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Deformation of an overriding plate varies along the strike of a convergent plate boundary whose curvature is greater than that of the Earth. For the Hellenic plate boundary, not only do relative plate-convergence vectors vary spatially along strike, but the subduction-zone curvature has increased temporally as the trench migrated south-southwestward since Early Miocene time. Structural mapping/kinematic analyses, tectonostratigraphy, and chronostratigraphy of the Pliocene-Holocene Messaras Basin (southern Crete, Greece) and Late Miocene-Holocene Apolakkia Basin (SW Rhodes), both within the eastern Hellenic forearc, address the changing kinematics along strike of the plate boundary as a function of increasing obliquity of convergence and the degree of coupling to the downgoing African lithosphere. Neotectonic uplift rates throughout Crete (up to 5 mm/yr) reflect transtension partitioned over an array of 10-km-scale N020E normal faults and N070E sinistral-normal faults with strike-slip:dip-slip ratios of 10:1 to 100:1. These previously unrecognized wrench faults pose a plausible modern seismic hazard.

Structures in both basins display continuity with offshore structures interpreted from bathymetry and seismic-reflection profiles suggesting the onshore basins reflect a fore-arc-wide sinistral transtensional shear system that accommodates both arc-parallel extension and oblique convergence. The Pliocene onset of strike slip in both basins (3.4-4.5 Ma) marked a threshold at which the increasing obliquity of plate convergence forced a wrench component in the forearc kinematics. Coeval incipient continental collision also promotes tectonic escape of forearc slivers along these wrench zones.

Evaluation of the 3D geometry of the downgoing lithosphere suggests an inflection line at 20-30 km depth with the dip of the African plate increasing 3-5 degrees. This kink corresponds to wrench zones such as the Messaras Basin and Pliny and Strabo "Trenches" in the overriding forearc suggesting that coupling prevails down to the kink above which the sinistral-shear component is concentrated in the overriding partitioned forearc.

T11H-12 1150h

Internal zone extension and external zone shortening in the Alps

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The eclogites of the Piemonte zone in the Alps were unroofed by SE-directed extensional shear from 100 km to 30 km depth. This shear zone, the Gressoney shear, was a surface subparallel to the subduction zone but with opposite movement sense. This scenario is tightly constrained by our mapping and geochronological work: unroofing occurred in the period 45-36 Ma. In the external zones, a marine foreland basin was actively migrating away from the orogen, and receiving clastic detritus at this time. This migration is of the same order of magnitude as the displacement induced by internal zone extension. They must have been strongly dynamically coupled, and local buoyancy played a key role. Although the eclogites are dense, they form a relatively thin sliver. Attachment to, or influence by, upwardly flowing continental material is likely to have been important. Numerical modelling confirms profound coupling between internal zone and external zone processes and between different levels in the lithosphere. It leads us to reappraise the dynamics of foreland basin evolution in this mountain belt.

T11I MC: 135 Monday 1100h

The Birch Lecture *(joint with NG, S, V, DI, MR)*

Presiding: **D L Turcotte,** Cornell University

T11I-01 1100h INVITED

Structure and dynamics of the deep mantle: An Earth odyssey

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Current and recent studies of mantle convection are investigating possible compositional heterogeneity in the lower mantle. Multiple compositional components in the mantle, probably persisting for billions of years, are indicated by geochemical data on mid-ocean ridge basalts (MORB) and oceanic island basalts (OIB). While the MORB source is primarily well-homogenized, the OIB source is more heterogeneous. Furthermore, numerical models of convection using homogeneous bulk composition exhibit rapid mixing and cannot account for these characteristics. Our model of a hot abyssal layer in the lower mantle reconciles diverse inferences about mantle dynamics and structure made from a wide variety of observations including isotope signatures, noble gas budgets, heat flow and seismic velocities. The noble gas systematics imply that the mantle is incompletely outgassed. The global heat flow budget requires a reservoir of mantle containing a higher concentration of heat-producing elements than the MORB source. These observations and models together suggest that a simple model of whole mantle convection is incompatible with the data. Although these constraints appear to conflict with seismic velocity models showing that subducted slabs penetrate across the mantle transition zone and into the lower mantle, compositional heterogeneity in the lower mantle can resolve the apparent discrepancy. Such heterogeneity may take the form of a hot abyssal layer of variable thickness starting at the mid-mantle (around 1600 km depth) or in the lowermost mantle (i.e. D''), or may consist of "blobs" in the lower mantle. We prefer the hot abyssal layer model, because hot, neutrally buoyant blobs are unlikely to persist for the long times required by chemical geodynamics. Chemical geodynamics and heat production also constrain the volume of a dense layer and suggest that the transition in composition should occur between about 1500-2000 km depth. A transition to a dense layer at these depths is also supported by recent seismological studies of lower mantle structure. The D'' region is unlikely to be the sole repository of any compositional variation; its volume is so small that excessive heat production may be required. Nevertheless, D'' cannot be entirely ruled out as a source. Whatever its depth, a hot abyssal layer is likely substantially, but not entirely, isolated from the overlying mantle.

T12A MC: Hall D Monday 1330h

Pacific and Atlantic Spreading Ridges *(joint with GP, S, V)*

Presiding: **R Dunn,** Brown University

T12A-0894 1330h POSTER

Off- and Along-Axis Slow Spreading Ridge Segment Characters: Insights From 3d Thermal Modeling

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Many observations along the Mid-Atlantic Ridge segments suggest a correlation between surface characters (length, axial morphology) and the thermal state of the segment. Thibaud et al. (1998) classify segments according to their thermal state: "colder" segments shorter than 30 km show a weak magmatic activity, and "hotter" segments as long as 90 km show a robust magmatic activity. The existence of such a correlation suggests that the thermal structure of a slow spreading ridge segment explains most of the surface observations. Here we test the physical coherence of such an integrated thermal model and evaluate it quantitatively. The different kinds of segment would constitute different phases in a segment evolution, the segment evolving progressively from a "colder" to a "hotter" so to a "colder" state. Here we test the consistency of such an evolution scheme. To test these hypotheses we have developed a 3D numerical model for the thermal structure and evolution of a slow spreading ridge segment. The thermal structure is controlled by the geometry and the dimensions of a permanently hot zone, imposed beneath the segment center, where is simulated the adiabatic ascent of magmatic material. To compare the model with the observations several geophysic quantities which depend on the thermal state are simulated: crustal thickness variations along axis, gravity anomalies (reflecting density variations) and earthquake maximum depth (corresponding to the 750°C isotherm depth). The thermal structure of a particular segment is constrained by comparing the simulated quantities to the real ones. Considering realistic magnetization parameters, the magnetic anomalies generated from the same thermal structure and evolution reproduce the observed magnetic anomaly amplitude variations along the segment. The thermal structures accounting for observations are determined for each kind of segment (from "colder" to "hotter"). The evolution of the thermal structure from the "colder" to the "hotter" segments gives credence to a temporal relationship between the different kinds of segment. The resulting thermal evolution model of slow spreading ridge segments may explain the rhomboedric shapes observed off-axis.

T12A-0895 1330h POSTER

Structural Analysis of the Knipovich Ridge, 74°-78°N, North Atlantic Ocean.

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The Knipovich Ridge is an ultra-slow (<1.5 cm/yr.), oblique-spreading mid-ocean ridge. The ridge axis trends ∼350° from 74° to 76°N, and trends 000° from 76° to 78°N, while the NUVEL-1A plate motion vector trends ∼307°NW. The ridge axis is characterized by a 10-15 km wide rift valley with steep, high relief (1-2 km) rift valley walls. The rift valley floor is highly faulted, and is interrupted by widely spaced (40-80 km), 0.5 to 1 km tall volcanic highs. Approximately 400 km of 30 kHz side scan sonar data (track width 2.5 km, resolution ∼5 m) were collected along the rift axis using the ORETech system on the R/V Professor Logachev (VNIIO, St. Petersburg, Russia). These data were interpreted and analysis of the imaged faults is discussed in terms of ridge axis structure and tectonics.

Structural maps were analyzed using a 10-km-wide moving window stepped down the ridge at 1-km intervals. Measured fault parameters include length, tip-to-tip length, tortuosity (length divided by tip-to-tip length), azimuth, fracture density (total length per unit area), and fault number (number of faults per unit area). The results of this analysis were compared to along-axis bathymetry, lava flow morphology, and gravity-derived segmentation.

Segment centers, (characterized by axial highs, gravity lows, and fresh lava flows) are dominated by normal and oblique-normal faults with high average length and tortuosity, low fracture density and low fault number. Conversely, segment ends (characterized by bathymetric lows, gravity highs, and heavy sediment cover) are dominated by oblique-slip faults with low average length and tortuosity, high fracture density and high fault number. Several exceptions to these trends are found along the ridge axis, however these occur in areas marked by steep slopes and mass wasting deposits identified on the sonar records.

These results suggest systematic relationships between faulting, magmatism, and oblique spreading on the Knipovich Ridge. We suggest that faulting in segment centers is strongly influenced by dike intrusion in an orientation controlled by the spreading direction, producing dike-related faults normal to plate motion. In time intervals between dike intrusions, or in areas away from segment centers, mechanical interaction between the oblique rift axis and plate motion produces oblique-normal faults in orientations compatible with results from analog experiments and observations in other oblique rifting environments. Faulting in segment ends (non-transform discontinuities) is controlled by accommodation between adjacent, en echelon spreading segments, producing short, oblique-slip faults characteristic of accommodation zones and transfer zones.

The oblique spreading regime along the Knipovich Ridge enables discrimination between dike-related faulting and rift-related faulting, and that the structures observed are useful for illuminating the relationships between tectonism and magmatism along this ultra-slow-spreading ridge.

URL: http://www2.ori.u-tokyo.ac.jp/~asada/k2k/