T51D MC: 135 Friday 0830h

Multidisciplinary Insights From Seismic Tomography, Mantle Dynamics, Geological Origins, and Evolution II *(joint with S, V, DI, MR)*

Presiding: **S Maruyama,** Tokyo Institute of Technology**; D Yuen,** University of Minnesota

T51D-01 0830h

The Importance of a High Viscosity Peak at 2000 km Depth for Time-Dependent Convection Dynamics: An Explanation for the Dominance of Degree-2 Structure in the Lower-most Mantle.

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In a recent study of the viscosity and thermochemical structure in the deep mantle, *Forte and Mitrovica* [Nature, 2001] carried out nonlinear, iterative inversions of all available global geophysical data associated with thermal convection in the mantle. These inversions were performed using a new viscous flow model based on recent high-resolution tomographic models of S-wave velocity anomalies. The radial viscosity profiles delivered by these inversions are characterized by a strong peak in viscosity near 2000 km depth, with viscosity then decreasing rapidly towards the core-mantle boundary. *Forte and Mitrovica* found that this viscosity peak has a profound impact on the pattern of present-day flow in the lower-most mantle, effectively suppressing all but the longest wavelengths of flow (characterized by harmonic degrees less than about $\ell = 6$). They argued that such a viscosity-induced low-pass filtering effect provides a simple explanation for the 'red' spectrum of heterogeneity in the bottom 1000 km of the mantle. Such tomography-based flow modelling is limited, however, because it only provides an instantaneous 'snapshot' of present-day convection dynamics. To confirm the impact of the high-viscosity peak on the time-dependent evolution of the thermal structure in the lower mantle, we developed a numerical model of high Rayleigh number thermal convection in 3-D spherical geometry [*Espesset and Forte*, 2001]. The model is compressible (in the anelastic approximation), it incorporates surface tectonic plates, depth dependent thermal expansivity and thermal conductivity, and it includes the geodynamically constrained radial viscosity profile inferred by *Forte and Mitrovica* [Nature, 2001]. As a starting point for the convection simulations we employ the temperature anomalies *Forte and Mitrovica* derived from the high-resolution seismic tomography models. The convection simulations at high Rayleigh numbers reveal the development and persistence of a pattern of thermal heterogeneity in the bottom 1000 km of the lower mantle which is strongly dominated by spherical harmonic degree $\ell = 2$. Comparisons with convection models using a constant viscosity or using a simple two-layer viscosity profile show that this dominance of degree-2 heterogeneity is due to the geodynamically-inferred high viscosity peak at 2000 km depth. The stability and dominance of this quadrupolar pattern of thermal heterogeneity over long times provides a straightforward explanation for the 'red' spectrum of deep mantle heterogeneity which has long been observed in the global seismic tomographic models.

URL: http://www.uwo.ca/earth/forte.htm

T51D-02 0845h

Seismic Evidence for a Rapidly-varying Compositional Anomaly at the Base of the Earth's Mantle Beneath the Indian Ocean

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Identifying chemically distinct reservoirs in the interior of the Earth is important not only for understanding the evolution and differentiation of the Earth, but also for studying mantle convection and geochemistry. Recently, Wen et al. [EPSL, 189, 141-153, 2001] report seismic evidence for a unique 300 km thick layer at the base of the mantle beneath the south Atlantic ocean, with a steeply dipping edge, anomalously low shear wave velocities linearly decreasing from 2% (top) to 10-12% (bottom), and a maximum P velocity decrease of 3% relative to the preliminary reference Earth model (PREM). They also suggest that the seismic characteristics and structural features of that boundary layer can be best explained by partial melt driven by a compositional change produced early in the Earth's history and a vertical thermal gradient within the layer. Here, I report seismic evidence for a seismic anomaly at the base of the mantle beneath the Indian ocean, which is geographically connected to the boundary layer beneath the south Atlantic ocean. I perform detailed travel time analysis and waveform modeling of the seismic data recorded in an African seismic array for earthquakes in the Fiji subduction zone. The seismic observations provide a good sampling coverage for the lowermost mantle beneath the Indian ocean and bracket the emergence of the low-velocity anomaly in the north and its disappearance in the south. This low-velocity anomaly has steeply dipping edges, rapidly varying thicknesses and geometries, and anomalously low shear wave velocities decreasing from 2% at 200 km above the core-mantle boundary to 9-12% at the core-mantle boundary (relative to PREM). These characteristics unambiguously suggest that it is a compositional anomaly and its velocity structures can be well explained by partial melt driven by the compositional change within the anomaly. More excitingly, this chemical anomaly geographically coincides with the DUPAL geochemical anomaly both in the south Atlantic ocean and in the Indian ocean, and may provide an explanation to the distinctive DUPAL isotope characteristics observed at the Earth's surface.

URL: http://geophysics.geo.sunysb.edu/wen/

T51D-03 0900h INVITED

Origin and evolution of the Pacific Superplume

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The Pacific superplume defined as P- and S-wave velocity anomalies in the mantle underneath the southern Pacific superswell which yields a bundle of 5 hotspots. Moreover, it has been well-known that it has become active during the Cretaceous time to form a series of huge oceanic plateaus such as Ontong-Java and other oceanic Lips. I summarize the history of the Pacific superplume and speculate its origin, based on UHP experiments, tomographic images, and paleogeography back to 1.0Ga. The Pacific superplume was born when the supercontinent Rodinia was rifted to bear the Pacific Ocean in it at 750Ma. Since then it has been activated episodically at 750-700Ma, 550-500Ma, 300-250Ma and 125-85Ma, the last of which has been well-recorded on both ocean-floor and in orogenic belts. During the pulsation period, it should be emphasized that not only superplume but also the ocean-floor spreading became 30-50% faster than that of normal period. Based on UHP experiments at 660km depth and tomographic images in whole mantle, pulsation can be explained by regional mantle overturn, by which more fertile and higher-temperature materials in the lower mantle replace the upper mantle to accelerate both plate tectonics and plume activity However, the birth of superplume may be different from regional mantle overturn. Presence of cold superplume was estimated first underneath Asia by P-wave whole mantle tomography. Paleogeographic reconstruction gives us an image that cold superplume swallow many continents into a black hole to form a supercontinent. A supercontinent formed by a cold superplume must be broken up subsequently by a hot superplume underneath. The upper mantle underneath the supercontinet must be coldest among all parts of upper mantle, because of extensive subduction hence refrigeration. Moreover, subduction carries water underneath the continents, particularly in the case of subduction of cold slab. Transformation of cold to hot superplume took about 200 m.y. after the birth of supercontinent for the past three supercontinents. This transformation may be explained by water. The hydrous mantle boundary layer at 410-660 km depth is a huge water reservoir where huge amounts of stagnant megalith enriched in water would turn to be dehydrated to release water-rich fluids at 410 km depth to bear plumes with time by conductive heating underneath. The hydrous MBL underneath supercontinent causes a birth of superplume. If this is true, cold superplume may be the most essential driving force to control the EarthOs dynamics and evolution of Earth. Moreover, the role of water may be more significant than temperature, acting as a chemical agent to drive the Earth.

T51D-04 0920h

Seismic Structure and Origin of Hotspots and Mantle Plumes

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A new model of whole mantle seismic tomography was developed with a novel approach. A grid parameterization was adopted, instead of blocks and spherical harmonic expansions which were used in most of the global tomographic studies. Ray paths and travel times were computed with an efficient 3-D ray tracing scheme [Zhao et al., 1992]. Moreover, the topography of mantle discontinuities at 410 and 660 km depths and the Moho discontinuity [Flanagan and Shearer, 1998; Mooney et al., 1998] were taken into account in the tomographic inversions. The three discontinuities exhibit lateral depth variations of tens of kilometers, which greatly affects the ray path and travel times, hence their depth changes should be taken into account in the inversions. This new approach was applied to a large data set of ISC travel times (P, PP, PcP, pP) which were reprocessed by Engdahl et al. [1998], resulting in a new model of whole mantle P-wave tomography. For the shallow mantle, this new model contains the general features observed in the previous models: a low-velocity ring around the Pacific Ocean basins and high-velocity anomalies under the old and stable continents in the depth range of 0-400 km. One significant difference from the previous models is that stronger and wider high-velocity anomalies are visible in the transition zone depths under the subduction zone regions, which suggests that most of the slab materials are stagnant for a long time in the transition zone before finally dropping down to the lower mantle. Plume-like slow anomalies are visible under the hotspot regions in most parts of the mantle. The slow anomalies under hotspots usually do not show a straight pillar shape, but exhibit winding images, which suggests that plumes are not fixed in the mantle but can be deflected by the mantle winds. As a consequence, hotspots are not really fixed but can wander on the Earth's surface, as evidenced by the recent geomagnetic and numeric modeling studies. There is a good correlation between the distribution of slow anomalies at the CMB and that of hotspots on the surface, which suggests that many hotspot plumes may originate from the CMB. However, there may be some small-scaled, weak plumes originating from the transition zone depths.

Zhao, D. (2001) Seismic structure and origin of hotspots and mantle plumes, Earth Planet. Sci. Lett., in press.

T51D-05 0935h

On the Relation Between Transition Zone Velocities and Topography of Discontinuities

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We present results from a joint inversion for mantle shear velocity and topography of transition zone discontinuities. Each travel time residual, corrected for the crust and free surface topography, is modeled as resulting from contributions from three-dimensional shear velocity perturbations to a spherical earth model and undulations of the 400- and 670-km discontinuities. We include independent measurements of transition zone thickness as additional constraints for the inverse problem. The best fit model reduces the variance of absolute and differential travel times of S, SS and ScS by 40–70%, and the differential travel times of SS precursors by 60–90%. The large-scale features of the resulting 3-D model correlate well with existing shear velocity models of the mantle. The variations of the topography of the 400 and 670-km discontinuities are $\pm$12 km and $\pm$18 km, respectively; such level of perturbations are slightly smaller than those inferred directly from SS precursors, which suggest that some of the latter anomalies can be better explained by variations in mantle shear velocity. The average transition zone thickness is $\sim$240 km. Our best estimates of the average depth to the two discontinuities are 409 and 649 km, and their lateral variations have strong signatures at degree 1 (400) and 2 (670) spherical harmonics. The topography maps of the 400- and 670-km discontinuities obtained from the inversion correlate better (than those inferred directly from SS precursors) with velocity variations above and within the transition zone, respectively. This suggests a more consistent relationship between boundary topography and thermal variations in the mantle. In addition, the depth perturbations of the 400- and 670-km discontinuities show very little correlation; this provides further evidence they are likely to be influenced by different thermal and dynamical effects in the mantle.

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T51D-06 0950h INVITED

Link Between Lower Mantle Superplume and Plume Cluster in the Upper Mantle

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The style of mantle convection is a subject of debate for more than a quarter of century. Evidence from seismic tomography suggests that the mantle convection has characteristics of both whole and layered convection. Perhaps the question of layered versus whole mantle convection may be better viewed from a regional standpoint. Up to now, numerical simulations in 3-D have not revealed the simultaneous apparence of features drawn from both whole mantle and layered mantle convection.

In this study of high-resolution 3-D spherical shell convection (256 spherical harmonics and 128 radial points), we will show that for realistic values of the internal heating and viscosity stratification it is possible to produce different scenarios in wich both types of features would appear in the presence of an endothermic phase transition at 660 km depth. It is well known that broad upwellings and long wavelength structures are favoured by a viscosity increase with depth, on the other hand endothermic phase change is able to stratify the dynamics. The high resolution of the model allows to observ a concurrence of whole-mantle and layered convection. In case of a simple stepwise increase of the viscosity at 660 km, we see plumes launched from the 660 km due to viscous heating in the lower mantle, coexisting with strong hot plumes ascending from the CMB. The addition of a low viscosity zone under the endothermic phase change blocks these strong plumes at the 660 km, inducing a clustering of plumes.

T51D-07 1030h

Where does the Source of the Icelandic Plume lie? (Enigmatic Observations with a Dynamic Solution)

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Recent observations concerning the root of the mantle plume under the Iceland hotspot seem to be rather contradictory (Foulger and Pearson, Geophys. J. Int. 145, 2001, F1-F5). Most seismic tomographic studies find a distinct low-velocity anomaly beneath Iceland in a columnar form which extends down to the 660 km discontinuity and no deeper. This would indicate an upper-mantle plume originating above the 660 km boundary. Very high $^3He^4He$ isotopic ratios and Sr/Nd/Pb characteristics measured in Icelandic lava rocks suggest however that they come from a primitive, undegassed mantle reservoir which is traditionally located in the lower mantle. In terms of classical plume dynamics it is very difficult to reconcile these observational discrepancies. We can explain this phenomenon by a newly found plume type (Cserepes and Yuen, Earth Planet. Sci. Lett. 183, 61-71, 2000): this comes from below the 660 km discontinuity with no plume stem in the lower mantle and no root situated in any thermal boundary layers of the mantle. Numerical convection modelling shows that this kind of plume (we will designate this as a 'mid-mantle plume') can arise if the 660 km discontinuity is due to an endothermic phase transition and if it is partially penetrable by vertical convective flow. Our 3-D numerical solutions show explicitly that the spinel-perovskite transition can be such a boundary. In this case, in analogy with the avalanche-like subduction events which can cross the 660 km boundary in an episodic manner, upwellings can and must break through the discontinuity intermittently . These avalanche-like upwellings arise from a diffuse but rather limited volume below the 660 km boundary in the middle mantle, and form a genuine cylindrical plume above the depth of 660 km. Thus, these mid-mantle plumes come from the top part of the lower mantle and transport lower-mantle material to the surface, but they have no deep stem and therefore no observable seismic anomalies in the lower mantle: they appear in tomographic images as upper-mantle plumes.

T51D-08 1045h INVITED

Consequences of a Viscosity Peak in the Lower Mantle for the Evolution of Plumes

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Recent work has indicated the existence of a 'viscosity hill' situated in the lower mantle between 1800 and 2000 km. We have employed 2d and 3d numerical models to examine the dynamical consequences of such a hill in the high Rayleigh number regime. Most numerical models are based on the extended Boussinesq approximation, including the effects of viscous dissipation and adiabatic (de)compression. All models include a decrease of thermal expansivity with depth. The viscosity increase in the lower mantle was assumed to range between 150 and 1000. In order to delineate effects we separately run cases with a purely depth dependent viscosity profile and such with a superimposed temperature dependence of the viscosity.The 'viscosity hill' leads to a transient stage which closely resembles the 'doming regime' as found in thermo chemical convection. Further, the 'hill' acts similar to a phase transition. Plume branching occurs in the mid lower mantle as seemingly found in tomographic studies. The lower mantle is characterized by the presence of big plumes which experience branching during ascent. The most remarkable consequence of the hill is that plumes are significantly cooler in the upper mantle.

T51D-09 1105h INVITED

Melting of MORB and Chemical Fractionation at CMB

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The presence of melt at the base of the mantle has been suggested from a number of seismic observations. Melting is the most important process that proceeds chemical differentiation of the EarthOs interior. High-pressure studies on MORB composition showed that its melting temperature is lower by 250 K at 60 GPa than that of pyrolitic composition, and is most likely lower at the core-mantle boundary if the melting curves are extrapolated to 135 GPa (Zerr et al., 1998; Hirose et al., 1999). Therefore, if the DOL region is the graveyard of the subducted lithosphere, the former MORB crust may be preferentially molten prior to the pyrolitic mantle. Partial melting experiments on MORB composition at 27.5 GPa in a multi-anvil apparatus showed that Ca-perovskite is the first liquidus phase, followed by stishovite and Al-rich phases, and that Mg-perovskite disappears near the solidus temperature (Hirose and Fei, 2001). The textures of run product heated above melting temperature in a laser-heated diamond-anvil cell suggest that this crystallization sequence does not change at least at 64 GPa. The trace element partitioning data between Ca-perovskite, Al-rich CAS-phase, Mg-perovskite, and melt were obtained for the run products synthesized at 25-27 GPa (Shimizu, Hirose, Fei, 2001). They show that Ca-perovskite contains much higher abundance of trace elements than Mg-perovskite. Partition coefficients for Ca-perovskitemelt are >10 for U and Th and <1 for Pb. Partial melting process thus strongly fractionates U and Th relative to Pb in the presence of Ca-perovskite. The MORB residue after extraction of partial melt has significantly higher UPb and ThPb ratios than the original MORB composition. The recycled MORB crust that experienced partial melting at the bottom of the mantle could be a source of HIMU magmas by mixing with the primitive mantle. Partial melt may be denser than the surrounding mantle and segregate downward to form a dense layer at the base of the mantle. This layer might be a very important geochemical reservoir with low UPb and ThPb and possibly low LuHf ratios, but is a forbidden layer that is isolated from mantle convection.

T51D-10 1120h

Low Seismic Anisotropy Channels below the Pacific Ocean and Geodynamic implications

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A new 3D anisotropic model has been obtained at a global scale by using a massive dataset of seismic surface waves. Though seismic heterogeneities are usually interpreted in terms of heterogeneous temperature field, a large part of lateral variations are also induced by seismic anisotropy of upper mantle minerals. New insight on convection processes can be gained by taking seismic anisotropy into account in the inversion procedure. The model is best resolved in the Pacific Plate, the largest and the most active tectonic plate. Superimposed on the large scale radial anisotropy within and below the lithosphere, correlated with present or past Pacific plate motions, are smaller scale (<1000km) lateral variations of radial and azimuthal anisotropy not predicted by plate tectonics. Channels of low anisotropy (hereafter referred as LAC) are observed and are the best resolved anomalies: One east-west channel between easter Island and the Tonga-Kermadec subduction zones and a second one extending from the south-west Pacific up to Hawaii, and passing through the Polynesia hotspot group of Polynesia for plate older than about 40 MA. These features are presumably related to secondary convection below the rigid lithosphere, predicted by numerical and tank experiments. The existence and location of these LACs are related to the current active plumes in Central Pacific. LACs, which are dividing the Pacific Plate into smaller units, associated with plumes might indicate a future reorganization of plates with ridge migrations in the Pacific Ocean.

T51D-11 1135h

Waveform Modeling of a Plume-like Velocity Anomaly in the Mantle Beneath South Africa

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Seismograms are synthesized in two- and three-dimensional representations of a plume-like anomaly that has been tomographically imaged in the mantle beneath South Africa. Pseudospectral integration of the wave equation in two-dimensions and Gaussian beam superposition in three-dimensions are performed to constrain the shape, intensity, and lateral gradients of the anomaly. To agree with waveform features, including multi-pathing in ScS, the intensity of the anomaly must be increased by factors of 2 to 3 in the ΔVp/Vp and ΔVs/Vs perturbations suggested by tomography. Observations of rapid spatial changes in core and anomaly grazing waveforms over densely sampled ray paths are used to test the continuity of the anomaly from the core-mantle boundary to the surface.

T51D-12 1150h

Transition zone thickness beneath the South Pacific Superswell as inferred from the ScS reverberation and PS-converted waves

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We analyzed broadband seismograms recorded by the SPANET (South Pacific broadband seismic network) and LDG stations deployed on oceanic islands in the South Pacific for deep Tonga-Fiji earthquakes to investigate the mantle transition zone (defined between the "410-km" discontinuity to the "660-km" discontinuity) structure beneath the South Pacific, where a large-scale hot plume might ascend from CMB. We employed two methods: the velocity spectrum method for receiver function to study the transition zone thickness beneath each of the stations and a ScS reverberation method to study the average transition zone thickness between an event and a station. Taking 250km as a

reference thickness of the transition zone, we obtained the transition zone thinner by up to 15 km beneath the stations on Tahiti, French Polynesia and that thicker by 30 km near the Tonga subduction zone. By the ScS reverberation method, we find clear signals associated to the "410-km" and "660-km" discontinuities. The transition zone thickness, which is constrained from the travel time difference between the reflection waves originated by the "410-km" and "660-km" discontinuities, is observed to be 15 km thinner beneath the South Pacific Superswell in average than the reference thickness. The result suggests that transition zone temperature beneath French Polynesia is approximately 100-200 K higher than the surrounding mantle.

T51E MC: 308 Friday 0830h

The Initiation and Early Evolution of Young Ocean Basins I *(joint with OS, S)*

Presiding: **A M Goodliffe,** University of Hawaii; **G D Karner,** Lamont Doherty Earth Observatory

T51E-01 0830h

Dynamic controls on the initiation of extension in continental and oceanic crust

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The initiation of extension depends strongly on the rheology of the nascent zone of deformation, but also on the magnitude and orientations of the applied tractions and on the crustal thickness. To investigate the importance of these effects, we construct numerical models of the evolution of zones of deformation after the imposition of applied tractions, accounting for changes in crustal or lithospheric thickness and subsequent changes in the isostatically compensated buoyancy. In oceanic systems, the buoyant torque acts to reinforce any lithospheric deformation, and the boundary either becomes predominantly divergent or completely convergent, depending on the initial loading. However there is a marked tendency for these systems to prefer evolution towards a divergent state, even when the initial loading is predominantly compressive (primarily due to an "unzipping" effect where extended crust becomes more prone to failure than contracted crust). In continental systems, the buoyant torque acts to oppose lithospheric deformation. One possible end state is that the rifting fails as the system develops a buoyant torque that matches the imposed torque, but if the imposed torque is very large it is possible for the deformation to continue and even accelerate with time. A naïve treatment of the stress gravitational potential energy suggests a buoyant torque that is absurdly large in comparison with the torques available to split continents apart from, for example, emplacement of flood basalts. A solution may be that part of the buoyant traction is transmitted elastically within the upper part of the continent, and it is wrong to include this traction in calculating the ongoing deformation.

T51E-02 0845h

Structure, Spreading Direction, Fault Formation and Caldera Control in the Ethiopian Rift

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The Ethiopian Rift is a Plio-Quaternary continental rift characterized by two interacting NE-SW trending segments. Remote sensing and field data show that the axial part of the Rift is made up of extensional fractures and open normal faults. These show a mean N50W opening direction along a distance of 400 km, indicating an overall NW-SE spreading direction between Nubia and Somalia plates. Field data and mechanical considerations suggest that when the extensional fractures in the axial part of the Rift reach critical dimensions (length about 800 m, depth about 600 m, width about 4 m), they cannot longer sustain a pure tensile behavior. Thus, the extensional fractures turn into shear fractures, becoming open normal faults at surface. Several Quaternary calderas within the Rift have an overall E-W elongation. Remote sensing and field data suggest that such elongation is controlled by pre-Rift E-W trending structures, mainly found on Nubia and Somalia plateaus. These systems have been reactivated during rifting as left-lateral faults, focusing the rise of magma and controlling the development of E-W trending magma chambers in the axial part of the rift.

T51E-03 0900h

Magmato-tectonic Evolution of Asal Rift, Afar Depression

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We investigate the relationships between magmatic and tectonic activities during rifting, taking the example of Asal, one of the most recent and active rifts of Afar. We sampled and performed combined geochemical (major and trace elements) and paleomagnetic analyses of the successive basaltic lava flows (total: 48) exposed in three of the highest (~30-80 m) normal fault escarpments, on either side of the rift inner floor and of the Fieale volcano. Previous dating suggests that lava emplaced in the rift from ~300 ka on, and the piles we analyzed between ~110 and 90 ka. The chemical analyses (48 samples) reveal that all lava was poured out from the same shallow (< a few km) reservoir. Each pile is made of two to four distinct flow sets, each ~10 to 50 m-high and having slightly, hence rapidly evolved through low pressure crystallization. The chemical evolution from one flow set to the next suggests re-feeding of the reservoir (or slight cooling of the mantle). The paleomagnetic analyses (190 samples) reveal that each flow set was erupted very rapidly, as a pulse, in less than a ~thousand years. By contrast, the entire flow piles have properly recorded the secular variation of the magnetic field, including the Blake excursion. It results that, at least between ~110 and 90 ka, the magmatic activity occurred by pulses rapidly pouring out large volumes of lavas every 10±5 ka. At the sites analyzed, the lava accumulated during each pulse at a rate of ~1-5 cm/yr, much larger than the fault slip rates. One might conclude that flows continuously covered up and erased tectonic features during rifting. However, the long time-span which separates the initiation of the present rift faults (~50±20 ka) from the latest lava flows (on rift shoulders, ~90 ka) implies that these faults did not exist before, with the possible exception of those bounding the present inner floor. Rifting therefore occurred through dominant magmatic activity, at least from ~300 to 50 ka, when normal faults started to initiate and accommodate part of the extension. Between ~300 and 90 ka, the magmatic activity seems to be mainly governed by a central volcano (Fieale). From ~90 ka on, it localizes within the present inner floor and becomes fissural. The volumes of lava which we estimate to have emplaced during these two periods of time (~20 and 10 km^3, respectively) imply a mean magmatic flux rate at the surface of $\sim10^5 m^3/yr$, similar to the current rate (1978 Ardoukoba eruption: $\sim10\text{-}20.10^6$ m^3, recurrence time ~120-230 yr), but ~10 times smaller than the flux rate inferred at depth. Magmatic activity would therefore have also kept constant overall during rifting, although occurring through successive pulses, the major ones being supplied from at least ~10 km^3 reservoirs.

T51E-04 0915h

The Role of Detachment Faulting in the Early Evolution of Oceanic Basins

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Models of continental break-up followed by seafloor spreading conventionally juxtapose continental and oceanic crusts. However, observations from ancient and present-day ocean-continent transitions (OCT) in the Alps and Iberia provide compelling evidence that along magma-poor rifted margins these two crusts are separated by a 40 to 170 km wide zone of exhumed continental mantle (ZECM), and that the architecture and tectonic evolution of this ZECM is controlled by downward concave faults interacting with a rising asthenosphere.

In both, the Iberian and Alpine OCT zones, top-to-the-ocean low-angle detachment structures can be traced across the thinned continental crust towards oceanic crust. Although these faults accommodated ~10-20 km offsets, they caused only minor submarine relief. The occurrence of isolated allochthons of continental crust and of tectono-sedimentary breccias over mantle rocks in the ZECM shows that these mantle rocks had to be exhumed by detachment faults. Trace element compositions of mantle rocks and their local association with lower continental crust clearly support the sub-continental origin of the mantle rocks within the ZECM. Because towards the future ocean the exhumed mantle rocks appear to be derived from hotter and probably also deeper lithospheric levels, we suggest that mantle exhumation was accomplished by concave-downward faults which became active only during a final stage of rifting when the crust was already thinned to <10 km.

In Iberia, basalts have not been drilled, and geophysical data suggest little but oceanward-increasing magmatic material within the ZECM. In the Alps, gabbroic bodies, <1 km across, intruded serpentinized mantle at 161 ± 1 Ma (U-Pb zircon ages) and occur as clasts in tectono-sedimentary breccias reflecting their syn-tectonic emplacement. Pillow lavas generally become more voluminous and grade from T- to N-MORB oceanwards. Their occurrence appears to be controlled by late, syn-magmatic high-angle faults parallel to the margin. These high-angle faults cut the low-angle detachment faults responsible for the exhumation of the subcontinental mantle. The basaltic lavas represent aggregated melts of low to moderate degrees of partial melting of an asthenospheric source. Trace element compositions and Nd and Hf isotopic compositions of basalts and parental liquids of the gabbros are very similar indicating a common source.

The transition from symmetric amagmatic rifting to steady-state seafloor spreading obviously includes a transient phase of simple-shear dominated asymmetric rifting which is accompanied by magmatism. We suggest that the evolving stresses and thermal fields associated with the rise of asthenospheric mantle and the onset of magmatic activity constrain the geometry of the lithosphere-scale concave-downward faults. Finally, the ascending but narrowing asthenospheric mantle led to the focused magmatism and tectonism characterizing present-day slow-spreading mid-ocean ridges.

T51E-05 0930h

The Seismic Nature and Response of Detachment Faults in Ocean-Continent Transition Zones

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The tectonic interpretation of basement structures in seismic reflection profiles from ocean-continent transition (OCT) zones of so-called nonvolcanic or magma-poor rifted margins is notoriously difficult and ambiguous due to the scarcity of borehole information. Prominent low-angle intra-basement reflections are commonly interpreted as low-angle detachment faults and locally the top of the basement was drilled and found to represent exhumed, so-called top-basement detachment faults. However, the seismic expression of such detachment faults is poorly understood and verification by deep-sea drilling is presently limited to the very top of several basement highs.

In this paper, we compare synthetic seismic profiles from the Tasna OCT, a superbly exposed remnant of a Tethyan margin in the Eastern Swiss Alps, with seismic reflection data from the Hobby High, a drilled basement high within the present-day OCT of the Iberia Abyssal Plain. Both sites are widely considered as being representative for OCT zones of magma-poor rifted margins. The geological similarity and complementary nature of the data from both sites enable us to develop a detailed model of the seismic structure of the Tasna OCT. This in turn provides insights into the seismic imaging of OCT zones in general and of detachment

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