW Iran on the South Caspian Block. In eastern Iran the major part of the convergence is accommodated by the Makran subduction (18 $\pm$ 2 mm/yr). The rest of the Arabia-Eurasia convergence after the subduction (6 $\pm$ 2 mm/yr) is transmitted to the north by the rigid Lut block to the Kopet Dag mountain range. Sites east of the Lut block show only few displacement between the Helmand block (Afghanistan) and the stable Eurasia. These velocities, decreasing from west to east at the same latitude involve right lateral displacements along the N-S border of the Lut (6-9 mm/yr). The highest dextral motion in Iran seems to occur in the transition zone between the Zagros collision and the Makran subduction (11 $\pm$ 2 mm/yr along N-S faults). It is the first time that a so sharp subduction-collision transition zone is monitored by GPS measurements.

S62B-1184 1330h POSTER

Active Tectonics of Eastern Iran

Richard T Walker[1] (+44 (0)1223 337059; rwalker@esc.cam.ac.uk)

James A jackson[1] (+44 (0)1223 337197; jackson@esc.cam.ac.uk)

[1]University of Cambridge, Bullard Laboratories Madingley Road, Cambridge CB3 0EZ, United Kingdom

Eastern Iran is a region of rapid active deformation, with abundant strike-slip and thrust faulting that poses a serious seismic hazard to local populations. About 15–20 mm/yr of north-south right-lateral shear occurs between central Iran and western Afghanistan. We suspect that the present-day tectonic configuration dates from about 5 Ma ago, a time of major re-organisation in both the Zagros and Alborz mountains.

South of 34 degrees N, right-lateral shear is accommodated on north-south right-lateral faults. North of 34 degrees N, the right-lateral shear is taken up on east-west left-lateral faults that rotate clockwise about vertical axes. However, little is known of the late Tertiary and younger offsets and slip-rates on these active fault systems, results that are important for estimating potential seismic hazard in the region, and also for understanding the regional tectonics.

We use the distribution of historical and instrumental seismicity, and indications of Holocene fault movements observed using high-resolution satellite imagery, to determine the present-day distribution of active faulting in eastern Iran. We then use displaced geological and geomorphic markers, as well as the overall morphology and orientation of the major fault systems, to estimate the total cumulative late Tertiary displacements across the fault zones.

By assuming that the pattern of active faulting dates from about 5 Ma, we can obtain rough estimates of the slip-rates on the major strike-slip faults, that are in agreement with dated offsets where we have them. The measured cumulative offsets across the faults compare well with the total amount of right-lateral shear (75 to 100 km) that is expected across the region in the last 5 Ma.

S62B-1185 1330h INVITED POSTER

Seismic Structure of the Middle East.

Alessia Maggi[1] (maggi@madingley.org)

Keith Priestley[1]

Dan McKenzie[1]

[1]Bullard Laboratories Cambridge University, Madingley Road, Cambridge, - CB3 0EZ, United Kingdom

The Middle East is a tectonically complex region. The final closure of the Tethys and its marginal basins, due to the northwards motion of Arabia towards stable Eurasia, occurred over the last 15 Ma and involved the accretion of island arcs and other continental fragments as well as the subduction of intervening portions of oceanic lithosphere. Since about 5 Ma ago, the collision between Arabia and the accreted terrains which now form Iran has been purely continental in nature. This complicated tectonic history is reflected in the heterogeneous crust and upper mantle velocity structure of the region. We combine surface wave studies of the region's mantle, a review of receiver function analyses of the crust, and observations of long-wavelength gravity anomalies to obtain information about the structure and dynamics of the Middle East. Our surface wave analysis was carried out using partitioned waveform inversion using mode-summation synthetic seismograms to match regional surface waves, thereby producing an ensemble of constraints on the 1-D average structure along the paths between sources and receivers. We then combined this ensemble of constraints on lithospheric structure into a single linear system and performed a cellular inversion to recover the 3-D seismic structure of the mantle in the Middle East. The surface wave tomography results show a pronounced low velocity zone (β $\sim$4.55 km/s) between 50–150 km depth extending from Central Turkey down through the Zagros mountains of Iran. This shear wave velocity anomaly correlates well with a long wavelength gravity high ($\sim$50 mGals at a wavelength of 800 km) observed running through Turkey and down the Zagros Mountains. Both anomalies are consistent with an increase in mantle temperature, which reduces shear wave velocity and creates buoyant uplift that deforms the Earth's surface, producing an overall gravity high.

S62B-1186 1330h POSTER

Crustal Rheology and Long Term Displacement Along the North Anatolian Fault, Turkey, by 3D Modeling

Ann-Sophie Provost[1] (33 4 67 14 45 97; provost@dstu.univ-montp2.fr)

Jean Chery[1] (jean@dstu.univ-montp2.fr)

Riad Hassani[2] (riad.hassani@univ-savoie.fr)

[1]Laboratoire de Geophysique Tectonique et Sedimentologie, Universite Montpellier 2, Bat 22 cc 60, Place E. Bataillon, Montpellier 34095, France

[2]Laboratoire d'Instrumentation Geophysique, Universite de Savoie, Le Chablais, Le Bourget-du-lac 73376, France

The North Anatolian fault (NAF) is part of a complex tectonic setting that extends over 2000 km. In this region of Eastern Mediterranean, the collision of the Arabian, African and Eurasian plates resulted in creation of mountain ranges (i.e., Zagros, Caucasus) and the westward extrusion of the Anatolian block. In this study we investigate the effects of crustal rheology on the long term displacement rate along the NAF. Heat flow and geodesy data were used to constrain our mechanical model, built with the three-dimensional finite element code ADELI (Hassani et al., 1997). Fault motion is controlled by a Coulomb type friction and the rheology of the lithosphere is composed of a frictional upper crust and a viscoelastic lower crust and mantle. The lithosphere is supported by a hydrostatic pressure at its base (representing the asthenosphere). We have developed a model of the long term deformation of the surroundings of the North Anatolian fault by adjusting rheological parameters that control the resulting velocity and stress fields. To do so we used a frictional range of 0.0 to 0.2 for the fault, and a viscosity varying between 10^{19} and 10^{21} Pa.s. By comparing our results with geodetic measurements (McClusky et al, 2000) and tectonic observations, we have defined a realistic model in which the displacement rate on the North Anatolian fault reaches 20 mm/yr for a viscosity of 10^{19} Pa.s and a fault friction of 0.05. One of the most striking results of our rheological tests is that the fault is locked if the friction reaches 0.2, making it a weak fault like the San Andreas fault in California. After adding topography with its corresponding crustal root, gravity flow appears south of the fault in central Anatolia, and the westward velocity of the Anatolian block is reduced in the Eastern regions. Because of a simplification of the geometry of the NAF in our model, we find a poor agreement between our calculated velocity field and what is observed with GPS in the Marmara and the Aegean regions. Indeed, the main trace of the NAF splits at least into two branches in the region of Marmara and dies off in the tensional Aegean region. Taking into account the weaknesses of these deforming regions should allow us to build a more realistic model that would match ground observations more appropriately. On the other hand our results fit well GPS measurements in central Anatolia, setting the basis of modeling crustal rheology in Turkey.

S62B-1187 1330h POSTER

Crustal anelasticity structure in southern Tibet from inversion of fundamental mode surface waves

Yosuke Aoki[1] ((845)365-8422; aoki@ldeo.columbia.edu)

Jiakang Xie[1] ((845)365-8553; xie@ldeo.columbia.edu)

[1]Lamont-Doherty Earth Observatory of Columbia University, P.O. Box 1000, Route 9W, Palisades, NY 10964, United States

Recently it has been found that the crustal guided (Lg) waves attenuate very rapidly along a segment of the INDEPTH II seismic profile in the southern Tibetan plateau. The measured 1-Hz Lg Q is extremely low (about 60) in the vicinity of the Indus-Yarlung Suture, where strong mid-crustal reflectors were previously found (Nelson et al., 1996) and were interpreted as marking the top of a partially melt and/or aqueous layer. The low Lg Q value reflects the crustal average that may be fit by many possible depth-varying Q structures. To resolve the depth-variation of shear wave Q along the INDEPTH II profile, we collected fundamental mode Rayleigh and Love waves from two regional earthquakes, and inverted for crustal velocity and Q structures with a two-station method. The inversion is difficult because of the short ($\sim$ 100km) inter-station separations and 3D structural complications that deviates from our 1D assumption. Nevertheless, we have consistently resolved, using both Rayleigh and Love waves, a highly attenuative mid-crustal layer in which shear wave Q is around 10. This low Q layer does not persist to depths greater than about 30-35 km, where the resolution of our inversion degrades owing to the lower signal-noise ratio of longer-period, regional surface waves. We are currently analyzing data from more events to improve the resolution, so that the bottom and the physical cause of the low Q layer may be better constrained.

S62B-1188 1330h POSTER

Active Deformation in the Zagros-Makran Transition Zone Inferred From GPS, Tectonic and Seismological Measurements

Roger Bayer[1] (0033467144291; roger@dstu.univ-montp2.fr); Esmael Shabanian[2]; Vincent Regard[3]; Farzam Yaminifard[4]; Philippe Vernant[1]; Faramarz Nilforoushan[5]; Mohammad Abbassi[2]; Jean Chery[1]; Mohammad Tatar[2]; Erik Doerflinger[1]; Michel Peyret[1]; Marc Daignires[1]; Olivier Bellier[3]; Denis Hatzfeld[4]; Mohammad Mokhtari[2]

[1]LGTS-CNRS/University Montpellier II, 4 place E. Bataillon, Montpellier Cedex 05 34095, France

[2]International Institute of Earthquake Engineering and Seismology, Farmanieh, Dibaji, Arghavan St., 27, Tehran 19531, Iran (Islamic Republic of)

[3]CEREGE-CNRS/University Aix-Marseille III, Europole Mediterraneen de l'Arbois BP80, Aix en Provence 13545, France

[4]LGIT-IRIGM/ University Joseph Fourier, BP 53, Grenoble Cedex 05 38041, France

[5]National Cartographic Center, Meraj ave., Azadi Square, Tehran 13185, Iran (Islamic Republic of)

The present-day N-S convergence between the Arabian and the Eurasian plates is accommodated in Southern Iran along the Zagros fold and thrust belt (with a shortening of 8 mm/yr)and by the subduction of the Oman oceanic lithosphere beneath the Makran (with a rate of 18mm/yr). The Bandar Abbas-Strait of Hormuz zone is considered as a transition between the Zagros continental collision and the Makran oceanic subduction. In this area, the strain is mainly accommodated along the NNW-SSE trending reverse right lateral Minab-Zendan-Palami faults and along the N-S trending faults of Sarduiyeh, Jiroft and Sabzevaran.

We used GPS network measurements (carried out in 2000 and 2002) to better understand how the deformation is distributed between between the Zagros continental collision and the Makran oceanic subduction. The analysis of the velocities (together with the measurements of the global network of Iran) leads to the following conclusions : - The rate of shortening in the Eastern Zagros is $<$ 8mm/yr. It is $<$ 5 mm/yr between the coast and the Main Zagros Thrust. - The horizontal residual velocities of the coastal sites in Zagros relative to Musandan are $<$ 3mm/yr, evidencing for a small deformation in the Persian Gulf. - Across the Minab-Zendan-Palami faults system GPS measurements are consistent with a N-S trending reverse right lateral motion at rate of $\sim$ 10 mm/yr. - West of the Lut block at the latitude of Khanuj, the N-S trending Sarduiyeh-Jiroft-Sabzevaran fault system is characterized by a 2 mm/yr right strike slip motion.

Local seismicity is located at an unusual depth down to 35 km. Little is associated with the Minab-Zendan-Palami faults strike slip faults. They rather suggest that they are associated with a complex transition between the Zagros collision and the Makran subduction. Times delays also suggest a large heterogeneity in the crust across the fault system. These measurements support the model that the convergence from the collision to the subduction is accommodated within a crustal transpressional fault system along the Minab-Zendan-Palami faults.

S62B-1189 1330h POSTER

Shallow seismic velocity structure of the Eastern Turkey from inversion of surface waves

Cemil Gurbuz[1] (90-216-3320242; gurbuz@boun.edu.tr)

Robert Bob Herrmann[2] (rbh@eas.slu.edu)

Zor Ekrem[1] (zor@boun.edu.tr)

Eric Sandvol[3] (sandvole@missouri.edu)

Niyazi Turkelli[1] (turkelli@boun.edu.tr)

[1]Bogazici University, Kandilli Observatory and Earthquake Research Institute, Cengelkoy, Istanbul 81220, Turkey

[2]Saint Louis University, Department of Earth and Atmospheric Sciences, Saint Louis MO 63103, United States

[3]University of Missouri, Department of Geological sciences, Columbia MO 65211, United States

Eastern Turkey, the location of a young continent continent collision zone, is a seismically very active and tectonically complex region. The Eastern Turkey Seismic Experiment (ETSE) was designed to investigate the Eurasian Arabian plate margins across the Bitlis suture and East and North Anatolian Fault zones. The ETSE PASSCAL consists of 29 station broadband array deployed for a period of two years. Analysis of surface wave data is an important tooll for determining the average shear wave velocity structure beneath the region. Well recorded regional and teleseismic surface wave data were used to calculate phase and group velocities. The velocity structure beneath the region was investigated by using different period ranges using regional and distant earthquakes. Results from the 38 and 50 second period ranges imply a different S-wave velocity disribution within the region. S-wave velocities in the middle of the array, where there is a triple junction,there is a low velocity zone. The thickness of the crust varies and variation in thickness of the crust can be attributed to the complexity of the region. It is thin at the northeastern part of the Anatolian Plateau. This indicates that the Arabian plate is being accomodated by the westward movement of the Anatolian plate. The surface-wave observations provide a needed constraint for the interpretation of other data, such as receiver functions.

S62B-1190 1330h POSTER

Structure and Kinematics of the Central Zagros (Iran)

Mohammad Tatar[1,2] (98 21 283 1116; mtatar@dena.iiees.ac.ir); Denis Hatzfeld[2] (33 4 76 82 80 64; denis.hatzfeld@ujf-grenoble.fr); Andrea Walpersdorf[2] (33 4 76 82 81 04; andrea.walpersdorf@ujf-grenoble.fr); Mohsen Ghafory-Ashtiany[1] (98 21 229 4932; ashtiany@dena.iiees.ac.ir); Keith Priestley[3] (44 1223 337 195; keith@esc.cam.ac.uk); Joseph Martinod[1] (33 4 76 82 80 64; jmartino@cec.uchile.cl); Jean Chery[4] (33 4 76 14 36 85; jean.chery@dstu.univ-montp2.fr)

[1]IIEES, PO Box 19395/3913, Tehran 1953714476, Iran (Islamic Republic of)

[2]LGIT-CNRS, BP 53, Grenoble Cedex 9 38041, France

[3]Bullard Lab, Madingley Rise, Cambridge CB30EZ, United Kingdom

[4]LGTS-CNRS, Universite de Montpellier II, Montpellier Cedex 34060, France

In 1997, we conducted a integrated geophysical study in the region of Ghir (Central Zagros of Iran). We installed a broadband seismological station and recorded teleseismic earthquakes. We deployed a local seismological network and recorded local seismicity. We measured twice a local geodetic network. The velocity structure deduced from both the 1D-inversion of local travel times and of receiver function analysis of teleseismic waveforms suggest an 11 km sedimentary layer overlying a 35 km crystalline crust beneath the station. The local earthquakes (located beneath the sedimentary cover) show NW-SE alignments that could be related to reverse faulting dipping either NE or SW. Focal mechanisms suggest that both reverse and oblique strike-slip faulting accomodate the shortening. GPS-measurements show that the Main Zagros Reverse Fault and the Persian Gulf are not deforming but that an approximate 1 cm/y of shortening affects the Central Zagros as a whole.

S62B-1191 1330h POSTER

First Seismological Data on the Crustal structure of the Zagros Mountain Belt

Anne Paul[1] (33-4-76828034; Anne.Paul@obs.ujf-grenoble.fr)

Ayoub Kaviani[1,2] (Ayoub.Kaviani@obs.ujf-grenoble.fr)

Jérôme Vergne[1] (Jerome.Vergne@obs.ujf-grenoble.fr)

Denis Hatzfeld[1] (Denis.Hatzfeld@obs.ujf-grenoble.fr)

Mohammad Mokhtari[2] (mokhtari@dena.iiees.ac.ir)

[1]LGIT, CNRS & Université Joseph Fourier, Maison des Géosciences BP 53, Grenoble 38041, France

[2]IIEES, 26, Arghavan St., PO Box 19395/3913, Tehran 3913, Iran (Islamic Republic of)

As part of the French-Iranian project set up to study the dynamics of the intracontinental collision zone of Iran, we installed a temporary seismological network across the Zagros mountain belt for 4.5 months in 2000-2001. This experiment aimed at investigating the lithospheric structure of the rather young Zagros orogen. The network included 64 broadband, medium-band and short-period stations located along a 600-km long line with an average spacing of $\sim$ 10 km. The profile ran from the Persian Gulf to the stable block of Central Iran across the towns of Shiraz and Yazd. A cross-section of radial receiver functions displays clear P-to-S conversions at the Moho beneath most of the profile. The average Moho depth is 45 to 50 km between the coast and the Shiraz region. The crust thickens rather abruptly beneath the highest regions of Central Zagros NE of Shiraz, the suture zone of the MZRF (Main Zagros Reverse Fault) and the Sanandaj-Sirjan (SS) metamorphic belt. The deepest Moho is located at $\sim$ 70 km depth beneath the SS belt, 80 km NE of the surface trace of the MZRF. Thus, the region of thickened crust appears to be rather narrow ($\sim$ 200 km) and shifted to the NE with respect to both the MZRF and the areas of highest elevations. NE of the volcanic belt, the crust of the Central Iran block is 40-to-60 km thick, displaying a possible 20-km Moho step beneath the region of Yazd. As a whole, the receiver functions display rather complicated waveforms along most of the profile, indicative of a complex crustal structure with thick sedimentary basins, a crust-mantle boundary with strongly-dipping segments and possible anisotropy.

S62B-1192 1330h INVITED POSTER

Regional Wave Propagation in Eastern Turkey and the Northern Arabian Plate

Eric Sandvol[1] ((573) 884-9616; sandvole@missouri.edu)

Rengin Gok[2] ((505) 646-1920; rgok@nmsu.edu)

Niyazi Turkelli[3] (turkelli@boun.edu.tr)

Muawia Barazangi[4] (barazangi@Geology.Cornell.Edu)

[1]University of Missouri, 101 Geology Building, Columbia, MO 65211, United States

[2]New Mexico State University, Department of Physics, Las Cruces, NM 88003, United States

[3]Bogazici University, Kandilli Observatory and Earthquake Research Institute, Istanbul 81220, Turkey

[4]Institute for the Study of the Continents, Cornell University, Ithaca, NY 14853, United States

The propagation characteristics of regional shear waves, Sn and Lg, have been used to constrain lithospheric structure and provide insights into the ongoing tectonics of the Eastern Anatolia. Thousands of regional earthquakes within the distance range of 2a-15a were recorded by the 29 broad-band stations of Eastern Turkey Seismic Experiment (ETSE). In addition to this data set we also use data from National Network of Kandilli Observatory and Earthquake Research Institute (KOERI), several broad-band stations from Global Seismic Network (GSN) and Cilician Network of TUBITAK-Earth Science Research Institute. The propagation efficiencies of Sn and Lg phases are visually examined and ranked by amplitude and frequency content. Attenuation maps are then tomographically constructed using the ranks of propagation efficiency. Results show that Sn propagates efficiently in the cold and fast uppermost mantle beneath the Mediterranean Sea, the Black Sea and the western part of Caspian Seas. Sn is not observed in eastern Turkey, and central Anatolia, while highly attenuated for paths that cross the Dead Sea Fault Zone. We observe efficient Sn along the Zagros fold and thrust belt. Our results are consistent with there being a region of thin hot lithospheric mantle beneath the Anatolian and Iranian plateaus. We observe Lg to be less efficient in the relatively stable Arabian platform and for paths that cross the Dead Sea fault zone. Lg is blocked throughout the northeastern Anatolia Plateau where there may be partial melt in the crust due to the wide spread volcanism in the region.

S

S62B-1193 1330h POSTER

InSAR-constrained locations of earthquakes in the Zagros mountains of Iran

Rowena B Lohman[1] (626 395 6974; fisheggs@caltech.edu)

Mark Simons[1] (626 395 6984; simons@caltech.edu)

[1]California Institute of Technology, 1200 E. California Boulevard, Pasadena, CA 91126, United States

The Zagros mountains of southern Iran accommodate a significant portion of the 3 cm/yr. of convergence between Arabia and Eurasia. The Zagros are marked by a zone of high seismicity (M_w $<$ 6) that broadens from a narrow band along the collisional front in the NW to a wider belt ($>$150 km) in the southeast near the Straits of Hormuz. Due to the lack of dense local seismic or geodetic networks, much of our understanding of how the continental crust currently accommodates this strain is based on catalogues of teleseismic earthquake locations. These catalogues have been used both to describe the spatial distribution of seismically released strain, and to place bounds on the percentage of convergence which is accommodated seismically. Both of these applications depend on the quality of the earthquake locations and magnitude estimates. Earthquake locations in this region commonly have errors of up to 50 km in map view. As the Zagros mountains

are only on the order of 250 km wide, these errors significantly reduce our resolution of the distribution of seismically released strain. Earthquake depths in the Zagros are also poorly determined, to the extent that it is not clear whether earthquakes occur in the basement or in the overlying 10-15 km of sediments. A depth of 15 km has previously been used to infer that seismically released strain in the Zagros only accounts for 10-20% of the convergence between Arabia and Eurasia. The inferred strain deficit is partially accommodated with strain in the Alborz mountains and through rotation and extrusion of rigid blocks in Central Iran. However, this estimate of convergence rate involves summing earthquake moments and assuming that they are homogeneously distributed throughout the seismogenic crust. If the thickness of the seismogenic crust is less than 15 km, then the inferred convergence rates would be correspondingly greater.

We locate several earthquakes that occurred in the Zagros mountains during the period 1992-2002 by examining ground deformation constrained by Interferometric Synthetic Aperture Radar. We show that we can locate events with precision of a few km. One test case, a M_w 5.1 earthquake in southern Iran on April 30, 1999, occurred 70 km from the Harvard CMT location, and was 40 km shallower than its catalogued depth.

InSAR provides a fast and straightforward method for augmenting the existing earthquake catalogues. We will be unable to create a complete catalogue, due to the limited spatial and temporal coverage of current SAR data, and we will not be able to detect small, deep earthquakes. Given the noise levels we observe in interferograms for southern Iran, we can expect to detect M_w 4 and 5 earthquakes that are shallower than 6 km and 17 km, respectively. The InSAR locations that we do find can be used to help calibrate seismic models for the region, which will help seismologists determine if earthquakes that are too small and deep to resolve with InSAR truly occur in the basement.

URL: http://www.gps.caltech.edu/~fisheggs/agu2002

S62B-1194 1330h POSTER

Very Long Period Magnetotelluric Data Across the India-Asia Collision Zone

Jessica E Spratt[1] (jespratt@syr.edu)

Alan G Jones[2] (ajones@nrcan.gc.ca)

K Douglas Nelson[1] (kdnelson@syr.edu)

Martyn J Unsworth[3] (unsworth@phys.ualberta.ca)

[1]Department of Earth Sciences, Syracuse University, Syracuse, NY 13244, United States

[2]Geological Survey of Canada, 615 Booth St., Ottawa, ON K1A 0E9, Canada

[3]Department of Physics, University of Alberta, Edmonton, AB T6G 2J1, Canada

The collision of the Indian subcontinent with Asia is unparalleled - it offers the holy grail for interpreting the cryptic rock record of ancient collisional orogens, and provides a benchmark for testing evolutionary theories of tectonic processes. But, despite its importance, it remains poorly studied. Project INDEPTH was initiated in 1992 to advance our knowledge of the Tibetan Plateau, and magnetotelluric surveying was added during INDEPTH II in 1995. Broadband and long period data were acquired in 1995 along a N-S transect crossing the India-Asia collision zone, the Indus-Zangbo suture, at ~90° E longitude. However, these data failed to penetrate to mantle depths due to: (1) Sunspot activity was at its lowest in the last 11-year solar cycle, (2) Tibetan crust is doubly-thickened, with Moho depth estimates of >70 km, and (3) Crustal conductivity is high at depths below about 20 km, and penetration beyond ~40 km was not possible.Mantle information is key for this region to provide a test of the model of subcretion to southern Tibet by the stiff Indian mantle lid.

In order to obtain deep crustal and upper mantle information, an ultra-long period experiment was performed across the suture in 2001 as a component of a second Indus-Zangbo-crossing profile. It was planned to acquire two months of data at each of the five ultra-long period sites, but a series of problems resulted in inadequate data for most sites, with the exception of reasonable data at one site just north of the suture. Preliminary processing of the data from that site indicates upward-trending ρ_a curves beyond 2,000 s, suggestive of an upper mantle resistive layer than could be the subcreted Indian mantle lid. Further processing and modeling will be shown.

This second profile also permits comparison of possible along-strike variation of the Indus-Zangbo suture by comparing the results obtained from this survey with those obtained in 1995.

S62B-1195 1330h POSTER

Himalayan Along-arc Stretching: Observations and a Model

Rebecca Bendick[1] (303-735-4685; bendick@cires.colorado.edu)

Greg Houseman[2] (greg@earth.leeds.ac.uk)

Z. Yang[3] (yangzq@pub.xaonline.com)

T. Tobgyal[4]

[1]CIRES, University of Colorado, Boulder, CO 80309-0399, United States

[2]School of Earth Sciences, University of Leeds, Leeds LS2 9JT, United Kingdom

[3]Department of Surveying, Chang'an University, Xi'an, SXI NA, China

[4]Survey of Bhutan, NA, Thimpu NA, Bhutan

Recent new geodetic observations of surface velocities from the far eastern and far western extent of the Himalayan range and Tibetan Plateau confirm the presence of tensional strain in the arc-parallel direction. This strain component produces a rotation of convergence vectors across the Himalaya such that they are everywhere sub-normal to the arc rather than parallel to the average direction of convergence between stable India and stable Eurasia. The total extension across the southern Tibetan plateau between the eastern and western Himalayan syntaxes approaches 30 mm/yr. This strain can be reproduced by thin viscous sheet numerical models of the plateau where pressure across the Himalayan front is nearly but not perfectly lithostatic. For a range of initial geometries, the boundary evolves into an small-circle shape where maximum horizontal compressive stress is oriented arc-normal, requiring a component of along-arc extension. Maximum strain and thickening occurs at developing syntaxial bends.

S62B-1196 1330h POSTER

Pn Tomographic imaging of Mantle Lid Velocity and Anisotropy at the Junction of Arabia, Eurasia and Africa Plates

Ali I. Al-Lazki[1] (968-513-407; aia2@cornell.edu); Eric Sandvol[2]; Dogan Seber[3] (seber@geology.cornell.edu); Muawia Barazangi[3]; Niyazi Turkelli[4]; Randa Mohamad[5]

[1]Sultan Qaboos University, Department of Earth Sciences, College of Science, P.O.Box 36, Al-Khodh 123, Oman

[2]University of Missouri, Department of Geological Sciences, University of Missouri, 101 Geology Building,, Columbia 65211, United States

[3]Cornell University, Intitute for the Study of the Continents, Snee Hall, Cornell University, Ithaca, NY 14853, United States

[4]Bogazici University, Department of geophysics, Kandilli Observatory and Earthquake Research Institute, Bogazici University, Istanbul 81221, Turkey

[5]Syrian National Seismological Center, General Establishment of Geology and Mineral Resources, Damascus 0000, Syrian Arab Republic

Arabia's northward motion is considered the primary driving force behind building the young mountain belts along the Zagros-Bitlis continent-continent collision zone and present-day escape of the Anatolian plate along the North and East Anatolian fault zones. Similarly, the westward motion of Anatolia influences subduction dynamics of the retreating Africa slab along the Hellenic and the Cyprean arcs.In this study we mapped Pn wave velocity and anisotropy beneath the Arabian, Eurasian and African plates' junction. Using a strict selection criteria we selected 166,000 Pn phases to invert for velocity and anisotropy, 5400 of which were data recorded by the 29-station array of the Eastern Turkey Seismic Experiment (ETSE). We find two types of low Pn velocity anomalies. A broader scale (~500 km) low Pn velocity zone (< 8.0 km/s) that underlies regions within and nearby the Arabian plate boundaries and beneath most of the Anatolian plate. Smaller scale (~200 km) very low Pn velocity (< 7.8 km/s) zones are found to underlie the Lesser Caucasus, southern Syria and northern Jordan, the Isparta Angle, central Turkey and the northern Aegean Sea back-arc region. At the northern and northeastern boundaries of Arabia the low velocity zone underlies regions parallel and northeast of the Zagros and north of the Bitlis sutures. In contrast, at the northwestern boundary of Arabia the low velocity zone underlies the Dead Sea Fault (DSF) system and the northwestern Arabian plate proper. We interpret the northwestern Arabia broad anomaly and the very low smaller anomaly within Syria, Jordan and nearby regions as part of the Red Sea and East Africa rift system. The broad low velocity zone beneath Iran, eastern Turkey and the Anatolian plate may be in part the result of subducted Tethyan oceanic lithosphere beneath Eurasia. High Pn velocities (8.1 8.4 km/s) underlie the Mediterranean Sea, the southern Aegean Sea, the Black Sea, the southern Caspian Sea extending eastwards under the Kopeh Dagh and westwards under Azerbaijan, eastern Romania, and central and the eastern Arabian plate. The extent of high Pn velocity of central and eastern Arabia across the Bitlis and Zagros suture lines is used to infer the possible underthrusting of the Arabian plate beyond the suture lines. Along the southern Zagros the high Pn velocity zone extends beyond the suture line, this may be indicative of Arabia underthrusting parts of the Sanandaj-Sirjan region of western Iran. In contrast, the lack of high Pn velocity beyond the Bitlis suture line implies limited underthrusting of Arabia beyond the Bitlis suture. Observed Pn anisotropy showed a higher degree of lateral variations in comparison to Pn velocity. In eastern Anatolia, where we observe a localized very low Pn velocity zone, the mapped Pn azimuthal anisotropy also shows coherency in orientations in the same zone. Moreover, the Pn anisotropy orientations are similar to observed orientations of polarization anisotropy based on shear wave (SKS) splitting analysis. This implies a thinned or absent mantle lid in eastern Anatolia and that Pn anisotropy and SKS splitting are both sampling asthenospheric deformation.

S62B-1197 1330h POSTER

Crust and Mantle Structure Beneath the INDEPTH-III Central Tibet Array

Thomas M Hearn[1] (505-646-5076; thearn@nmsu.edu)

Xiaofeng Xiao[1] (xxiao@nmsu.edu)

James F Ni[1] (jni@nmsu.edu)

. INDEPTH-III Team[1] (thearn@nmsu.edu)

[1]New Mexico State University, Physics Department, Las Cruces, NM 88003, United States

The INDEPTH-III Tibet expedition deployed stations in a north-south array straddling the boundary between northern and southern Tibet. The 400 km long linear array had an average station of 10 km making it ideal for determining the crust and mantle structure beneath the array. We used about 400 Pn traveltimes from events north and south of the array for a tomographic inversion. Results show little variation in crustal thickness along the profile. Pn velocities in the southern half of the array are very high, around 8.4 km/s, and very low, around 7.7 km/s, in the north. The transition between north and south cannot be resolved better than 100 km. Crustal velocities are also lower in the north, by about 0.1 km/s, mostly in the upper half of the crust.

These results suggest that the mantle beneath Tibet is much hotter in the north, both within the lower crust and mantle. Numerous authors before have commented on this, but the mantle velocity contrast beneath the INDEPTH-III line is extremely large. Additional mapping of Pn velocity beneath Tibet using Pn tomography shows that the change extends east-west, approximately along the Bangong-Nujiang suture. We associate the high velocities in the south with the cold subducted Indian shield, and conclude that the Indian plate dives into the mantle there. Low velocities to the north must be caused by near solidus conditions. Higher temperatures (1100 degrees C) and the presence of water in the lithospheric mantle will create partial melting conditions. Water could be left over from ancient subduction episodes. We suggest that convection induced by the subduction of the Indian plate is coupled to convection in the north, removal of the lithosphere, and subsequently heated crust and mantle.

S62B-1198 1330h POSTER

Tracking the Demise of the Neotethys Ocean Between Arabia and Eurasia

Nadine McQuarrie[1] (626-395-6486; nmcq@gps.caltech.edu)

Joann M Stock[1] (626-395-6938; jstock@gps.caltech.edu)

Charles Verdel[1] (626-395-6135; cverdel@gps.caltech.edu)

Brian P Wernicke[1] (626-395-6192; brian@gps.caltech.edu)

[1]California Institute of Technology, Division of Geological and Planetary Sciences MC 100-23, Pasadena, CA 91125, United States

The young continental collision of Arabia with Eurasia reflects the final demise of the Neotethys Ocean through northward subduction of oceanic lithosphere under Eurasia. Several aspects of this collision still poorly understood include, the width of the Neotethys Ocean basin, the relationship between the demise of this ocean basin and voluminous magmatic arcs in Iran, age of collision between the Arabian and Iranian margins and the connection between the opening of the Red

Sea and growth of the Zagros Mountains. We present updated rotations within the Africa-North America-Eurasia plate circuit in conjunction with established poles of rotation describing the opening of the Red Sea to illustrate the direction and rate of subduction of the Neotethyan oceanic lithosphere. Minimum shortening estimates across the Zagros Mountains, Alborz / Kopeh Dagh Mountains, and Central Iran permit reconstructions of the northern margin of Arabia and the southern margin of Eurasia.

Continental margin reconstructions combined with plate motion reconstructions delineate the maximum amount of subducted ocean crust (~1000 km) since 68 Ma and the latest possible time of collision of Arabia and Eurasia. The rate of motion of Arabia to Eurasia has been fairly constant at ~2 to 3 cm/yr since 59 Ma. Perhaps surprisingly, the opening of the Red Sea at ~25 Ma does not significantly alter the rate of convergence, but the direction of motion of Arabia to Eurasia changes from northeast from 59 to ~25 Ma to due north from ~25 Ma to present. The reconstructed margins of Arabia and Eurasia collide at ~10 Ma and mark the onset of continental collision and deformation of Iran from the Zagros to the Alborz at a rate of ~2 cm/year. The slow, steady rate of subduction from 59 Ma to present contrasts with the strong episodicity in accumulation rates of arc magmatism, which are greatest in the interval of ~45 Ma 25 Ma.

S62B-1199 1330h POSTER

The Crustal Structure of Eastern Turkey from Receiver Function Inversion

Ekrem Zor[1] (902163080525; zor@boun.edu.tr)

Eric Alan Sandvol[2] ((573) 884-9616; sandvole@missouri.edu)

Cemil Gurbuz[1] (902163320242; gurbuz@boun.edu.tr)

Dogan Seber[3] (seber@geology.geo.cornell.edu)

Muawia Barazangi[3] (barazangi@geology.geo.cornell.edu)

[1]BU Kandilli Observatory and Earthquake Research Institute, Cengelkoy, Istanbul 81220, Turkey

[2]Department of Geological Sciences, University of Missouri, Columbia 65211, United States

[3]Cornell University, Institute for the Study of the Continents (INSTOC), Snee Hall, Ithaca, NY 14853-1504, United States

The crustal structure of Eastern Turkey has been analyzed using receiver functions obtained from the teleseismic recording of the V-shaped array of 29 broadband PASSCAL stations [Eastern Turkey Seismic Experiment] deployed by the cooperation of Bogazici University, Kandilli Observatory in Turkey and Cornell University in US. The three component recordings of teleseismic events from a wide range of epicentral distances (25-90) were used to obtain single-event receiver functions. In this study we analyzed the receiver functions by modeling with a grid search algorithm in order to obtain S-wave velocity structure as well as the profiling of the single-event receiver function along the western and eastern transects of the array. The stacking of single-event receiver functions was used to reduce signal generated noise and scattered energy in order to control the effects of lateral structural changes. The stacked receiver functions were modeled by performing a 6-plane layered grid-search scheme in order to model the first-order features in the receiver functions with a minimum degree of trade-off. We found no significant crustal root beneath the western portion of the array, but there is some evidence of crustal thickening in the north. The crust thickens from 44 km in the southern part of the Bitlis Suture Zone to 50 km towards the northern end of the array in the vicinity of the North Anatolian Fault. We found a low velocity zone in the crust beneath the middle part of the array where the crustal thickness is around 46-48 km. In the eastern part the array crustal thickness is increasing from the southern tip of the array where it is 40 km to the middle section of the array where the thickness reaches 48 km. The average crustal p-wave velocities are higher in the east and reach 6.25-6.40 km/s. The crustal thickness in the Arabian plate, south of the Bitlis-Zagros Suture Zone is between 38-45 km/s with the highest average velocities observed (6.40-6.60 km/s).

S62B-1200 1330h POSTER

First Images of the Lithospheric Structure of Western Tibet

Jérome Vergne[1] (0033 4 76 82 80 27; jvergne@obs.ujf-grenoble.fr)

Jiang Mei[2] (meij@public3.bta.net.cn)

Gérard Wittlinger[3] (Gerard.Wittlinger@eost.u-strasbg.fr)

Georges Poupinet[1] (georges.poupinet@obs.ujf-grenoble.fr)

[1]LGIT-CNRS, 1381 rue de la piscine BP 53, Grenoble 38041, France

[2]Institute of Mineral Deposits, Chinese Academy of Geological Sciences, Baiwanzhuang road, Beijing 100037, China

[3]EOST-CNRS, 5 rue Rene Descartes, Strasbourg 67084, France

In the framework of the long term cooperation between France and China in the exploration of the lithospheric structure of the Tibetan plateau, a new network of 53 seismic stations have been deployed in western Tibet in 2001. This study was particularly motivated by the relatively lack of informations about the nature and state of the lithosphere in a region where the plateau reaches his highest elevation and is significantly shorter than in its central part Three strike-slip faults (Altyn Tagh, Gozha and Karakorum) and the Banggong suture are the first order tectonic features of this region. Stations were installed for 5 months, with an average spacing of ~15 km, along the road between Yecheng, at the southern edge of the Tarim basin, and Shiquanhe (Ali), near the Indian border. This network consisted in short, intermediate and long period seismometers, which allows a multi-scale analysis of the crustal and upper-mantle seismic properties of this region.

Here we present the first results derived from a receiver function analysis and a P-wave teleseismic tomography. A join approach of these two methods is of particular interest since converted waves are more adapted to detect seismic discontinuities, whereas teleseismic tomography is more sensitive to lateral velocity variations. The moho is clearly imaged all along the profile by the receiver functions analysis, and reach an unusual depth of ~85 km in the central part of the plateau. One other important result that comes out from this study seems to be the key role played by the Altyn-Tagh fault. Indeed, this fault is associated to a ~15 km high jump in the moho topography and separate a +3% high P-wave velocity lithospheric block to the north (Tarim) from a -3% low velocity block to the south (Tibet). This result confirms that the large strike-slip faults of the Tibetan plateau act as lithospheric boundaries.

S62B-1201 1330h POSTER

Evidence for timing of the initiation of India Asia collision from igneous rocks in Tibet

Xuanxue Mo[1] (86-10-8232-2712; mxx@cugb.edu.cn, moxuanxue@hotmail.com); Zhidan Zhao[1] (86-10-8232-1115; zhaozd@cugb.edu.cn); Su Zhou[1] (86-10-8232-1115; zhousu@cugb.edu.cn); Guochen Dong[1] (86-10-8232-1115; guochdong@263.net); Tieying Guo[1] (86-10-8232-2586; mxx@cugb.edu.cn); Liang Wang[1] (86-10-8232-1115; zhaozd@cugb.edu.cn)

[1]China University of Geosciences, Beijing, 29 Xueyuan Road, Beijing, BJ 100083, China

Resent studies on igneous rocks in Tibet provide new evidence for timing of the initiation of India-Asia collision. It has been defined that the NeoTethys started to open from middle Triassic (T2) and reached its widest width in J2K1 (177 120 Ma) by petrological and paleontology evidence from IndusYalung Zangbo ophiolites, which marked the suture between south margin of Lhasa block and north margin of Indian block. Andesitedominated arc volcanic rocks and calc-alkaline granitoids in the Gangdese to the north of the ophiolites zone, as indicators of subduction of Neo-Tethys oceanic plate, formed in 155.7 65 Ma. Petrotectonic assemblages of muscovitebearing granite, leucogranite and high potassium calcalkaline granite aged from 55.7 Ma to less than 10 Ma are no doubt records of collision and postcollision processes. Wide spreading postcollisional highpotassium volcanic rocks (high-K calcalkaline and shoshonitic series) in Tibet erupted during 40 30 Ma, 25 10 Ma and less than 10 Ma. Therefore, IndiaAsia collision took place during the period between 65 Ma and 55 Ma. More critical evidence, however, came from Linzizong volcanic formation, which widely spread in southern Gangdese magmatic belt. The PaleoceneEocene (aged 63.89 49.2 Ma) subhorizontal terrestrial volcanic strata unconfomably overlay on the late Cretaceous sedimentary strata (Shexing Formation) being strongly deformed. Linzizong volcanic formation mainly consists of high-K2O andesite, trachyandesite, trachyte, rhyolite and thick acidic ignimbrite, characterized by high content of K2O and partly peraluminous, especially in the middle to upper parts of the column, showing obvious geochemical signature of collisional postcollisional volcanic rocks. In combination with the stratigraphical and paleontological evidence in southern Tibet that documented dramatic change in sedimentary facies and microfuna content across the Cretaceous Tertiary (K/T) boundary (Wan et al., 2002), it is concluded that the collision between India and Lhasa Continental blocks was most likely initiated at ~ K/T boundary time (~ 65 Ma).

S62C MCC: Hall C Saturday 1330h

Tonga Deep Earthquakes, 19 August 2002 Posters *(joint with T, DI, MR)*

Presiding: **D Wiens,** Washington University**; M Brudzinski,** University of Wisconsin

S62C-1202 1330h POSTER

Seismicity along Subduction Zones: Visualization with a Physical Basis

Wang-Ping Chen[1] (w-chen@uiuc.edu)

Michael R Brudzinski[2] (608-262-5567; brudzins@geology.wisc.edu)

[1]University of Illinois, Department of Geology, Urbana, IL 61801, United States

[2]University of Wisconsin, Department of Geology and Geophysics, Madison, WI 53706, United States

It is a common practice to plot epicenters and hypocenters as symbols of equal sizes on maps and cross-sections. While this representation is effective in relating seismicity to high-angle faults, it lacks a physical basis because equal weights are assigned to events that span several orders of magnitude in seismic moment. Furthermore, for cases such as subducted lithosphere where seismicity does not occur along major, through-going faults, "connecting the dots" leads to erroneous impressions of true seismogenic structures. Another common practice is to plot each event according to its magnitude. In principle, this preserves the size of earthquakes by using the logarithmic magnitude scale. The results, however, are not intuitive and the physical meaning of the magnitude scale is unclear. In contrast, we use simple scaling laws between fault area and seismic moment to plot seismicity in a way that conforms to the true scale of maps and cross-sections. The results are intuitive and often quite distinct from plots produced from common practices. We will illustrate the utility of our approach with examples from several different tectonic settings, including the large (Mw 7.6 and 7.7) August 19, 2002 Tonga deep earthquakes, configurations of sub-horizontal outboard earthquakes and complex Wadati-Benioff zones [Chen and Brudzinski, Science, v. 292, p. 2475, 2001], aftershock productivity of deep earthquakes [Wu and Chen, GRL, v. 26, p. 1977, 1999], and dual, out-of-sequence thrusts at mid- to lower-crustal depths [Kao and Chen, Science, v. 288, p. 2346, 2000].

S62C-1203 1330h POSTER

State of Strain in Sub-horizontal Slabs

Michael R Brudzinski[1] (608-262-5567; brudzins@geology.wisc.edu)

Wang-Ping Chen[2] (w-chen@uiuc.edu)

[1]University of Wisconsin, Department of Geology and Geophysics, Madison, WI 53706, United States

[2]University of Illinois, Department of Geology, Urbana, IL 61801, United States

Fault plane solutions of earthquakes in subducted lithosphere typically show down-dip compression (DDC) or down-dip extension (DDE): the axes of maximum compression (P-axes) or extension (T-axes) closely follow the dip of slab as revealed by the distribution of seismicity. This pattern is strong evidence for slabs acting as a stress guide in the mantle: a uniform strain field develops within the cold, strong slab as it sinks ("slab-pull") and encounters increasing resistance at greater depths [Isacks and Molnar, Nature, v. 233, p. 1121, 1969]. We use a database of 1600 fault plane solutions to explore the limit of this time-tested paradigm in situations where the slab is sub-horizontal. Two well-known cases occur beneath northern Argentina and southern Peru, where seismicity concentrates near depths of 100 km over large areas of about 400 x 400 km^2. In each case, there is no obvious clustering of the T-axes. This is expected in that slab-pull has little horizontal component when the slab is sub-horizontal. Meanwhile, a clear pattern of DDE is evident for slab dips as small as 10 degrees, setting an empirical limit of the paradigm. At depths greater than 300 km, large regions of outboard earthquakes occur beneath Vanuatu and Fiji where P-axes do not follow a distinct pattern of DDC observed in surrounding zones of active subduction. In the latter case, seismic anisotropy and lateral heterogeneities of P- and S-wave speeds indicate that in fact a buoyant petrologic anomaly accompanies the outboard earthquakes, offering a dynamic process that explains the sub-horizontal configuration of seismicity and its deviation from DDC.

S