Second Crystal2Plate Workshop

18-22 January, 2011
Estepona, Malaga, Spain

List of participants

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Crystal2Plate Second Workshop
Estepona, Spain
18-22 January, 2011
Agenda

	DAY 1 Tuesday 18 January	DAY 2 Wednesday 19 January
	------------------- **Welcome Dinner** Estepona Port 9:00pm	2nd Workshop 9:00am-12:30pm *Lunch at hotel* 2nd Workshop 2:00- 8pm
DAY 3 Thursday 20 January	**DAY 4** Friday 21 January	**DAY 5** Saturday 22 January
Ronda Peridotite **Field trip** **8 am: group departure from hotel** On-site visit & picnic **5pm: group departure from outcrop** *18:30-20h preparation of discussion session*	2nd Workshop 9:00am-12:30pm *Lunch at hotel* 2nd Workshop 2:00-7:30pm	Plenary Discussion 9:00am-12:30pm Departure

Accommodation details	
Hotel for participants	**H10 estepona palace** **Avda. Del Carmen, 99.** **Playa de Guadalobon** **Estepona, Malaga - Spain** **Tel: +34 952 79 00 40** **FAX: +34 952 79 79 33** **www.h10hotels.com** Accommodations are covered directly by the coordinator. *Reservations will be made from Monday 17 or Tuesday 18 January 2011 through Saturday 22 January, breakfast, lunch and internet connection included.*
Expenses reimbursement	
	Participants should MAKE their OWN TRAVEL ARRANGEMENTS. Your travel expenses are to be covered by your main host institution.
Meeting Details	
Location	H10 estepona palace Avda. del Carmen, 99 Playa de Guadalobon Estepona, Malaga - Spain Tel: +34 952 79 00 40 FAX: +34 952 79 79 33 www.h10hotels.com
Contact Meeting Organisation	Andrea Tommasi +33 (0) 4 67 14 49 12 – Mobile: +33 (0) 6 77 29 25 39 deia@gm.univ-montp2.fr Nathalie Modjeska +33 (0) 4 67 14 37 43 – Mobile: +33 (0) 6 25 45 32 37 crystal2plate@gm.univ-montp2.fr
Material to bring with you	Students should bring a poster to present their science (A0 portrait)
Group event	**Tuesday 18 January 2011** **Dinner** at 9pm at the port in Estepona

2nd WORKSHOP AGENDA

Day 1 – Tuesday 18 January 2011

21:00	**Dinner**	**Group dinner** for all participants 21h – Estepona port

Day 2 – Wednesday 19 January 2011

Attendees: **Main PIs, Crystal2Plate fellows (12) and external students (13)**
Venue: **Estepona hotel**

Time	Item	Description
8:45 – 9:00	**Introduction**	**Workshop objectives and program** by Andréa TOMMASI (UM2)
9:00 – 10:00	**Lecture**	**Deep mantle structures** by Christine THOMAS (Univ. Muenster)
10:00 – 10:30	**Posters**	**Short presentation of posters** by students (1 slide / 2 minutes per person)
10:30	**Break**	**Coffee break**
10:30 – 12:30	**Posters**	**Poster session**
12:30 – 14:00	**Lunch**	**Restaurant hotel**
14:00 – 19:00	**Workshop**	**Free time for joint work on collaborative projects** with coffee break at 16:30
19:00 – 19:30	**Field trip preparation**	**Short presentation of the Ronda peridotite** by Carlos GARRIDO (CSIC, Granada)
19:30 – 20:00	**Preparation of discussions**	**Start organisation of discussion sessions:** ▪ Definition of 4 (max. 5) discussion groups / topics

Day 3 – Thursday 20 January, 2011

Attendees: **Main PIs, Crystal2Plate fellows (12) and external students (13)**

Venue: **Field trip to Ronda Peridotite**

Transportation from hotel by personal & rented cars

Logistics for the day: Bring walking shoes, rain gear and warm clothes. Picnic lunch bags will be provided by the hotel.

Time	Item	Description
8:00	**Group Departure**	**Carpool drive to Ronda Peridotite**
9:00 – 17:00	**On-site**	**With picnic break**
17:00		**Leave site to return to hotel**
18:30 – 20:00	**Preparation of discussions**	**Continue organisation of discussion session:** ▪ Finalize the definition of the discussion groups / subjects / questions ▪ Sign up in a discussion group (paperboard) ▪ Designation of moderator & secretary for each group ▪ Paperboard : list of questions /points which would benefit from a brief presentation by senior scientists

Day 4 – Friday 21 January, 2011

Attendees: **Main PIs, Crystal2Plate fellows (12) and external students (13)**
Venue: **Estepona hotel**

Time	Item	Description
9:00 – 11:30	**Discussions**	**Discussion in groups of 8-10** as organised on Thursday evening with coffee break at 10:30
11:30 – 12:30	**Preparation**	**Preparation** of reports of group discussions by the secretary with help of young researchers
12:30 – 14:00	**Lunch**	**Restaurant hotel**
14:00 – 14:30	**Lecture**	**What can geochemistry tell us about plate tectonics?** by Tim ELLIOTT (Univ. Bristol)
14:30 – 16:30	**Plenary discussion**	**Plenary discussion** including short informal presentations by seniors on methods or clarifications on specific topics that arise from previous discussion sessions.
16:30 – 17:00	**Break**	**Coffee break**
17:00 – 19:30	**Plenary discussion**	**Continuation of plenary discussion**

Day 5 – Saturday 22 January, 2011

Attendees: **Main PIs, Crystal2Plate fellows (12) and external students (13)**
Venue: **Estepona hotel**

Time	Item	Description
9:00 – 12:30	**Plenary discussion**	**Continuation and wrap up of Plenary discussion** with coffee break at 10h30
12:30	**Departure**	*Lunch at the hotel can be organized for those who request it*

Poster abstracts for C2P Second workshop – 19-22 January 2011, Estepona (Malaga), Spain
All students

Ms. Kate ADENA - *University of Bristol, Bristol, U.K.*

δ^7Li, U and Th under the Cape Verde Archipelago as indicators of recycling and melt residue

Katherine Adena (Supervisor: Tim Elliott, Bristol)

The Cape Verde Archipelago is an ocean island sitting atop the effectively stationary African plate on the largest bathymetric anomaly in the oceans. Fogo and Santo Antão are the youngest of the islands, last erupting in 1995 and 0.1Ma respectively. Seismic studies have indicated the presence of a 90km deep depleted swell root under the islands as the cause of this uplift. However, to create a depleted root, large degrees of partial melt are required and this is not supported by previous geochemical studies. δ^7Li isotopic data has been collected from samples from Fogo and Santo Antão to attempt to establish the contribution that recycled crust has in the upwelling mantle. Removal of such material during melting may contribute to the buoyancy of the depleted root. U and Th disequilibrium data has also been collected for the island of Fogo. Excess of ^{230}Th in these rocks indicates the presence of garnet or high-P cpx in the residue. U and Th isotopes, particularly when coupled with Pa, can help to constrain the source composition (e.g. presence of recycled mafic component) from an assessment of the rate of melting.

Mr. Roberto AGRUSTA - *Université Montpellier 2, Montpellier, France*

Mantle plumes: influence of partial melting on the lithosphere erosion

Roberto Agrusta, Diane Arcay, Andréa Tommasi
Géosciences Montpellier, Université de Montpellier 2 & CNRS, Place E. Bataillon, 34095 Montpellier, France.

Mantle plumes are traditionally proposed to play an important role in continental breakup by erosion of the base of the lithosphere. However, previous models show that unless the plate is almost motionless in a hotspot reference frame the thermo-mechanical erosion does not exceed 30 km. We propose to further investigate this process, focusing on the role of partial melting on the plume-lithosphere interaction, by using a 2D petrological-thermo-mechanical numerical model based on a finite-difference method on a staggered grid and marker in cell method.
An homogeneous peridotite composition is used to represent the plate and the underlying mantle. The lithosphere-asthenosphere boundary initially follows the half-space cooling model and we impose a constant velocity of 5 and 10 cm/y at top of the plate. We modeled plumes with a diameter of 50 km and thermal anomalies between 200 – 400 K in a mantle deforming by diffusion creep; the viscosity at the base of the upper mantle ranges between 10^{20} and 10^{21} $Pa \cdot s$. Partial melting is estimated using the melting curves for anhydrous melting as a function of pressure, temperature, which have been modified to account for the progressive depletion of peridotites by solely considering difference between the instantaneous melt fraction and the cumulated one for a given marker; this modified model predicts reasonable melt fractions at the base of the lithosphere (<2 %). The effect of partial melting on the viscosity of the sublithospheric mantle has then been studied using an experimentally-determined flow law for partially molten peridotite, in which the viscosity depends exponentially on melt fraction, pressure, and temperature.
The impact of a plume beneath the lithosphere leads to thermal rejuvenation of the lithosphere by favoring a small-scale convection in the plume-fed low-viscosity layer at the base of the lithosphere. The plumes induce up to 30 km of uplift of the 1200 °C isotherm. The viscosity of the mantle and the plume buoyancy flux, depending on temperature anomaly and plume
diameter, play an important role in controlling the behavior of the plume and, consequently, its erosional potential and amount of melting. Smaller plate velocities result in similar behaviors to those observed in models with low mantle viscosity, large part of the plume material moves upstream from the axis plume and overrunning the large-scale flow induced by plate motion.
Using a melt-dependent rheology the viscosity at the lithosphere base reaches very low values, facilitating the small scale convection, and then the lithosphere erosion, compared to the results obtained without considering the influence of melting. Differently results are obtained when the progressive depletion is taken in account, very low melting fraction (< 2%) values are too much low to reduce the viscosity at the lithosphere base. Despite this, the model gives the advantage to keep in the memory on the marker (rock) the melting history and then a more realistic description plumes-lithosphere interaction.
The model will be expand to consider more sophisticated melting law and melt migration (two-phase flow), and also we will model the upper mantle rheology like a non-Newtonian rheology.

Ms. Flora BAJOLET - *UNIROMA 3, Rome, Italy.*

Dynamic topography in mountain building from experimental approach

Flora Bajolet
Supervisors: Claudio Faccenna, Francesca Funiciello
Roma TRE University

Delamination is a vividly discussed process which have often been used to explain regional uplift associated with alkaline magmatism (e.g. Tibet, Anatolia, Colorado plateau, Sierra Nevada California), either by peeling and coherent detachment or convective removal of lithospheric mantle. But mechanisms of delamination, relationships between mantle flow and lithosphere, and surface consequences remain poorly understood. We performed a series of analogue experiments to investigate the dynamic of delamination by peeling of the lithospheric mantle at different structural levels, and explore the influence of several parameters. Our set-up consists in a three-layers visco-elastic model (upper crust, lower crust, lithospheric mantle) lying on a low viscosity material simulating the asthenosphere. The reference experiment includes a part of thickened lithospheric mantle to simulate a lithospheric root and an adjacent weak zone. We record the mantle flow with particle image velocimetry and evolution of surface topography with a 3D laser scanner during the experiments.

We observe three main phases of evolution. First, a slow stage of initiation with progressive tilting and decoupling of the extremity of the lithospheric root while moderate mantle flow rises in the adjacent weak zone. A higher zone is present above the weak zone from the beginning of the experiment and a dynamic depression deepens above the lithospheric root. During a second stage, the ascending asthenosphere intrudes the lower crust and triggers delamination of the lithospheric mantle, which propagates parallel to the length of the model. A signal of dynamic topography follows the hinge of the delamination: an uplifted bulge caused by upward mantle flow, a trough due to the detaching lithospheric mantle and a small bulge due to bending. In the final stage, the delaminating lithospheric mantle sinks near-vertically and the upper part of the model moves rapidly in the direction opposite to the delamination. This motion is related to the growth of a counterflow rising in the delaminated area and pushing the whole upper part of the model retroward. Amplitude of topography increases until the delaminating lithospheric mantle reaches the bottom of
the box.

These results highlight a strong interdependence between mantle flow circulation, delamination dynamics, plate kinematics and surface topography. The global dynamics and velocity of the delamination are consistent with others models (analytical and numerical), although amplitude of the topographic signal (especially the dynamic part) and evolution of the weak zone, can differ. The main features of the delamination process can
be extrapolated to natural systems where delamination has been proposed, such as Sierra Nevada (California). For instance, the pattern of subsidence over the delaminating lithospheric mantle and uplift associated with poloidal (return) flow and with replacement of lithospheric mantle by more buoyant asthenosphere is consistent with the subsidence of the Tulare Lake basin, in the southern Great Valley, and with the adjacent uplift and tilting of the Sierra Nevada range.

Ms. Amel BARICH - *CSIC, Granada, Spain*

The Rif of northern Morocco and the Betics of southern Spain represent the western terminasion of the Alpine orogenic system, resulting from the Mesozoic-Cenozoic plate convergence between Africa and Eurasia. In the internal Rif, the effects of the Alpine orogenic evolution are clearly documented in the Sebtides units. These units consist of two major metamorphic complexes: an upper one made of HP/LT rocks and a lower one made of Barrovian-type, amphibolites-to-granulites grade sequences , where granulites are in direct contact with peridotites complex known as the Beni Bousera massif. This peridotite massif is formed in a major part of Spinel-bearing lherzolite rimed by a layer 100m thick of garnet-bearing peridotite which is in direct contact with HP-HT granulite metamorphic rocks (16Kbar, 860°C). According to detailed recent study, this shearing contact between these two formations shows the presence of metamorphic ultramafic intercalations underneath the deformed granulites.

Foliation is well distinct and allocate in both rocks with a succession of metamorphic micro-zones with very diverse mineral assemblages. Its originality comes from the spatial arrangement of 3 centimetric zones separating garnet-spinel bearing peridoties from garnet-kyanite bearing granulites:

- Phlogopite, orthopyroxene, spinel zone.
- Corundum, sapphirine, kornerupine zone.
- Sillimanite, spinel zone.

Geochemistry of the different phases shows peraluminous (corundum, kornerupine sapphirine, spinel) and magnesian (phlogopite, enstatite) assemblages, the P-T conditions estimated using thermocalc are 9 to 10Kbars and 700 to 900°C in the saphirine – sillimanite – corundum stability domain.

These thermobarometric conditions reveal that these rocks -forming the top of the peridotite massif- have incurred a metamorphic evolution at high temperatures, which is related to an isothermal decompression after or during the setting up of these rocks at the base of the crust (60 km thick). However, the kornerupine could have formed sequentially under nearly constant P–T conditions (sillimanite stability field) during the infiltration of fluid in the rocks. These hydrothermal processes are also involved and drive the peridotites to a metasomatic contamination at the contact with fluid-rich crustal rocks that leads to crystallization of phlogopite and amphiboles. This contact is possibly a shear zone crossing the limit crust- mantle.

The data show that in the Rif Mountains the granulites and formerly diamond bearing ultrabasic mantle rocks are uplifted in the same geodynamic environment and give very strong constraints on the Alpine metamorphic evolution of the whole Alboran domain.

Key words: Phlogopite, Kornerupine, Corundum, Sapphirine, Metasomatism, Peridotites, Rif

Mr. Mickaël BONNIN - ***Université Montpellier 2, Montpellier, France***

Westward migration of San Andreas plate boundary: consequences on the anisotropy in the asthenosphere

Mickaël Bonnin, Andrea Tommasi
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The study of the seismic anisotropy beneath the Northern California using SKS waves evidenced the presence of an anisotropic layer located in the asthenosphere and characterized by a smooth rotation from NW/SE to NE/SW of the directions of polarization of the fast splitted waves. We proposed this pattern to be the consequence of the westward migration through time of the Pacific/North America plate boundary that would induce a progressive reorientation of the crystallographic fabric from directions close to parallel to the absolute plate motion (APM) of the Pacific lithosphere (NW/SE) to directions close to parallel to the APM of the North America plate (NE/SW). The presence east the San Andreas Fault (SAF) system of E/W directions of polarizations, i.e. intermediate between NW/SE and NE/SW, could represent an evidence of the reorientation of the crystal preferred orientations close to the plate boundary.
In this work we want to test this hypothesis with 3D numerical modeling using a finite elements code for the mechanical aspect (Adeli) associated to visco-plastic self-consistent approach (VPSC) in order to constrain the anisotropic properties of the medium. The model consists of four materials, three for the crust (1 for the Pacific crust, 1 for the North America crust and 1 for the fault zone) and one for the mantle. The crustal blocks follow an elasto-visco-plastic rheology while the mantle, only visco-plastic, follows a power law rheology depending on the pressure. Absolute plate motions velocities from HS3-NUVEL-1A are applied at the boundary of the "Pacific" and "North American" lithosphere (in the yz plane) in order to induce right lateral strike slip together with a westward translation of the fault zone that would produce and localize deformation in the asthenosphere. At this stage, we observe strain localization in a domain corresponding to the asthenosphere due to the shear imposed by the horizontal movement of both the "Pacific" and the "North America" lithospheres together with a narrow deformed domain beneath the fault zone explained by a strike-slip dynamics. Once the mechanical approach will be achieved, strain rate obtained from the numerical experiment will be used to model crystallographic fabric reorientations in VPSC. Finally synthetic seismograms should be used to check the consistency between the model and the SKS data.
This work is still in progress, for this reason only the mechanical part of the numerical modeling will be presented.

Ms. Erika DI GIUSEPPE - *FAST, Orsay, France*

Modelling lithospheric ageing during subduction: Implications for the Izu-Bonin-Mariana trench

AUTHORS:
Erika Di Giuseppe, Claudio Faccenna, Francesca Funiciello, Jeroen van Hunen, Serge Lallemand

ABSTRACT:
Lithosphere bends and subducts into the mantle at trenches. Subducting plate cools, thickens, and contracts in time, inducing changes in the strength of the litosphere and its buoyancy as it grows older.
Recent worldwide databases reveal that most of the trenches roll back, but a significant amount of them migrates in advancing toward the upper plate. On Earth this dichotomy is exhibited in the Pacific area: most of the advancing slabs are located in the Western Parific, whereas the Eastern Pacific trenches retreat. It seems that the age of the slab, and consequently the slab strength, to a certain extent controls the subduction style.
In this study we select a region where geological studies illustate a variability in trench migration in time. The Izu-Bonin-Mariana (IBM) system, the oldest subducting lithosphere on Earth, represents a significant esample. The reconstruction of the trench migration of the IBM subducting system shows a long episode of asymmetric trench rollback, followed by a recent phase of trench advance.
We suggest that this evolution of trench migration from retreating to advancing mode would be the consequence of the subduction of progressively older and stiffer lithospheric material. We tested this speculation by performing 2-D numerical, fully dynamic models, implemented in order to mimic the influence of the progressive lithospheric ageing on trench kinematics. The arrival of older and stiffer lithosphere at the trench has, as consequence, the gradual slow down of the trench migration, and the continuous increase of the resisting force for bending. Hence, the plate is forced to move in advancing, and the change in trench migration occurs.
Despite the simplified assumptions of the model, we are confident in the robustness of our results. This model can be applied to the IBM subduction system reconciling down-dip slab shape with the recent transition of trench kinematics from retreating to advancing style.

Ms. Jenny DI LEO - *University of Bristol, Bristol, U.K.*

Shear-Wave Splitting beneath Northern Sulawesi and the southernmost Philippines
The Sangihe Subduction Zone

J. Di Leo*, J. Wookey, J.O.S. Hammond, and J.-M. Kendall
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Located at the junction of the Eurasian, Indo-Australian, and Philippine Sea Plates, the Sulawesi region is a complex, active subduction environment. Constraints on the mantle flow-field, mantle composition, and state of stress in the area are lacking, but these parameters are nevertheless expected to be reflected in measurable anisotropic fabrics.

We present new shear-wave splitting results for both local and teleseismic data for northern Sulawesi, where two subduction zones converge at ca. 200 km depth, the Celebes Sea Plate dipping south and the Molucca Sea Plate dipping northwest beneath Sulawesi.

Results for the northwest dipping Molucca Sea subduction show little variation in delay time with depth for local earthquakes, indicating that the anisotropy is confined to the lithosphere, whereas the mantle wedge is probably isotropic. Delay times of *SKS* splitting are significantly higher (an average of ~1.36 s for *SKS* splitting as opposed to a local-*S* average of ~0.56 s), suggesting that there is additional anisotropy in or around the slab not sampled by local events.

Fast direction orientations vary considerably, especially for local-*S* splitting, exhibiting nearly the full 180° range of directions and thereby indicating that the anisotropic fabrics are complex. However, to a large extent, the local-*S* and *SKS* fast directions are approximately between 10° and 80°. The likely cause of the complexity is due to two subducting slabs converging at depth as well as the ongoing clockwise rotation of the north arm of Sulawesi.

We forward model the shear-wave splitting results with a subduction zone model based on regional tomographic images in order to place constraints on the location and orientation of anisotropy: We calculate ray paths for each shear-wave used in our study for a standard 1-D velocity model. We then calculate the travel-time for each of these rays through the tomographic model and compare with that predicted from the 1-D model. The discrepancy between the two travel-times gives a proxy as to how much time each ray may have spent within the subducting slab, hence constraining possible locations of the anisotropic fabrics. Without exception, the local events arrive earlier than predicted by the reference Earth model, highlighting the fact that all rays are likely to have spent some time in the subducting slab. However, we see no apparent correlation of arrival time perturbation with the splitting results, indicating that, at least for local events, the ray path within the slab is unlikely to harbour the source of the measured anisotropy, making a shallow lithospheric fabric the most likely explanation. This implies a second, deeper (deep slab interior or subslab) region of anisotropy to explain the larger *SKS* results.

Mr. Thibault DURETZ - ***ETH, Zurich, CH.***

Combining thermo-mechanical and analytical models of slab detachment: towards the calibration of an effective slab flow law?

T. Duretz, S. M. Schmalholz, T. V. Gerya

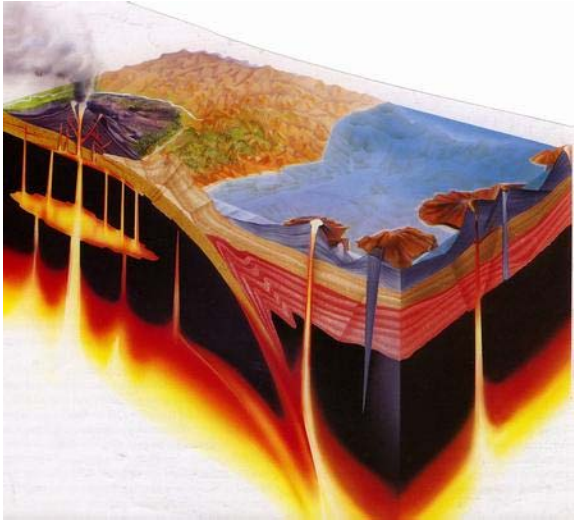
In order to study the dynamics of slab detachment, we have been developing 2D thermo-mechanical models of continental collision. In numerical models, the deformation of the mantle is usually modeled using a complex composite olivine rheology. These composite rheology takes into account the effects of viscous (diffusion-dislocation creep) and plastic (Mohr-Coulomb, Peierls) deformation. The non-Newtonian rheological components allow for strain localization and eventually lead to slab detachment. The parameters governing these flow laws are calibrated from laboratory experiment of olivine deformation.

In Duretz et al. (2010), we showed that, using the same rheological description, slab detachment can happen at various depths (40-400 km), leading to a wide range of geodynamic (eduction, plate decoupling, extension) and topographic evolution. These different end-members are related to the activation of different rheological mechanisms within the slab and therefore display different slab necking dynamics.

Schmalholz (2011) presents the application of an analytical solution of necking in a layer to slab detachment. This 1D solution can predict the necking in a layer of power-law fluid under its own buoyancy and is governed by the layer thickness, the necking time, and the stress exponent. We compile all our slab detachment data computed with the geodynamic code (I2VIS, Gerya and Yuen, 2003) and express it in terms of neck thickness versus necking time. We observe that our numerical data well reproduces the necking evolution predicted with the analytical solution. The modeled detachment events are characterized by a narrow range of characteristic necking time (0.8-2.5 My) despite the variety of rheological mechanism involved. We propose that a simple power law rheology, characterized by an effective stress exponent, may be use to describe the rheology of the slab during slab detachment.

Ms. Diana DYMKOVA ***- ETH, Zurich, CH.***

2D Numerical modelling of a porous flow in the subduction zone



Numerical modelling of a porous flow has a wide range of applications in geosciences and industrial engineering. The purpose of our project is to investigate partial melting and melt percolation which happens in the mantle wedge of the subduction zone. This process is triggered by the subducting slab dehydration.

We created a two-dimensional model of a two-phase flow in a porous media solving a coupled Darcy-Stokes system of equations for two incompressible media for the case of visco-plastic rheology of solid matrix. We use a finite-difference method with fully staggered grid in a combination with marker-in-cell technique for advection of fluid and solid phase. We performed a comparison with a simple benchmark of a thermal convection in a closed bottom-heated box to verify the interdependency of Rayleigh and Nusselt numbers with a theoretical one.

We have also demonstrated the stability and robustness of the algorithm in case of strongly non-linear visco-plastic rheology of solid including cases with localization of both deformation and porous flow along spontaneously forming shear bands.

Also we have checked our model for the forming of localized porous channels under a simple shear stress (channelling instability).

We have included simple melting into the model as a function of pressure and temperature. Currently we elaborate on the setting of subduction-like setup of the model and expanding the system of equation for the high-porosity limits (Darcy equation is usually limited from above with the value of porosity equal to 20-25%) and stabilizing of the system under conditions of high porosity contrasts.

In the future we plan to include elasticity, fluid/solid compressibility and complex melting in our numerical model as a function of water content and composition as well as of pressure and temperature (currently done). Also we plan to perform porosity waves benchmarking (Connolly and Podladchikov, 1998).

Ultimate goal is to simulate in a realistic self-consistent manner fluid and melt generation and transport in subduction zones including fluid/melt focussing phenomena.

Mr. Erwin FRETS - *CSIC, Granada, Spain*

Thermo-mechanical evolution of the subcontinental mantle above a convergent zone

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The Beni Bousera peridotite massif (BBPM) crops out in the Rif mountains, the westernmost branch of the Alpine belt in Morocco. It is an exceptional outcrop of about 75 km² of subcontinental mantle. Former studies on the Ronda peridotite massif on the other side of the Alboran basin have shown that these rocks probably represent a fossil lithosphere – asthenosphere boundary exhumed due to continental thinning above a subduction zone.
The BBPM is mainly composed of spinel tectonites, with locally harzburgites and dunites with diffuse boundaries. Abundant centimeter to pluridecimetrical pyroxenite bands define a compositional layering in the peridotite. Pyroxenites range from spinel to garnet clinopyroxenites (+/- orthopyroxene). The latter have sharp contacts with the host peridotite and are often boudinaged, while the former may also have diffuse contacts.
New geological and structural mapping including the transition from garnet– to spinel–bearing pyroxenites in the spinel tectonites (Seiland and Ariegite subfacies) and analysis of the deformation in the peridotites and pyroxenites offer preliminary constraints on the thermo-mechanical evolution of the BBPM. Both peridotite and pyroxenite dominantly deform by dislocation creep, but average olivine grain size globally increases towards the structurally deeper domains, recording deformation under decreasing stress conditions probably associated with a temperature gradient. In the northernmost profile, olivine grain growth is strikingly correlated with the transition from garnet – to spinel bearing pyroxenites is interpreted in the Ronda peridotite massif as due to heating and melting. Analysis of WR geochemistry and chemistry of the main mineral phases will enable to constrain partial melting in the peridotites and the relation with deformation.

Ms. Sonja GREVE - *University of Utrecht, Utrecht, Netherlands*

Upper mantle heterogeneity and depth-dependent anisotropy in the central Mediterranean subduction zone

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The central Mediterranean subduction zone evolved in a complex dynamic process with a westward retreating trench. The openings of several basins, such as the Tyrrhenian Basin are coupled to the slab evolution. However, details of the process are still unclear. Further complexities of the subduction dynamics are caused by a series of slab windows in the Calabrian arc, as indicated by body wave tomography and complex pattern of magmatism.

Mantle anisotropy measurements provide a direct tool to investigate mantle dynamics and to measure strain in the mantle. However, shear-wave splitting measurements for Italy show complicated pattern and their restricted depth resolution hinders detailed interpretation for 3D processes. Moreover, measurements are restricted to onshore. The transition of the anisotropic fast orientations in the Tyrrhenian Sea from the prevailing E-W on Sardinia to the complex pattern on mainland Italy is therefore still unknown.

Here, we apply a surface wave dispersion tomography with the aim to identify depth dependent azimuthal anisotropy for Italy and the Tyrrhenian Sea. We use data from various temporary and permanent seismic stations in Italy, Tunisia, Corsica and Sardinia to measure interstation fundamental mode Rayleigh wave phase velocities. The measurements are then used to obtain azimuthal anisotropic phase velocity maps. Changes in fast orientations and anisotropic strength appear for different periods corresponding to different depths. These results can complement teleseismic shear wave splitting measurements to provide a more sophisticated image of the 3D anisotropic structure of the Tyrrhenian Sea and Italy. An additional inversion of the phase velocity maps for isotropic shear wave velocities reveals the 3D distribution of heterogeneities. The combined results of the anisotropic and heterogeneous structure help to improve our understanding of the dynamic evolution of the central Mediterranean subduction zone and the Calabrian arc.

Mr. James HAMMOND - ***University of Bristol, Bristol, U.K.***

Continental breakup in Africa: From superplume to rifting

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It has long been recognised that low seismic velocities underlie Africa and are present from the core mantle boundary to the surface. However, the connectivity of this feature remains unclear. These low velocities are commonly assumed to represent a thermal upwelling, the African superplume, and can explain the dynamic topography of East Africa, and have long been associated with the extensive volcanism and rift activity in the region.

Over the last decade East Africa has seen many deployments of seismic stations, with the aim of understanding continental breakup in the region. We have combined data from 5 of these experiments, to enable us to resolve high resolution models of upper mantle P- and S- wave velocities, and seismic anisotropy extending from the Red Sea to Kenya.

Relative travel time tomographic inversions highlight that a sheet like upwelling underlies this whole region. It is oriented SW-NE and extends from at least the transition zone to the crust. This is most likely associated with thermal upwelling material associated with the African superplume. In the uppermost 100 km strong P- and S- wave low velocity anomalies exist and are likely associated with partial melt. These anomalies underlie the most recent rift related volcanism.

Detailed high quality SKS splitting results suggest that depth variations in anisotropy exist beneath large parts of Ethiopia. The lower layer has a similar SW-NE fast direction to the low velocity material, suggesting a correlation with superplume flow in the asthenosphere. The upper layer is more similar to structural features at the surface, likely associated with aligned melt in the crust/lithosphere.

These results suggest that thermal instabilities arising from upwelling material provides heat for melting and uplift, but rifting probably follows pre-existing weaknesses in the lithosphere.

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Layered dunite-harzburgite-lherzolite bodies from the plagioclase tectonite zone of the Ronda peridotite massif, Spain

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The processes that take place during the transport of melts through the convecting mantle are the least understood and, therefore, state-of-the art problems among a series of processes of formation and evolution of mantle magmas. It is widely accepted that, dunite channels might be pathways by which mantle melts easily pass through the overlying mantle (e.g. Kelemen et al., 1997). However, accepted models explain formation of dunitic lithology mostly in oceanic environment, but one would face several challenges trying to apply them to the subcontinental lithospheric mantle.
The Ronda massif (southern Spain) is the largest (*ca.* 300km^2) of several orogenic peridotite massifs exposed in the Betic and Rif (northern Morocco) mountain belts in the westernmost part of the Alpine orogen that was tectonically emplaced during early Miocene times. One of the most remarkable features of the Ronda massif is the 'recrystallization front' that represents the transition from the spinel-tectonite to the coarse granular peridotite domain corresponding to a narrow boundary of a partial melting domain caused by thinning and coeval asthenospheric upwelling formed at the expense of former subcontinental lithospheric mantle and associated with melting and kilometer-scale migration of melts by diffuse porous flow through the 'asthenospherized' domain (Van der Wal & Bodinier, 1996; Lenoir et al., 2001; Vauchez & Garrido, 2001). In the vicinity of the recrystallization front, coarse granular peridotites pass into layered granular peridotites with a typical layered structure composed of plagioclase lherzolites, depleted lherzolites, harzburgites and dunites.
Here, we present preliminary structural, petrophysical and geochemical data of these layered bodies. The main scientific goals of this study are to test new mechanism(s) for the formation of dunites and dunite-harzburgite-lherzolite layered bodies in the subcontinental lithospheric mantle on the example of Ronda peridotite massif (Spain), and to introduce new processes that are expected to lead the evolution of the subcontinental lithospheric mantle in extensional settings.

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Deformation in a shallow partially-molten mantle: Constraints from the study of the Oman Ophiolite mantle section

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It has been widely documented through experiments, numerical models and natural data that the presence of even a small volume of melt can have large effects on the strength of peridotites. Experiments also show that shearing may lead to segregation of the melt into planar bands. Since peridotites are considered to be the bulk composition of the upper mantle these observations can reasonably be extrapolated to assume that small volumes of melt in the mantle can change the overall mantle rheology and thus have implications for strength profiles, deformation distribution, and seismic anisotropy in the upper mantle.

In this study we conduct a small-scale (from the outcrop to the µm) analysis of natural samples, in a section of the Oman ophiolite crust-mantle transition zone, which is known to have been subjected to large shearing while partially molten, to better understand the effect of the presence of melt on peridotite deformation.

More than 50 samples were collected in 100m vertical section from the flanks of one of the proposed diapirs feeding the Oman ridge where the partially molten mantle has been subjected to high horizontal shear strains. The outcrop has a well-developed compositional layering parallel to both the locally sub-horizontal foliation and the regional Moho. The cm- to m-scale layering consists of dunite, wehrlite, troctolite, and olivine gabbros bands often with diffuse contacts. All samples show a strong foliation and E-W lineation (approximately 90° to the proposed ridge axis) therefore records the subhorizontal shearing which accommodates the difference in motion between the newly-formed oceanic plate and the underlying, relatively faster moving, asthenosphere.

There are no systematic changes in modal composition nor in the intensity of olivine crystal-preferred orientations (CPO) along the section. There is however a clear correlation between olivine CPO pattern and the modal composition that reveals the influence of the melt (which presence is recorded by crystallization of plagioclase + clinopyroxene) on the deformation. The more dunitic samples have a typical high temperature, low stress axial [100] olivine CPO with the a-axis parallel to the shear direction. However as the percentage of plagioclase and clinopyroxene increases and the rocks become more gabbroic there is a dispersion of the olivine [100] axis within the foliation plane and the [010] axis tends to concentrate normal to the foliation, resulting in an axial [010] pattern. This change in CPO pattern is gradual and occurs around 25% of plag+cpx. The lack of dispersion of olivine CPO (J indexes that quantify the CPO strength are similar for both patterns) implies that instantaneous melt fractions remained at all times small (a few wt. %) and that the change in CPO pattern is controlled by the finite strain accumulated in presence of melt. Both the CPO and the present modal compositions result therefore from time-integrated processes. Preliminary major-element analysis do not show any evidence of mineral zonation, suggesting crystallisation in an open system (continuous melt feeding), though the long-lasting near-solidus conditions deduced from the microstructural analysis may have allowed fast compositional homogenization by diffusion.

Our observations support experimental evidence for shear-induced melt segregation into bands subparallel to the shear plane. Such melt-rich bands will have a lower strength and result in an anisotropic reduction of the viscosity, which may aid plate-boundary stabilization. Further work includes constraining the mechanisms associated with the change in the olivine CPO pattern and with the development of the plg and cpx CPO and a finer analysis of major and trace-element compositions to check for mineral zonation and small scale compositional changes with the aim of constraining how much melt the system has seen and the composition of this melt.

Mr. Zonghai LI - *FAST, Orsay, France*

Buyancy-driven subduction

Analysis of Free Subduction Using the 3D Boundary-Element Method

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An analytical and numerical study of free subduction is being conducted using a three-dimensional boundary-element method (BEM) in combination with an asymptotic theory of thin viscous sheets. The overall goal is to determine quantitative scaling laws for key subduction parameters (velocities of plate advance and trench retreat, slab deformation style, state of stress within the plate, induced seismic anisotropy) that can be compared with both geophysical observations and the results of analog laboratory experiments.

The first task is testing and debugging the boundary-integral solver used to determine the instantaneous velocity field for a sheet of a given geometry. The accuracy is verified against three analytical solutions: (1) a falling fluid sphere in an infinite fluid with an arbitrary viscosity contrast; (2) a falling fluid sphere in a half-space of infinite fluid with the same viscosity and a traction-free boundary; (3) a rigid sphere in an infinite fluid half-space with a traction-free boundary. The results show that the error is proportional to $1/\Delta^4$, where Δ is the linear element dimension.

Using asymptotic thin-layer theory, we have built an explicit solver to calculate the velocity field on the mid-surface of the slab, which can then be used for scaling subduction dynamics. The preliminary results are consistent with previous two-dimensional analyses showing that the fundamental length scale of the deforming plate is the `bending length', defined at each instant as the length of the portion of the plate's mid-surface where the bending moment is significant. It also indicates that the crucial dimensionless parameter governing the plate's dynamics is its 'stiffness', which quantifies whether subduction is resisted primarily by the viscosity of the slab itself or by that of the ambient fluid.

The current version of the code works well with relatively low resolution (Δ = sheet thickness/2) and viscosity contrast λ up to 10^3. We are now developing a non-uniform discretization of the sheet to obtain good accuracy for higher viscosity contrasts.

Ms. Anna MASSMEYER - *FAST, Orsay, France*

Thermal Convection with plate tectonics in the laboratory

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The earth’s surface is divided into several plates. Those plates are moving and this phenomenon is explained by the theory of plate tectonics. Today, 50 years after the acceptance of this theory, it is accepted to see convection of the earth’s mantle and plate tectonics as an integrated system, where convection drives the plates and vice versa. But the question is still: how do plate tectonics arise from convection in a self-consistent manner?

For a long time, studies (i.e. [1], [2], [3]) aimed at producing plate tectonics in a self-consistent manner by employing a Newtonian but strongly temperature-dependent-viscosity-fluid (e.g. sugar syrup in the laboratory). For earth-like parameters, this approach leads to a stagnant-lid-regime. Later studies (i.e. [4], [5], [6]) have shown that the key-element to produce convection with plate tectonics is non-Newtonian rheology (fluid with a nonlinear stress-strain relation). Those studies show that assuming non-Newtonian-rheology, the system leads to different regimes with plate like behaviour, depending on the initial condition. This project therefore aims at producing thermal convection with plate like behaviour in the laboratory by using complex rheology fluids. The fluid which will be used is Carbopol.

The study consists of three steps. In a first step, I characterized the Carbopol-rheology and showed that it has a yield stress as well as shear thinning behaviour. Both can be changed by changing the concentration and/or the pH of the Carbopol-water(-glycerol) mixture. In a second step the sugar syrup (Newtonian but strongly temperature dependent viscosity) is employed. This enables us to test and improve the experimental setup as well as to get a more quantitative understanding of the 3D structure of convection – both at onset and in steady state. This step will provide a valuable “reference” study to isolate the non-newtonian effects which will occur in the third step of the study where the sugar syrup will be replaced by the Carbopol-solution.

For the convection-study a Rayleigh-Bénard-setup is employed. It consists of a rectangular box, heated from below and cooled from above. To track the velocity field, small particles are injected into the fluid, which reflect the light of a laser sheet. To visualize the temperature liquid crystals are used. Those crystals have the property to reflect the light of the laser sheet at a certain temperature. This way we are able to observe isotherms, cf. [7]. This visualization is only 2D, but the setup for the laser is also able to move the laser sheet horizontally. After synchronizing this movement with a camera, a MatLab routine was developed to have a 3D-visualization of the brightest isotherm, to be able to take account to spatial effects. Furthermore, the temperature is measured at different depths with 16 thermocouples. Before convection starts, heat is transported by conduction, which can be described analytically. Therefore we are able to compare the experimental results with an analytical solution.

To get a good understanding of the onset of convection in a temperature-dependent-viscosity-fluid, a series of experiments was performed, where pictures were taken from a horizontal and a vertical cross-section, while the fluid was heated from below. It can be seen, that plumes arise from a triple-junction of a network of ridges, like already observed in numerical cartesian studies, e.g. [8].

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High-pressure hydrofracturing during deserpentinization

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Volatiles released from dehydration reactions have to migrate across a relatively cold (<750°C), peridotite-layer above the incoming slab in subduction zones. To unravel the mechanisms allowing for this initial stage of fluid transport, we performed a detailed field and microstructural study of prograde peridotites in the Cerro del Almirez ultramafic massif (Betic Cordillera, Spain), produced during the HP antigorite breakdown (1.6-1.9 GPa & ~680°C) [1-2]. The metamorphic texture is partially obliterated by grain-size reduction zones (GSRZ), a few mm to meters wide, which form roughly planar conjugate structures characterized by (1) sharp, irregular shapes and abrupt terminations contacts with undeformed metaperidotite, (2) an important reduction of the olivine grain size (60-250 µm), and (3) decrease in the opx modal amount. Analysis of olivine crystal-preferred orientations in GSRZ shows similar patterns, but a higher dispersion than in neighboring metaperidotite. We propose that hydrofracturing is the main mechanism accounting for GSRZ supporting the substantial reduction of the opx modal content. Development of the GSRZ network was probably linked to the fluid release during atg-dehydration allowing for the formation of high permeability channelways for overpressured fluids. HP hydrofracturing may be an essential mechanism in the first stages of fluid flow through the coldest parts of top-slab mantle in subduction zones. The near lithostatic pressure associated with this process produces transient low seismic velocities similar to those associated with episodic tremor and slip attenuation zones.
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Stability of Archaean cratons and their influence on the strength of the lithosphere

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It is now well accepted that mantle convection and plate tectonics form an integrated system and cannot be treated independently. Although this is a promising improvement in understanding Earth, there is still a striking feature, which is nowadays not yet included in this integrated system, namely the existence of the Earth's lithospheric heterogeneity - in other words - the difference between oceans and continents.

It has been shown before that continents might have a first-order effect on the dynamics of the Earth as they might modulate convective wavelength, surface heat loss and - due to thermal insulation - the internal mantle temperature. Another possible effect concerns the critical yield strength of the lithosphere. So far convection models with plate tectonics but without continents have always shown way to low yield strength values compared to laboratory experiments. But the strong contrasts in physical properties at the boundaries between oceans and continents are supposed to focus convective stresses. That may result in a reduction in critical yield strength in the presence of continents.

In the present study continents are simplified as cratonic roots, the strong Archaean cores of the continents. They differ from normal mantle in buoyancy and rheology, but besides that they are treated like normal mantle. This allows them to move and/or deform, which is in contrast to most previous studies.
It is well known that cratonic roots are tectonically stable since the late Archaean at least. Stability conditions have been investigated before, but neither for purely internal heating nor spherical geometry nor in 3D, that might be of importance as the topology of subduction zones can be different in 3D. First results from the present study indicate that the mentioned differences do not significantly change the stability criteria of cratonic roots: if yield stress and viscosity of the roots are sufficiently higher as for oceans, cratons are stable and this observation is basically independent of the root buoyancy.

In a further step models with and without continents are compared focusing on the resulting tectonic regime, i.e. if the lithosphere behaves mobile or stagnant for a given yield strength. First results show that continents can cause changes in the tectonic regime and can force the lithosphere to remain mobile – at least episodically. However, this effect depends on the size and maybe also the number of continental units in the model.

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Seismic properties of the sub-arc mantle

Soustelle V., Tommasi A., Demouchy, S.

Peridotite xenoliths sampling the sub-arc mantle are rare but essential because they may give significant constraints to interpret large-scale seismic studies on the mantle wedge. In this work, we analyzed microstructures, measured minerals crystal preferred orientations (CPO) and water contents, and calculated the seismic properties of two series of spinel peridotites xenoliths extracted from the base of the supra-subduction plate by the calc-alkaline volcanism in southern Kamchatka (Avacha volcano) and the alkaline volcanism near the Lihir Island, Papua New Guinea, and. The aim is to constrain the effect of the interactions between deformation and reactive melts or fluids percolation on sub-arc seismic properties.

The studied peridotite xenoliths display microstructures and CPO consistent with deformation under high temperature low stress, which occurred in the mantle wedge. The main slip system in olivine is {0*kl*}[100], which results in fast S-wave polarization parallel to the flow direction in the mantle. Infrared analyses show that olivine from the both collections contains less water than the theoretical saturation calculated for their estimated equilibrium temperature in the spinel stability field. These low water content are similar to those observed in spinel peridotites from other subduction zones and probably record both the low solubility of water in olivine at relatively low pressure and dehydration during exhumation of the xenoliths. These measured water contents as well as theoretical saturation estimations are not sufficient to change the dominant slip direction of in olivine from [100] to [001].

In most samples, there are textural evidences for a synkinematic reactive percolation of Si-rich fluids or hydrous melts leading to pyroxene crystallization at the expenses of olivine. This led locally to development of pyroxene-rich lenses parallel to the foliation. These lenses are characterized by a decrease of the average olivine grain size and a dispersion of the olivine CPO without changing the dominant slip system. This results in a decrease of the intrinsic seismic anisotropy of the supra-subduction mantle that may lead to an underestimation of the anisotropic layer thickness by up to 33%. The observed orthopyroxene enrichment also lowers the Vp/Vs ratio, but cannot explain Vp/Vs < 1.7 mapped locally in the Japan and Andes fore-arc mantle. Such low Vp/Vs ratios may however be explained by considering the intrinsic anisotropy of the peridotites, which is generally ignored in large-scale Vp/Vs ratio mapping of the mantle wedge.

Mr. Marcel THIELMANN - *ETH, Zurich, CH*

Shear heating and subduction initiation

M. Thielmann , B.J.P. Kaus

Despite their importance in geodynamics, the processes that result in subduction initiation remain incompletely understood. Shear heating has been put forward as a mechanism to create lithospheric-scale shear zones (e.g. Ogawa 1987, Regenauer-Lieb et al. 2001). A scaling analysis highlighted the governing parameters that control shear localization (Kaus and Podladchikov 2006), and showed that the boundary between localization and no localization is quite sharp. Recently, this scaling analysis was extended to include more realistic lithospheric rheologies and structures and it could be demonstrated that shear-heating induced lithospheric scale localization might occur for Earth-like parameters (Crameri and Kaus, 2010).

It is however unclear if all lithospheric-scale shear zones evolve into self-sustaining subduction zones. Here, we therefore extend the models used by Crameri and Kaus to greater depths and take into account an underlying asthenospheric mantle. This results in a more pronounced localization where the deformation is taken up in one single shear zone. It could be shown that whole lithosphere failure does not necessarily lead to subduction initiation. Only for a certain range of parameters and with ongoing convergence, this shear zone evolves into a self-sustaining subduction zone.

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Mixing and sampling the Earth Mantle by thermal plumes
Laboratory experiments and hybrid particle advection method

As they bring deep mantle material to the surface, mantle plumes offer an unique opportunity to probe the planet's deep interior. But deciphering their geochemical message requires to understand quantitatively plume dynamics and sampling. For several decades, much effort has been devoted to understand plume dynamics and to provide scaling laws for plume ascent velocity or for plume growth by entrainment of ambient fluid. However, only a few of them have focused on entrainment, deformation and sampling of material, both in transient and steady state.

Using a laboratory model of a thermal plume generated from a small heat source in a high Prandtl number fluid which viscosity depends strongly on temperature, we present a study of the entrainment of fluid as a function of the temperature of the source, the height, density and viscosity of the fluid and the dimensionless numbers. In order to understand the mechanism of entrainment, we designed a new experimental set-up which allow us to visualize simultaneously the temperature field, the velocity field and the displacement of passive markers without disturbing the flow. We observe that the sampled material systematically passes by the source of the plume. We also observe that a plume is a powerful mixer, which stirred and streched the viscous fluid around the center of the convective cell. This study could also yield the characteristic spatial and temporal scales of heterogeneities in a mantle mixed by thermal plumes.

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Numerical modeling of crustal growth at active continental margins

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The dynamics and melt sources of crustal growth at active continental margins are investigated on the basis of a 2D coupled petrological-thermomechanical numerical model of an oceanic-continental subduction zone. The model includes spontaneous slab retreat and bending, dehydration of subducted crust, aqueous fluid transport, partial melting, melt extraction and melt emplacement in form of both extrusive volcanics and intrusive plutons. Depending on variable model parameters such as plate velocities and degree of rheological weakening induced by fluids and melts, the following three geodynamic regimes of crustal growth were identified: (i) stable arcs (ii) compressional arcs with plume development and (iii) extensional arcs.

Crustal growth in a stable arc setting results in the emplacement of flattened intrusions within the lower crust. At first trondhjemitic melts, extracted from partially molten rocks located atop the slab (gabbros and basalts), intrude into the lower crust followed by mantle-derived (wet peridotite) basaltic melts from the mantle wedge. Thus extending plutons form in the lower crust, characterized by a successively increasing mantle component and low crustal growth rates (20 km^3/km/Myrs). Compressional arcs are accomplished by the formation and emplacement of hybrid plumes. In the course of subduction localization and partial melting of basalts and sediments along the slab induces Rayleigh Taylor instabilities. Hence, buoyant plumes are formed, composed of partially molten sediments and basalts of the oceanic crust. Subsequently, these plumes ascend, crosscutting the lithosphere before they finally crystallize within the upper crust in form of silicic batholiths. Additionally, intrusions are formed in the lower crust derived by partial melting of rocks located atop the slab (basalts, gabbros, wet peridotite) and inside the plume (basalts, sediments). Crustal growth rates increase with time before reaching a steady state (60km^3/km/Myrs).

Subduction in an extensional arc setting results in decompression melting of dry peridotite. The backward motion of the subduction zone relative to the motion of the plate leads to thinning of the overriding plate. Thus, hot and dry asthenosphere rises into the neck as the slab retreats, triggering decompression melting of dry peridotite. As a result crustal growth rates increase to values of about 100km^3/km/Myrs.

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Can global or regional scale seismic anisotropy in D'' be used to constrain flow patterns in the lowermost mantle?

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Observations of shear wave splitting in ScS phases reveal the signature of strong seismic anisotropy in D'' and suggest that it may be possible to use seismology to probe the dynamics of the lowermost mantle. A key step in this quest is to establish the mechanism leading to anisotropy in D'' and show how this is linked to mantle flow. In this study we test the hypothesis that the observed regional scale anisotropy under the Caribbean and North America is caused by deformation-induced crystallographic preferred orientation by combining 3D models of current mantle flow with simulations of texture development and compare the predicted splitting with new seismic observations. We also test the hypothesis that the global scale D'' anisotropy is caused by the same mechanism.

The starting point is a model of current mantle flow. For this we use a global three-dimensional flow field derived from the TX2008 model of mantle density (Simmons et al. GJI 2009). This is generated by joint inversion of data including S-wave travel times, the global gravity field, dynamic surface topography, observations of plate motion and of the excess ellipticity of the core-mantle boundary. The inversion makes use of realistic mineral physics parameters and seeks to explain as much density variation as possible in terms of thermal, rather than compositional, anomalies. Using this flow model, we trace the pathlines followed by packets of material moving through the post-perovskite stability field. We calculate the velocity gradients tensor at steps along each pathline and use these as the boundary conditions for the calculation of the textural evolution of post-perovskite aggregates.

Texture development in the polycrystalline aggregates are modelled using the self-consistent visco-plastic (VPSC) approach where the interactions between grains are represented by embedding each grain in a homogeneous effective medium representing the other grains in the sample. This results in the compatibility and equilibrium conditions being fulfilled in an average way while allowing the stress and strain in each grain to differ. Parameters describing the single crystal plasticity (e.g. slip activities) are currently poorly constrained by experiment and theory. To compensate for this a range of key parameters are chosen empirically, to agree with selected experimental results, or are taken from Peierls-Nabarro models of dislocations using density functional theory and assuming deformation is rate limited by the intrinsic Peierls potential. We calculate the elastic constants tensors of each textured aggregate and use this as input for forward modelling of the propagation of seismic waves corresponding to our observations. By investigating the texture, and aggregate elastic constants tensors, generated by a wide range of different single crystal parameters we are able to examine the ability of each to explain seismic observations.

We predict the shear wave splitting parameters - the delay times and fast polarisation directions - for seismic waves propagating through our model and compare these with regional studies that measure shear wave splitting in two directions in the study areas. This allows us to compare the model predictions with current constraints on the anisotropy of D''. We also predict the ξ parameter on a global basis assuming vertical transverse anisotropy ($\xi = V^2_{SH}/V^2_{SV}$). This allows us to compare the results of the model with observations in areas where the anisotropy of D'' is constrained by single azimuth measurements. We are able to reject several feasible models of single crystal plasticity on the basis of disagreement with observation but cannot uniquely constrain the glide plane for easy-slip in post-perovskite. Furthermore, the study shows that knowledge of the easy-slip system is, by itself, insufficient to constrain the modelled texture. The activities of secondary slip systems in post-perovskite are also needed but these are currently particularly poorly constrained by experiment. Another promising avenue would be to place further constraints on the deformation parameters from seismic observations.