middle and lower crust are modeled as non-Newtonian visco-elastic materials. Faults in the brittle layer are formed by locally lowering the cohesion as a function of strain. We vary the strength of both the brittle and ductile layers and the amount of transtensional obliquity. We find that both the amount of obliquity and the relative strength of the brittle crust vs. the lower crust control whether the deformation is localized or delocalized. Our model results are compared to the observations from the northern Gulf of California.

T51E-11 1120h

Implications for the Formation of Transform Faults from Pliocene Basins on Isla San Jose, Southern Gulf of California

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Pliocene basins on islands in the southern Gulf of California offer a superb opportunity to evaluate how transform faults form in a highly oblique plate boundary. Pliocene strata are exposed in two subbasins on Isla San Jose, 100 km north of La Paz, Mexico. The subbasins have broadly similar stratigraphy and part of the basin is subsided offshore. A ∼1 km thick lower sequence deepens upward from a thick alluvial fan unit through marginal marine strata to an outer shelf to upper slope mudstone (based on lithology and benthic forams). The uppermost mudstone has planktonic forams that indicate an early late Pliocene age (∼3.5-3 Ma). There is evidence for widespread syn-sedimentary deformation in the lower sequence. The upper sequence is a ∼50 120 m thick shallow marine calcarenite that lies across a low-angle to abruptly gradational unconformity. The overall stratigraphy represents 1 1.5 km of subsidence in the lower sequence before 3 Ma, followed by local tilting of the basin and rapid upward shallowing at and after 3 Ma. A late Pliocene to Quaternary unconformity lies above the basin and most Quaternary deposits are alluvial. The southern subbasin is bounded by NW-N striking Pliocene normal and normal-dextral faults, while the northern subbasin has mainly buttress unconformities and local faults along an irregular embayment.

The subbasins on Isla San Jose may have initiated at the northern end of an early transform fault emanating from the Cerralvo trough, which suggests basin inception at 5 6 Ma. This implies a reasonable rate of subsidence for a rift basin. The rapid basin uplift indicates a major reorientation (or cessation) of Cerralvo transform faulting at ∼3 Ma. Mudstone deposition at 3.5 3 Ma followed by basin uplift is similar to events in the Perico basin on Isla Carmen, 120 km to the NW near Loreto. These synchronous events on two separate islands may mean that the development of early transform faults acted in unison from Loreto to the mouth of the Gulf. This implies that there was a major reorganization of early transform faults to the modern configuration at 3 Ma. In contrast, later fault reorientation in the Loreto basin at 2.4 2 Ma suggests that there may be a northward propagation of transform fault development. The evidence from the islands shows that MCS and bathymetric data from the narrow shelf are needed to resolve the connections from the basins and faults we are studying on the islands to the main plate boundary transform spreading ridge system in the middle of the Gulf of California.

T51E-12 1135h

Ocean-Continent transitions in the South Balearic Basin: Crustal Structure and Processes East of the Alboran Basin and in the South Iberian Margin

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The South Balearic and Alboran basins, behind the Gibraltar Arc, originated by continental lithosfere stretching and crustal extension mechanisms occurred in a "back-arc" setting under plate convergence contexts. Geophysical data and seismic reflection profiles provide constraints on progressive crustal thinning and decrease in lithosphere thickness from the continental Alboran Basin to the oceanic South Balearic.Basin. Structures in the transition from the stretched continental crust in the East Alboran Basin to the oceanic crust beneath the South Balearic Basin denotes that extensional deformation (detachment faults) preceded continental break-up and oceanic basement growth, which probably occurred by the late Miocene.

Extremely high magma production (from 10 to 2 Ma) characterize the Alboran-South Balearic transition, which resulted in seafloor outcropping or suboutcropping volcanic highs. Normal faulting, with roughly E-W extension direction, and tilting may affect the oceanic basement. To the contrary, ocean-continent limits north of the western South Baleric Basin correspond to brusque boundaries that separates the oceanic crust and the stretched Alboran Crustal Domain (the thinned continental crust of the eastern Betic Cordillera in south Iberia at the Palomares and Mazarron margins). These crustal limits are active seismogenic tectonic lineaments involving high-angle normal and strike-slip faults. Major faults shaping the Palomares and Mazarron margins continue onshore within late-Miocene to Recent wrench-fault zones. Present day ocean-continent organization in the westernmost Mediterranean is be due to complex lithosphere and crustal deformation from Neogene to Present African-Europe plate convergence.

T51F MC: 121 Friday 0830h

Syn-Convergent Extension in the Apennines, Italy I *(joint with G, S, V)*

Presiding: **M Brandon,** Yale University**; D Cowan,** University of Washington

T51F-01 0830h

Geodynamic Mechanisms of Coeval Extension and Contraction With Application to the Northern Apennines

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Various models have been proposed to explain the coeval, and closely juxtaposed, extension and contraction observed in the Apennines of Italy and elsewhere. These mechanisms include: (1) gravitational collapse of pre-existing topography, (2) slab breakoff with isostatic rebound, (3) vertical extrusion of a rigid crustal block, (4) viscous spreading of a growing orogenic wedge driven by underplating or frontal accretion and (5) slab rollback with upper plate extension. We consider the applicability of these mechanisms to the northern Apennines and find difficulties in all models except the last. The principle distinguishing characteristic of the Apennines is the fact that extension has reduced the surface elevation to below sea level in the Tyrrhenian Sea, ultimately resulting in the formation of new oceanic crust. Of the mechanisms considered here, only slab retreat is capable of extending crust to this degree. Although this does not exclude other mechanisms from contributing to extension, it does strongly support the existence and importance of slab rollback in this setting.

We present a mechanical analysis of the slab rollback (retreat) model. Closely juxtaposed extension and contraction requires three kinematic components whose differential motion defines separate regions of extension and contraction. In this setting, these components are the subducting slab, the stable upper plate and a region of the upper plate which remains adjacent to the subducting slab as it retreats away from the interior of the upper plate. This third kinematic component moves relative to the stable upper plate at the rollback velocity, thus defining the region and rate of extension. Predictions of crustal deformation as a consequence of this model are demonstrated through the use of a finite element model which uses a kinematic description of the upper mantle motion as boundary conditions. Crustal deformation by plastic and viscous mechanisms is a consequence. The three-component model described above produces an orogenic wedge of steady size with one side in contraction and the other in extension. The transition is at the topographic divide, consistent with observations from the Apennines. Kinematic paths of particles which transit this orogenic wedge record a deformational history of accretion, early contraction, and late extension and exhumation, consistent with observations from the Apennines and with the moving "orogenic wave" model.

T51F-02 0845h INVITED

The Tyrrhenian Sea and the Apennines, 30 Myr of Backarc Post-Orogenic Extension

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Active extension in the Apennines and the southern Tyrrhenian Sea is the most recent event of a long process of extension which started some 30 Myr ago. Extension is the result of two superimposed phenomena, backarc extension due to the retreat of the subducting African plate and collapse of the thickened alpine crust. A migration of extension from Provence to the present-day Apennines is recognized in the geological record offshore and onshore, in the Liguro-Provenal basin, in Corsica, in the Northern Tyrrhenian Sea and in Tuscany. The eastward migration of deformation follows that of the volcanic arc.

The eastward migration of extension is contemporaneous with a migration of the thrust front. Like in the Aegean region the construction of an accretionary complex is contemporaneous with backarc rifting. Extension thus reworked the subduction complex during the eastward migration.

Extension is achieved by east-dipping shallow shear zones and normal faults. This is observed along the whole transect from Corsica to the internal Apennines where active east-dipping extensional shear zones have been recently described. Only the eastern most part of the transect shows west-dipping normal faults which reactivate earlier thrusts.

Extension started almost at the same time in the whole Mediterranean region from the Alboran region to the Aegean Sea. This drastic change in the stress regime of the backarc domains is probably a consequence of the hard collision between Africa and Eurasia 30 Myr ago which slowed down the absolute northward motion of Africa and thus favored the southward retreat of the subducting African plate. Variations in the velocity of extension through time are partly a consequence of the interaction of the subducting slab and the mantle, especially the upper-lower mantle boundary. Any mechanical model of the evolution of the Apennines should include the long-term evolution of deformation and thermal regime, as well as the complex boundary conditions imposed by the geometry of the plate boundary at the surface (oceanic subduction and continental collision zones in a small region) and by the deep behavior of the slab, not only the instantaneous deformation features.

T51F-03 0900h INVITED

Terminal Stage Subduction in the Central Mediterranean: Horizontal and Vertical Motions in a Dynamic Framework

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The overall geodynamic nature of the Mediterranean region is that of a convergent plate boundary zone, between the Eurasian and African plates. Regional scale processes, however, do not only show evidence of the expected compression but also of extension. Here we present a dynamic framework for the Tertiary evolution of the region in terms of a convergent plate boundary zone in a late to terminal stage. The landlocked basin setting concept (le Pichon, 1982) serves as a starting condition for the lithospheric processes in this stage. We use the 3D results from seismic tomography studies, numerical modelling, in combination with geological, geophysical and geodetic data to investigate how the region evolved from this starting condition. Particular emphasis is put on the central Mediterranean/ Apennines region. The vertical motions along the Apenninic foredeeps were studied in detail. They show a migrating pattern of subsidence and uplift, which is in support of migrating slab detachment as the underlying cause. The geodynamic evolution is represented as a hierarchy of processes with interconnected vertical and horziontal motions and associated

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stress field variations, from roll-back and back-arc extension to (a suite of) smaller scale vertical and horizontal motions along plate boundaries. Stress concentration in combination with lithospheric rheology leads to highly transient stages in the evolution. We propose that slab detachment plays a key role in the plate boundary processes. It involves gravitational and thermally induced vertical motions, each class with its specific time scale. We conclude that the dynamics of the Mediterranean region are largely governed by the internal dynamics of the Africa-Eurasia plate boundary zone, with "gravitational settling" as the basic process.

T51F-04 0915h

The Northern Apennines as an Example of Deep Accretion Beneath a Lidded Subduction Wedge

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Lids of ophiolite and oceanic crust are a common feature of many convergent margins, including the Apennines, Cascadia, Franciscan, and Costa Rica. Accretion in front of the lid is easy to resolve, but deeper accretion is more difficult to demonstrate, either because the lid has been uplifted and eroded away (e.g. Franciscan) or because it remains in place, hiding the deeper structure of the wedge (e.g. Costa Rica). In the northern Apennines, much of the lid of Ligurian units and epi-Ligurian sediments is still preserved as a thin sheet. The northwest plunge of tectonic units, coupled with the preserved lid, affords an unusually complete cross-sectional view of a wedge. Accreted materials were added to the wedge chiefly by underplating, which began in early Oligocene time and may continue at present. Underplated materials comprise foreland-basin deposits, and Mesozoic units scraped off of the descending Adria plate. Faults that bound duplexes of underplated materials merge with a roof thrust that underlies the Ligurian lid. We suggest that the extensional deformation observed in the western Apennines might be driven by underplating, in the manner proposed by Platt (1986). The extreme lithospheric thinning observed beneath the Tyrrhenian Sea, just west of the Apennines, certainly must be due to extensional flow in the underlying mantle that is associated with slab rollback. Underplating cannot be the cause of this deep-seated extension, but it may influence the style and distribution of active upper crustal normal faulting pervasive along the western flank of the Apennines.

T51F-05 0930h

On the Decollement Depth in the Apennines and Barbados

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The accretionary prism is, by definition, the volume of rocks accreted from the lower plate of a subduction zones into the fold and thrust belt of the upper plate. The volume is function of the depth of the decollement plane; e.g., a 200 km subduction with a decollement at 5 km average depth will generate in a cross-section an accretionary wedge of 1000 km2, assuming negligible compaction and erosion. We compared the Apennines and the northern Barbados accretionary prism which present main basal decollement at 6-10 km depth and < 1km depth respectively. The continental sections of the Apennines foreland have deeper decollement than the oceanic sections of the Barbados, because the sediment is thinner on the incoming Barbados plate and its denser oceanic structure is more easily subducted. Despite of these differences, the geometry of both decollement shows comparable trajectories, developed at the boundary between the crust and the sediment pile where is located the main density and strength contrast. Variations in depth of the decollement occur moving along strike in both accretionary prisms. Assuming the aforementioned depth of the decollement and a 200 km of plate subduction, comparable areas of the accretionary prism should range between 1200-2000 km2 and <200 km2 respectively. This explains the higher elevation of the Apennines with respect to the Barbados prism which is mainly below sea-level. Both accretionary prisms are cross-cut by extensional faults. However the normal faults and the associated seismicity are less evident in the Barbados, and this could be a consequence of the thicker hangingwall crust and higher topography of the Apennines where the larger lithostatic load is triggering stronger earthquakes.

T51F-06 0945h

Active Tectonics in the Apennines: Seismological Constraints

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Seismological studies carried out in the past decade have brought a great deal of new information on active tectonic processes in Italy. Although the rate of tectonic strain accumulation is relatively low, earthquakes have caused huge damages and thousands of casualties in the past centuries due to the high density of inhabitants and to the presence of many ancient buildings. I review here the three main contributions of seismological research to the understanding of past and present tectonics. The research on historical earthquakes allows us to recover the main areas of deformation in the last millennium, but repeat times of large events may be larger than the time span covered by catalogues. Seismic networks operating in the past two decades allowed us to depict fairly well the geometry and style of faulting of many active sources, also before large ruptures occur. These nets have also provided the basic data to construct high quality tomographic models of the crust and upper mantle beneath Italy. It is now possible to link in a coherent view the deep processes and the crustal seismicity and deformation, although a robust geodynamic model that quantitatively explains all the relevant data is still to be developed. The whole set of seismological information suggests that the crustal seismicity in the northern Apennines is best explained by a process of continental subduction and slab retreat, with earthquakes accommodating extension in the arc and transpression at the outer front. Normal faulting earthquakes in the northern arc occur on west-dipping low angle faults, whereas in the south active faults are larger and steeper. The fault segment size and location along the whole extensional belt is strongly controlled by the inherited compressive structure. The abrupt transition which is evident between northern and central-southern Apennines from both upper mantle structure and shallow tectonics is most likely due to the lateral heterogeneity of the Adriatic-Apulian subducted lithosphere, which is thicker in the south and might have slowed down the subduction process, possibly triggering a slab breakoff beneath the southern Apennines. The only segment of the Apenninic arc where oceanic (Ionian) lithosphere still enters the subduction zone is beneath the Calabrian arc where we observe the highest rate of slab retreat and the largest (M>7), deepest (z>500km) earthquakes occur, accompanied by large crustal earthquakes above.

T51F-07 1020h

Active Tectonics of the Umbria Region (Central Italy) in the Framework of the Neogene-Quaternary Extension of the Northern Apennines

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The Northern Apennines are interested by contemporaneous compression in the external part (Po Plain and Adriatic coast) and extension in the internal part (Apenninic Ridge), as revealed by seismological and geological data on the present-day stress field. The pair compression/extension has been migrating from W to E since Middle Miocene (i.e. about 20 Ma). The eastward migration of the extension reflects on the crustal setting of the Northern Apennines: the Western part (Tyrrhenian domain) is characterised by positive Bouguer anomalies, high values of heat flow and by a flat-young-thinned crust (20-25 km); whilst the eastern part (Adriatic domain) is characterised by negative gravity anomalies, low values of heat flow and a west-dipping-old crust, about 35 km thick. The CROP03, deep NVR profile, crossing the Italian peninsula from the Tyrrhenian coast (Punta Ala, Tuscany) to the Adriatic coast (Gabicce, Marche), gave an important contribution for understanding the geometry and modes of the extensional tectonics in the Northern Apennines, showing that the most relevant structural feature in the upper crust of the western domain is the presence of five main ENE dipping, crustal scale normal faults, producing severe extension of the Tuscan crust and deeply disrupting the previously formed, compressional features. At the hanging-wall of these extensional shear zones, antithetic, high angle, west-dipping normal faults are also present. The Neogene-Quaternary sedimentary basins of the region appear to be geometrically and genetically related to these major shear zones. Many recent studies, based on both geological and geophysical data, confirm the presence of these low angle detachments, and effectively depict the migration of the extension in space and time, from the Corsica basin to the axial zone of the Apennines. The easternmost of these shear zones, named Altotiberina fault , is located in Umbria, at the border between the western domain and the eastern Domain. The geometry of this east-dipping, low angle (about 20°) detachment has been reconstructed in great detail across an area of about 1500 km2, using a network of seismic reflection profiles, calibrated on deep wells and surface geology data. The fault displacement is of about 8 km. A surveying of the microseismicity, operated by a local network, shows that the earthquakes cluster along the fault trace, and are limited in the hangingwall of the fault. The major recent earthquakes, as well as most of the historical seismicity, are associated to a set of high angle, SW dipping normal faults, antithetic to the Altotiberina fault. The active faults of the Umbria region can be regarded as the present-day expression of the process of crustal extension of the western domain of the Northern Apennines, a process begun about 20 Ma in the Northern Tyrrhenian area, and regularly migrating since that time towards North-east, possibly driven by the roll back of the Adriatic crust, subducting westward into the upper mantle.

T51F-08 1035h

Geomorphic Evidence for the Style of Quaternary Uplift and an Orogenic Standing Wave, Apennines, Italy.

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The Italian Apennines represent concurrent crustal shortening and extension related to the overall ongoing convergence of Africa and Eurasia. They are one of only a few orogens world-wide where the evidence for concurrent crustal shortening (the Adriatic-Po flank) and extension (the Tyrrhenian flank) are well-exposed above sea level. Despite 35 m.y. of orogenesis, there is some reason to suspect that emergence and uplift of the range is a relatively recent event that initiated rapidly in the late Cenozoic. We examine the regional-scale geomorphic expression of Apennine orogenesis to determine the location and degree of continued shortening, test the concept of an orogenic standing wave, and provide quantitative constraints of permanent deformation across the orogen. Spatial coincidence of thrust-sense seismicity, the historic record of damaging earthquakes, and alluvial river channel adjustments are supportive of ongoing shortening at the Apennine deformation front beneath the Po Plain. Evidence for continued shortening in the emergent portion of the fold and thrust belt is equivocal, but a rich record of fluvial terraces mark rates of fluvial incision as high as 1 mm/yr. Rivers flowing north and east, transverse to the fold the thrust belt on the Adriatic flank, show clear evidence of having their headwaters pirated by west-flowing, Tyrrhenian-flank rivers draining the extending portion of the range. Parts of the Tyrrhenian flank appear to be evolving like a great escarpment, and everywhere the drainage divide is migrating eastward. Extensional processes are clearly active near the range crest as supported by the diverted drainages and a high degree of historic and modern seismicity. Middle Pliocene shallow marine sediments are preserved on the interfluves of both flanks and there are flights of uplifted Quaternary marine terraces along the Adriatic and Tyrrhenian coasts, data that are used to support of the prevailing interpretation of recent, peninsula-wide arching and emergence of the range. We present an alternative interpretation for range uplift that does not

rely solely on recent arching of the range, but rather suggest that the Apennines have long existed as an eastward-migrating arch with a landscape close to or in geomorphic steady-state. The geomorphic steady-state condition is expressed by the mouths of Adriatic-Po flank streams that are elongating as the thrust front propagates eastward at the same rate that their head-waters are being pirated away by the Tyrrhenian flank drainages. From a frame of reference outside the Apennines, the rate of eastward divide migration is matched by the rates of eastward elongation of Adriatic-Po flank river mouths and eastward consumption of Tyrrhenian flank river mouths by subsidence. The result is a topographic "standing-wave". Our ongoing investigations are dedicated to documenting these steady-state geomorphic processes and whether they have resulted in a steady-state Apennine topography, or if the topographic standing wave has recently changed in both width and amplitude.

T51F-09 1050h

Geomorphological Evidence Bearing on the Paired Compressional-Extensional Fronts of the Northern Apennines

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The close association of compressional folding and extensional normal faulting in the Northern Apennines has long attracted the attention of geologists. Elter et al.(1) showed that an extensional front has been following along, about 100 km behind a NE-migrating compressional front. This puzzling tectonic pattern has most commonly been explained by delamination and rollback, but the identity of the delaminating unit has been controversial.

Little attention has been paid to the question whether the migration of the paired tectonic fronts and the generation of structures has been episodic or steady state. Since most or all of the Northern Apennines has emerged from the sea in Neogene time, the drainage pattern of the Peninsula may provide evidence bearing on this question. At the latitude of Gubbio, many short, straight, parallel rivers flow northeast from the main drainage divide to the Adriatic Sea, cutting through large anticlines between the extensional and compressional fronts. Alvarez (2) showed that this pattern arose from a process suggested by Mazzanti and Trevisan (3), in which incipient anticlines, additions to the coastal plain, and downstream increments of the rivers formed synchronously at the advancing shoreline. Deeper and deeper gorges cutting higher and higher anticlines southwest from the Adriatic coast show that the eastern third of the Northern Apennines formed in a roughly steady-state process.

From the Tyrrhenian coast to the drainage divide, grabens that formed behind the extensional front have produced a trellis pattern in the three master streams (Arno, Ombrone, Tiber). In the steady-state hypothesis, many short, straight, parallel streams the former headwaters of the Adriatic rivers would have been disrupted by graben formation and progressively (from SW to NE) added to the trellis pattern. Close to the extensional front, this disruption would have occurred only in Quaternary time, and one would predict that the abandoned headwater tracts would be recognizable. A few candidates are currently under investigation, but the predicted patterns are difficult to detect, and there is little to suggest that the present drainage divide has migrated. This suggests that the steady-state migration of topographic features does not extend back beyond Late Miocene or Early Pliocene time. This is supported by the fact that the Monte Nerone-Monte Catria anticline, forming the main Umbria-Marche Ridge, about 15 km east of Gubbio, is far more structurally elevated than any feature for 100 km to the west.

Departure from steady-state topographic evolution may have been driven at the surface by km-scale sea level drawdown during the Messinian salinity crisis or by 100-m-scale Quaternary sea-level oscillations. Or the driver may have been at depth, e.g., duplexing or out-of-sequence thrusting, or episodic delamination. On the other hand, the model of migrating paired fronts, which has guided Apennine research for 25 years, might be in need of major revision.

(1) Boll. Geofis. Teor. Appl. 17, p. 3, 1975. (2) Basin Res. 11, p. 267, 1999. (3) Geog. Fis. Din. Quat. 1, p. 55, 1978.

T51F-10 1105h

Geodetic Deformation in the Central-Southern Apennines (Italy) From Repeated GPS Surveys

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We analyzed the horizontal strain rate field of a sector of the Central-Southern Apennines. This area was a site of large earthquakes in the past, and its present low seismicity could suggest a high seismic hazard. The number of permanent GPS stations is still too limited to provide a satisfactory description of the highly heterogeneous strain field which seems to affect this zone; thus, the use of non continuous but denser GPS networks is still a fundamental tool. We used GPS data collected during yearly repeated campaigns performed from 1994 to 2001 on the GEOMODAP network. Site velocities were obtained starting from the daily coordinates and covariance solutions, using a Kalman filter approach. We used the ITRF2000 solution for European IGS stations to compute an Euler pole and to determine a stable Europe reference frame. The residual velocity field obtained shows two different prevalent motion trends, NNE-ward for the eastern sector of the network and NW-ward for most of the sites of the western side. The mean strain rate tensor obtained from a least square inversion method, over a sub-network oriented approximately SW-NE, shows a significant extensional deformation (1.5x10-8 strain/yr) about normal to the Apennine chain, in agreement with seismological and neotectonic data. On the basis of a network dimension of about 250 Km, this value gives a well constrained estimate of the extensional velocity of about 4.0 mm/yr, normal to the chain axis, that can be considered an upper bound of the active extensio of this area. In order to detect changes in the spatial pattern of the strain rate field within this sub-network we used a least square inversion method that interpolates the velocity solution and solves for the velocity gradient tensor over a regular grid. This analysis shows a more complex picture, with a transition of the strain rate field from about N-S compression in the Tyrrhenian side to about NE-SW extension toward the Adriatic.

T51F-11 1120h

Active Microplate Deformation and Crustal Delamination in the Southern Circum-Tyrrhenian region, Italy: GPS Velocities from the Peri-Tyrrhenian Geodetic Array

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A GPS velocity field for 30 sites of the Peri-Tyrrhenian Geodetic Array distributed around the southern Tyrrhenian basin indicates differential motion between Sardinia, Sicily, and southern Italy. The GPS sites are located in bedrock and were occupied in 1995, 1997, and 2000 for 18 to 24 hours during each campaign. The GPS data were processed with BERNESE (4.2) in the ITRF97 realization using the continuous GPS sites at Matera (MATE) in southern Italy, Noto (NOTO) in Sicily, and Cagliari (CAGL) in Sardinia for fiducial reference. In a reference frame fixed on Sardinia, which has a velocity consistent with Eurasia, both Sicily and southern Italy show N to NW motion of 5-10 mm/yr. Differential NW-SE convergence of 5-8 mm/yr between Sardinia and Sicily is consistent with thrust earthquake focal-mechanisms along the southern Tyrrhenian margin. In a southern Italy fixed reference frame, shortening in the Apulian foreland is accompanied by NE-SW extension at 6-8 mm/yr along the Tyrrhenian margin, consistent with contractional and extensional earthquake focal-mechanisms. In a fixed Sicily reference frame, southern Italy moves S to SE at 4-6 mm/yr. NE-SW extension along the eastern margin of the Tyrrhenian Sea is accompanied by net N-S shortening across the basin. Sicily and southern Italy have velocities inconsistent with both Eurasia and Africa suggesting active displacement of the Adriatic microplate. Differential motion between Sicily and southern Italy indicate non-rigid behavior and internal deformation within Adria. The SE-directed late Miocene to recent migration of active oceanic seafloor formation in the southern Tyrrhenian basin may reflect propagation of crustal flexure and crustal delamination driven by N-S shortening.

T51F-12 1135h INVITED

Seismic structure of the Adriatic Lithosphere.

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We use data collected by the 1994 Northern Apennines Transect to investigate the structure of the lithosphere beneath the eastern coast of Central Italy. We reprocessed records of teleseismic P waves obtained at station NAP9 (Monte Conero, near the Adriatic coast) with a multitaper spectral correlation (MTC) receiver function estimator. This station lies above the Adriatic lithosphere, in the foredeep of the Apennines convergent margin. We computed both radial and transverse receiver functions (RFs).

Use of the MTC algorithm allows us to examine data from a broad range of directions and distances. Best sampling in backazimuth is obtained in the northeastern quadrant (0° - 110°), where sources span a range of epicentral distances between 30° and 150°. Examination of the wavefield evolution with backazimuth and epicentral distance helps us identify converted-mode phases that are associated with the seismic structure of the lithosphere. We also explore the frequency dependence of the wavefield to assess the length scales of seismic structures associated with specific phases in RFs.

P-S converted phases observed in broad backazimuthal ranges are consistent with the folowing seismic structures within the Adriatic lithosphere: 1) a mid-crustal shear zone at 15-20 km depth; 2) a sharp increase of seismic velocity at $\sim$50 km depth, with considerable anisotropy implied by a well-developed transverse RF phase; 3) a diffuse increase of seismic velocity at $\sim$30 km depth, best seen from the ENE direction; 4) an anisotropic boundary at $\sim$100 km depth not associated with a significant change of isotropic properties.

Both features 2 and 3 are candidates for the crust-mantle transition within the Adriatic lithosphere. Complicated structure and uncertain definition of the Moho have been noted in this region from previous active-source seismic profiles. The transverse converted-phase that defines feature 4 does not switch polarity in the 0° - 100° backazimuthal range. This is consistent with anisotropy-inducing fabric lineation along the strike of the subduction margin in the Adriatic. A similar orientation of mantle fabric was suggested by teleseismic shear-wave birefringence measurements at this site.

T51G MC: 310 Friday 0830h

Nankai Seismogenic Zone: Fluids, Sediments, Experiments, and Fault Rocks *(joint with OS, S)*

Presiding: **J C Moore,** University of California Santa Cruz; **M Underwood,** University of Missouri

T51G-01 0830h INVITED

New Insights on the Fluid Flow Regime in the Nankai Trough Subduction Zone

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The Nankai Trough accretionary prism is formed by subduction of the $\sim$15 Ma Philippine sea plate beneath the SW Japan arc at 4 cm/yr, and by active sediment accretion. The Nankai Trough has generated earthquakes of larger than magnitude 8, the most recent one in 1946. Recent modeling found the up-dip limit of the seismogenic zone to coincide with the $\sim$150C isotherm and the down-dip limit with the 350°-450°C isotherm.