T52E-2 1345h

DEFORMATION DURING MAGMATIC UNDERPLATING IN THE IVREA-VERBANO ZONE, NORTHWESTERN ITALY

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A 1- to 10-km-thick intrusive complex (IC), formed during Hercynian magmatic underplating, is an important element of the lower crustal terrane known as the Ivrea-Verbano Zone (IVZ). Situated between upper-mantle peridotite and lower-crustal paragneiss and schist, the IC consists of variably deformed gabbroic to intermediate intrusive rocks and septa of metapelitic rocks. A foliation and less-well-defined lineation are widely developed. Intrafolial folds and boudins are evident in both layered gabbros and banded metapelitic rocks. Dikes are commonly disrupted and folded, and their contacts with wall rocks are locally drag folded. Tensional faults are healed by thin, undeformed veins crystallized from late-stage melts in the gabbros and partial melts in metapelite septa. In other places, similar late-stage and partial melts crystallized in undeformed, coarse-grained patches that crosscut foliation and fill pressure shadows at the ends of boudins. Apparently, the foliation, lineation, and many of the outcrop-scale structures in the IC formed while the gabbros were still a crystal mush.

Preliminary mapping in the southern IVZ reveals a metapelitic septum, which is concordant with gabbro layering, parallels the base of the IC for several kilometers, and curves up section to the south into the roof of the IC. We propose that this septum may define the lower, upwardly concave floor of a lopolithic structure within the IC and that the observed hypersolidus structures formed as melt-rich cumulates flowed downward and outward during growth of the lopolith. These events appear to have occurred beneath crust undergoing extension based on: (1) independent evidence for extensional tectonics in the overlying, lower-crustal paragneiss and schist; and (2) the occurrence of similar synmagmatic structures and upwardly steepening layering and foliation in gabbros of the Oman ophiolite, which clearly formed in an extensional, albeit oceanic, environment. Rifting in the IVZ may have occurred during the incipient opening of the Neotethys, or at an earlier time in a region of continental extension analogous to the Basin and Range Province of the southwestern United States.

T52E-3 1400h

First Results on the Broadest Ophiolitic Klippe in a Collision Belt: the Jungbwa Thrust Sheet, North Tibet.

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The Jungbwa thrust sheet in the Tsangpo suture zone (North Himalaya suture zone) is the broadest (3500 km) ophiolitic klippe known in a collisional belt. For geographical and political reasons, the only geological observations in this region date from 1939 (Heim and Gansser) and the area has not been studied since this time. Study of such a broad ophiolite belt will bring significant improvement to our understanding of obduction processes related to continental collision.

We have begun to investigate the geological setting within which this ophiolite belt is located, including structure and stratigraphy, using remote sensing. Combining multispectral and panchromatic observations of four SPOT 1 images, we applied principal component analysis and gradient filtering to enhance the geological and tectonic patterns. The result is an accurate image at 1/200,000 scale of the entire region. From this image and with the help of photos taken on the ground we were able to construct the first geological map of this region.

The main geological formations identified in the Tsangpo Suture zone are widely recognized. The main events resulting from continental collision in this part of Tibet can thus be precisely determined:
- reactivation of sutures in Oligocene time,
- recent extensional tectonics in the autochtoneous,
- quaternary faulting normal and paralell to the mountain belt.

T52E-4 1415h

$^{40}Ar/^{39}Ar$ Thermochronology of Linzizhong Volcanics and Timing of Deformation in Takena Formation, Southern Tibet

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As part of the subduction-generated Gangdese magmatic belt, andesites and rhyolitic ignimbrites of the Linzizong Formation are exposed around Maqu, about 30 kilometers NW of Lhasa. Previous $^{40}Ar/^{39}Ar$ dates on presumed equivalent volcanics from a place 50 Km northeast of Maqu were interpreted to give its eruption age of 50-60 Ma. New $^{40}Ar/^{39}Ar$ data from three K-feldspars from ignimbrites near Maqu all show step up patterns of age spectra ranging from about 35 to 53 Ma. The K-feldspar separates consist of single population of grains. Several diffusion domains exist for these K-feldspars. Multidomain calculations on one of the K-feldspar age spectra indicates a slow cooling history from 340 ^{o}C to 240 ^{o}C during the interval 55-45 Ma. This indicates that the Linzizong volcanics near Maqu have experienced slow cooling at a rate of ~10 $^{o}C/Ma$ some time after eruption, suggesting that they have been deeply buried and heated up to, but not above, 350 ^{o}C, because a schist pebble from conglomerate yields a muscovite plateau age of ~240 Ma. This is consistent with evidence both to north and south, where granites that are in either intrusive or fault contact with the Maqu volcanic sequence have also been discovered to have slow cooling histories in the same general time frame, from 50-36 Ma in the south, and 50-20 Ma in the north. Assuming a geothermal gradient of 30 $^{o}C/km$ we convert the slow cooling rate to a surface approach rate of 0.3 mm/yr during the period of 55-45 Ma. This may also reflect surface uplift in a zone of active mountain building like Tibet. The above data suggest that one should be cautious in interpreting $^{40}Ar/^{39}Ar$ data from these volcanics since the true eruption age could be underestimated. Clearly it is not a good choice to put 50 Ma as the youngest limit for the strong folding deformation present in the Takena formation, which is unconformably underlying the Maqu volcanics, as the volcanics have experienced argon loss. A biotite sample from a post-folding diorite stock gives a flat age spectrum with total gas age of ~62 Ma, suggesting the deformation occurred at least 62 Ma ago. This requires that the crustal shortening represented by the deformation in the Takena Formation occurred prior to the start of the India-Asia collision in this part of the Himalaya-Tibetan Plateau system, which is suggested from other evidence to have occurred no more than 50 Ma ago.

T52E-5 1430h

The Effects of Surface Erosion on the Temperature Structure of Orogenic Belts

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Metamorphic rocks now exposed at the surface in many eroded mountain belts show evidence that the maximum metamorphic temperatures experienced by these rocks at depth increased structurally upwards with increasing distance from the main thrust fault. Evidence for true inverted geotherms within upper plate rocks is less abundant, but recent PT data from the Himalaya give strong evidence that inverted geotherms existed within a 5 to 10 km thick zone immediately above the MCT. Perhaps a more compelling argument for the existence of inverted geothermal gradients is the presence of young leucogranites in the upper part of the upper plate, indicating that melting occurred at shallow structural levels far above the MCT but not at deeper structural levels near the MCT. Such data are difficult to reconcile with published two-dimensional thermal models, which fail to produce inverted thermal gradients and, for reasonable values of radiogenic heat production, also fail to explain the very high metamorphic temperatures preserved in many orogenic belts. I suggest that such models fail because they neglect the effects of surface erosion, which has a dramatic effect on thermal structure of the underlying lithosphere. A simple two-dimensional analytical model that includes the effects of surface erosion (and can also accommodate accretion of lower plate rocks onto the upper plate across the thrust zone), predicts that inverted geotherms are the natural consequence of sufficiently rapid rates of surface erosion. Even in the absence of radiogenic heat production, erosion rates of 1 mm/yr or greater are sufficient to produce elevated temperatures and inverted geotherms for reasonable thrust sheet geometries and rates of underthrusting. Because denudation of the MCT zone in eastern Nepal has occurred at an average rate of at least 1 mm/yr over the past 20 Ma, the results of this analytic model are consistent with the existence of inverted geotherms in this region.

T52E-6 1445h

Foreland Thrusts: a Cause Revisited

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In a previous paper, Panian and Pilant (J. Geophys. Res., 95, pp. 8607-8615, 1991) used an approximate algorithm to explain why thrusting should appear on the foreland side of a topographic high. This explanation involved the coincidence of a stress concentration, a region of horizontal incipient fracture direction, and a weak flat-lying decollement. This coincidence occured in that part of the model lying to the foreland side.

In this paper, finite element analysis (FEA) has been used to determine more accurate stress patterns and incipient fracture directions. Significant changes have been observed. Although a small stress concentration is still present, it is confined very near to the surface and would not penetrate to a likely depth for a decollement layer. On the other hand, the region of horizontal incipient fracture is much broader and thus provides a larger surface where the potential thrust is subjected to shear. As in the previous paper, the region of horizontal incipient fracture lies to the foreland. It descends with increasing regional stress until coincidence with a weak decollement layer. If, at this coincidence, the maximum resolved shear stress exceeds the strength of the decollement material; disruption along the decollement will occur .

T52E-7 1520h

ON MOVING MOUNTAINS

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The land surface has provided an excellent time-scale and economic benefits, but knowledge of the Earth's internal behaviour has been needed to explain tectonics. New information from ocean floors and the interior show that fluid flow in the mantle breaks the thin and brittle lithosphere into plates by three classes of faults defined by laws of physics. Plate motions produce three corresponding types of mountains. Collisions between plates of different compositions (i.e. seafloor, continents, etc.) at different angles of incidence and by different modes of subduction produce many sub-classes. A second major type forms along coastal transform faults. Mantle plumes uplift the third type and anchor them relative to the mantle so that they migrate across plates and leave tracks. Over two dozen are active in oceans and a dozen of which the tracks are obscure on six continents and New Zealand. Neglected methods help to identify tracks. Plumes also feed and lubricate ranges, like the Wasatch Uplift, which migrate. Coordination of data from land, oceans and the interior enables physics to be applied to revise tectonics. That provides an astonishingly different view of Earth's behaviour which is of far more value in solving problems.

T52E-8 1535h

Modeling the Mechanics of Backstops

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We have used numerical and laboratory modeling to analyze the mechanical role of backstops in the overriding plate at subduction zones. For the purposes of this modeling, a backstop is defined as a region within a forearc that has greater shear strength than the sediments lying farther trenchward. We calculate the stress and displacement fields within forearcs for various backstop models using the finite-element method and we simulate deformation over a backstop using a small-scale laboratory model.

The geology of modern forearcs differ widely, but they share some essentially ubiquitous features. In a transect across an arc, one typically passes from a broad seaward-vergent accretionary wedge to a structurally elevated outer-arc high, to an 'inner deformation belt' (a narrow zone usually with arcward vergent thrusting), and finally (abutting the arc) to a forearc basin area in which sediments are much less deformed that those in the rest of the forearc.

We find that the growth of an outer-arc high and an undeformed forearc basin can be explained by assuming the existence of a geometrically simple backstop with geologically reasonable contrasts in mechanical properties compared to the sediments just trenchward of it. These models also produce accretionary wedges and inner deformation belts with appropriate widths and in which the preferred vergences are as observed. The inner deformation belt may be an example of a hitherto unobserved class of critical wedge predicted by critical wedge theories, deforming under a maximum (as opposed to minimum) possible taper.

The structures produced in our numerical models are quite insensitive to the rheology, boundary conditions, or exact mesh geometry employed. Although natural forearcs are far more complex than our simple models, they exhibit many of the same features, indication that relatively simple backstop mechanics may be a very important factor in the overall growth of forearcs.

T52E-9 1550h

Tectonics of the Northern Termination of the Tonga Subduction Zone From Seismicity and Focal Mechanisms

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At the northern termination of the Tonga subduction zone, plate convergence gives way to complex strike-slip motion associated with the Fiji Fracture Zone and back-arc extension in the northern Lau Basin. The tectonics of this region is investigated using centroid moment tensor (CMT) solutions, first-motion focal mechanism solutions, and seismicity. The complex deformation in the region is also associated with the densest concentration of large earthquakes along the Tonga subduction zone, including six events of Ms>7.0 this century. The dense clustering of events in the "Samoan corner" rapidly decreases to the south along the Tonga Trench and to the west along the Fiji Fracture Zone.

Our focal mechanism data base consists of 196 shallow earthquakes from the Harvard CMT catalog (1978-1988), previously published first-motion focal mechanism solutions (including those published by the USGS) and 12 previously unpublished first-motion focal mechanism solutions. We also use the ISC seismicity data base for 1963-1984. In contrast with the relatively simple underthrusting along most of the Tonga arc, we can identify five distinct types of earthquake focal mechanisms. We can identify focal mechanisms associated with (1) bending of the Pacific Plate prior to subduction east of the Tonga Trench, (2) underthrusting of the Pacific Plate beneath the Indo-Australian Plate west of the Tonga Trench, (3) hinge faulting associated with the tearing of the Pacific Plate in the proximity of the northern termination of the Tonga Trench, (4) strike-slip faulting in the complex Fiji Fracture Zone, and (5) high-angle reverse faults near the "Samoa corner". The seismicity patterns suggest that the underthrust Pacific Plate is being torn into several sheets approximately parallel to the direction of Pacific Plate motion and normal to the Tonga Trench axis as the Pacific Plate is being subducted in the northernmost region of the Tonga subduction zone. We are also investigating more precise focal depth determinations using waveform modelling of body waves to help distinguish the spatial distribution of the various types of focal mechanisms.

T52E-10 1605h

Metastable Olivine and Its Gravitational Effects on a Subducting Lithosphere

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Based on their studies of phase changes in ice, Kirby et al. (Science, in press) revive an earlier idea of Sung and Burns (Tectonophysics, 31, 1-32, 1976), that metastable olivine can exist within a subducting slab at a depth exceeding the 400 *km* seismic discontinuity, and suggest its existence as a possible mechanism for the generation of deep focused earthquakes. Iidaka and Suetsugu (EOS, 71, No. 43, 1574, 1990) examined travel time data from local stations of many deep events within the Japanses Slab, and found that metastable olivine does appear to penetrate beyond the 400 *km* depth. The existence of metastable olivine within a slab can have profound implications to the geodynamics of

The sharp composition boundary of the amphibole fragments formed as a result of dissolution of the highly deformed margins of the fragments and reprecipitation of new Al-rich amphibole.

With increasing strain there is a decrease in amphibole grain size and an increase in the proportion of lath shaped grains. Crystallographic orientation relationships indicate that amphibole laths have rotated in to parallelism with the shear zone boundary. These observations suggest that strain was concentrated within the shear zone due to the development of small, lath-shaped grains with rotation accomplished by grain boundary sliding.

T52D-8 1530h

A Dislocation Model of Seismic Wave Attenuation and Micro-Creep

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Earth shows non-elastic behavior at various time scales ranging from seismic wave attenuation and creep at the geological time scales. One of the key issues in microscopic models of these processes is to clarify the relation among the deformation with different time scales. Recent analysis of seismological and laboratory data indicates that dislocations in minerals play important roles in seismic wave attenuation as well as in long-term deformation. However, one of the difficulties encountered by dislocation models is that the inferred mobility of dislocations in seismic wave attenuation is much higher (factor of up to 10^{10}) than that at long-term deformation. Models so far proposed assumed that dislocation glide is much easier than climb and the former is responsible for seismic wave attenuation and the latter for long-term deformation. However, such a notion is not consistent with the microdynamics of dislocations in silicates where the Peierls stress is large and therefore dislocation glide itself is already difficult.

Here I propose a model consistent with this notion (high Peierls stress). In this model, seismic wave attenuation is assumed to be due to the migration of *geometrical kinks* along the Peierls potential (micro-glide) whereas long-term deformation involves the nucleation of kinks over the Peierls potential (macro-glide). Since the migration of kinks is much easier than their nucleation, much faster mobility of dislocations would result. However, this motion will stop when all the available kinks are exhausted. Thus there will be a cut-off time scale determined by the dislocation density and geometry beyond which high dislocation mobility will not be observed. This model provides a physical basis for the absorption band model which is consistent with dislocation microdynamics in silicates. Constraints on microscopic parameters such as kink mobility and geometry will be discussed based on the comparison of the model with seismological and laboratory data.

T52D-9 1545h

The Documentation of the Natural Superplastic Flow of Quartz in a Quartzofeldspathic Rock in the Blue Ridge of Georgia

Satya P. Gargi (Department of Physics, Prairie View A & M University, Prairie View, Texas 77446)

The Corbin Gneiss Complex (CGC) which forms the Grenville basement, was affected by intense crustal scale ductile deformation during the Acadian orogeny. As a result of this deformation quartz-monzodiorite (Corbin gneiss) of the CGC was sheared with varying degrees of mylonitization ranging from the least deformed Corbin gneiss (CG) through protomylonite and mylonite to ultramylonite (UM).

The least deformed CG is highly coarse-grained, and nonfoliated. Even in this rock, quartz phenoclasts show some deformation features such as the formation of serrated grain boundaries, and thin zones of newly crystallized quartz grains of extremely fine size between the phenoclasts. The protomylonite stage is marked by the feeble foliation due to slight stretching of quartz and feldspar grains, and the subparallel alignment of stilpnomelane neoblasts. The latter have formed as a result of stress induced reaction between plagioclase and garnet/ilmenite. A few quartz phenoclasts show recrystallization along the deformation bands also. The newly crystallized grains are equant (20μ), polygonal, and show high angle boundaries with a mismatch of 20°-25° with the host grain.

In the mylonite stage, foliation is highly pronounced, and quartz phenoclasts are stretched to elongate ribbons and trails. The increased crystallization of quartz phenoclasts has led to distinct core and mantle structure. The size of the new grains increases to about 45 u. In the UM stage, foliation is defined by extremely elongate wisps of quartz and orthoclase. The matrix in the UM as a result of high degree of grain refinement is reduced to a fine felty mass of chlorite, white mica, and some quartz. The subgrains of quartz (with a mismatch of less than 8°) become optically visible only in the UM stage, and are almost of the same size as the nearby new grains. The new quartz grains are elongated, and have irregular lobate margins which suggests their syntectonic growth by dynamic crystallization.

The c-axes of quartz phenoclasts in the mylonite form a well defined type-I crossed girdle pattern with very strong maxima close to the Z-axis. The fabric formed by the new quartz grains in the mylonite, is similar but slightly diffused. The similarity of the two fabrics indicates that the new grains have formed by strain induced boundary migration and progressive misorientation of subgrains under dislocation creep regime. The c-axes fabric of the recrystallized quartz grains in the UM in contrast, is highly diffused as the maxima are of very low intensity, and the pole free areas are highly reduced. The fabric gives the appearance of a very wide oblique girdle similar to the type-II girdle pattern. It consists of many maxima of equal intensity close to the Y- and midway between Y- and Z- axes. This suggests a change in the slip system from dominantly basal slip to a combination of basal and prismatic slip which under the given low temperature conditions can take place only at low strain rates, and high strains. Such conditions promote grain boundary sliding, and result in random fabric, and superplastic flow. The UM of the CGC meet all the criteria for the superplastic flow as established from the study of experimentally produced superplastic flow of calcite. These are, the weak quartz c-axes fabric, extremely high finite strain, high initiating stress as indicated by the very small size of the new grains in the unfoliated CG, optically visible subgrains, and their large size relative to the new grains in the matrix, and the presence of a dispersed second phase. These features suggest that the dominant mechanism of deformation in the UM was by grain boundary sliding and rotation which was accommodated by dynamic recovery and recrystallization under conditions of superplastic flow.

T52D-10 1600h

Superplasticity in $CaTiO_3$ Perovskite

P Li and S Karato (Department of Geology and Geophysics, University of Minnesota, Minneapolis, MN 55455)

Diffusion (or superplastic) creep and dislocation creep in rocks result in quite different rheological behavior, including the steady state creep law, transient behavior and the development of lattice preferred orientation. To estimate the transition conditions between the two regimes in the lower mantle of the Earth, we have studied the high temperature creep in $CaTiO_3$, an analogue material of $(Mg,Fe)SiO_3$ perovskite.

$CaTiO_3$ has orthorhombic structure up to ~ 1250°C where it transforms into tetragonal structure. High temperature creep was studied mainly under the conditions where orthorhombic structure is stable. The specimens used are fine-grained (5-30 micron grain size) hot-pressed aggregates. Stable deformation was achieved up to 5-30% strain (the magnitude of maximum strain depending on grain-size) where localization of porosity often resulted in shear fracture. Rheological data were collected where stable deformation was observed. Under all the tested conditions, the specimens showed approximately linear rheology with strong grain-size sensitivity. The results are interpreted in terms of diffusion creep models. The observed dependence of creep rate on oxygen partial pressure is consistent with the control by diffusion of cations (Ca^{2+} or Ti^{4+}).

The results are compared with the data on dislocation creep in single crystals to construct a deformation mechanism map. It is found that diffusion creep domain in perovskite is significantly more pronounced than that in olivine, suggesting the importance of linear rheology in the lower mantle.

Experimental studies are underway to investigate the role of structural phase transformation at around T~1250°C.

T52D-11 1615h

Experimental Deformation of Muscovite

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The strength of muscovite has been investigated by shortening single crystals at 45° to their basal plane and the [110] and [310] directions at temperatures T of 20, 200, and 400°C and confining pressures P_c from 50 to 400 MPa at a constant strain rate of $\varepsilon = 10^{-5}$/s. At all conditions yielding occurs by slip and dislocation glide along the basal plane giving rise to gentle undulatory extinction and low-angle kink band boundaries. Samples oriented favourably for slip in the [110] direction yield at lower stress (σ_1-σ_3 = 18 MPa at 400°C) than those oriented for [310] shear (σ_1-σ_3 = 34 MPa). Yield strengths exhibit a weak dependence on temperature and can be described by $\sigma_1-\sigma_3 = (Q/\alpha RT)+(B/\alpha)$, where $Q/\alpha = 65 \pm 24$ kJ/mol and B depends on strain rate. Little or no pressure dependence has been detected over the range of 100 to 400 MPa.

Despite previous inferences that muscovite shear strengths exceed those of biotite (Wilson and Bell, 1979), our results compared with data for biotite (Kronenberg et al, 1990) show that muscovite is weaker at experimental conditions. However, the temperature dependence of strength exhibited by muscovite appears to be smaller than that measured for biotite ($Q/\alpha = 200 \pm 35$ kJ/mol) and predictions of strength at natural strain rates will require constraints on α. Differences between the parameters describing glide in muscovite and biotite are likely to result from oxygen layer distortions of muscovite relative to the basal oxygen sites of biotite and associated changes in potassium-oxygen bonding. Ongoing investigation of slip in the [100] and [010] directions should help clarify the differences between slip in dioctahedral and trioctahedral micas.

T52D-12 1630h

High Temperature Creep of Garnet

Z Wang, S Karato (Department of Geology and Geophysics, University of Minnesota, Minneapolis, MN55455) and K Fujino (Ehime University, Matsuyama, Japan)

Garnets are among the most important constituent minerals in the transition zone of the Earth. In particular, the subducting oceanic crust is composed mostly of garnets at the depth range of ~400-650km. Thus the dynamics of these layers depends critically on the rheological properties of garnets. Karato's (1989) preliminary survey of existing data suggests that garnets in general have significantly higher creep strength than other silicates or oxides. However, the rheological data on garnets are still very sparse and no reliable data on stress and temperature dependence on rheology has been published.

To collect more data on plastic flow in materials with garnet structure, we have started the experimental study on some analogue materials. Here we report the results on high temperature creep in the single crystals of $Ga_3Gd_5O_{12}$ garnet (GGG). High temperature creep experiments were made at T=1450-1560°C (T/Tm=0.86-0.92) at strain rate = 10^{-5}-10^{-6} s^{-1} for compression along <001> where the slip systems {110}<111> and {112}<111> are activated. GGG turned out to be so strong under these conditions that fracture rather than creep often occurred. However under limited conditions, we achieved steady state deformation. These data showed significantly higher creep strength ($\sigma/\mu = 2\text{-}4 \times 10^{-3}$) than olivine and perovskite ($\sigma/\mu = 2\text{-}4 \times 10^{-4}$) compared at the same homologous temperature, suggesting that a garnet rich layer would have a significantly higher creep strength than others. More detailed deformation experiments and TEM observations of dislocations are underway.

T52D-13 1645h

High-Temperature Creep Experiments on the Olivine and Spinel Polymorphs of Mg_2GeO_4: Implications for the Rheology of the Earth's Upper Mantle

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Laboratory studies of the ductile flow strength of mantle minerals and their analogues provide important constraints for numerical models of mantle convection. Constant strain-rate experiments at 1200-1600 K and 1.0-3.0 GPa are being conducted on the olivine and spinel polymorphs of Mg_2GeO_4 to infer the viscosity of the Earth's upper mantle. In particular, we aim to determine if the mantle transition zone (400-670 km), where silicate spinel is stable, is stronger than the mantle above 400 km where olivine is stable. Recently, Meade and Jeanloz (1990) speculated that the mantle transition zone is significantly stronger than the mantle above 400 km, based on their analysis of pressure gradients in room temperature diamond anvil cell experiments on silicate olivine and spinel. A strong contrast in the mechanical behavior of the mantle transition zone would likely affect the nature of mantle convection and the way mantle plumes interact with the mantle transition zone.

Our preliminary data indicate that polycrystalline (15-20 μm) Mg_2GeO_4 spinel samples at 2 GPa confining pressure are about a factor of two stronger than polycrystalline olivine samples at 1 GPa at the same temperature and strain rate. The strength of germanate olivine polycrystals is comparable to that of silicate olivine polycrystals at the same temperature and strain rate. This latter result implies that high-temperature creep experiments on the germanate analogue system may be useful for determining the viscosity of the upper mantle. We suggest therefore that the mantle transition zone is only slightly stronger than the mantle above 400 km.

T52E CC: 107 Fri 1330h

Convergent Margin Tectonics

***Presiding:* L Royden, MIT; W H Wang, SUNY Stony Brook**

T52E-1 1330h

Magmatic Evidence for Roll-Back and Failure of the Subducting Slab During Arc-Continent Collision in Wopmay Orogen, Northwest Canada

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Samuel A. Bowring, Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139

Wopmay orogen is an early Proterozoic orogenic belt formed by the accretion of Hottah terrane, an arc-bearing microcontinent, to the western margin of the Archean Slave craton at about 1.89 Ga. Three periods of magmatism, one just prior to, and two during the collision provide evidence for sequential roll-back and gravitational failure of the subducting slab. The oldest are sedimentary rocks and a bimodal basalt-rhyolite suite (Grant Group) erupted on the leading edge of Hottah terrane just prior to the collision. Rocks of the suite are compositionally heterogeneous and were affected by an early high-T/low-P metamorphism. The second suite, termed Morel sills, constitutes a 200 km long northerly-trending, orogen-parallel swarm of mafic sills, mainly located at the passive margin shelf-slope break, but extending locally over 100 km into the foreland. The sills are syncollisional as demonstrated by the fact that they cut orogenic flysch yet were folded, thrust eastward, and metamorphosed. The Hepburn batholith, which is also syncollisional, comprises plutons ranging temporally and compositionally from peraluminous granite to metaluminous norite and ultramafic rocks. They intrude the suture zone and were transported onto the Slave craton while still hot, as evidenced by Pb and Nd isotopic signatures that are distinctly different than those of the Slave craton; the marked lack of any recognized plutons cutting Slave crust; and the presence of hot-side-up isograds beneath the batholith which cut obliquely across the sole thrust.

Early bimodal magmatism, sedimentation, and consequent high-T/low-P metamorphism that occurred on the leading edge of the upper plate (Hottah) are attributed to extension and asthenospheric upwelling during roll-back of the lower plate just prior to collision. The northerly-trending belt of Morel sills, intruded during the collision, suggests syncollisional extension in the lower plate. We relate the extension and magmatism to gravitational failure and detachment of the oceanic lithosphere with consequent adiabatic melting of upwelling asthenosphere. The upwelling culminated in regional heating of the crust, melting, and generation of the syncollisional Hepburn batholith prior to thrusting onto the Slave craton.

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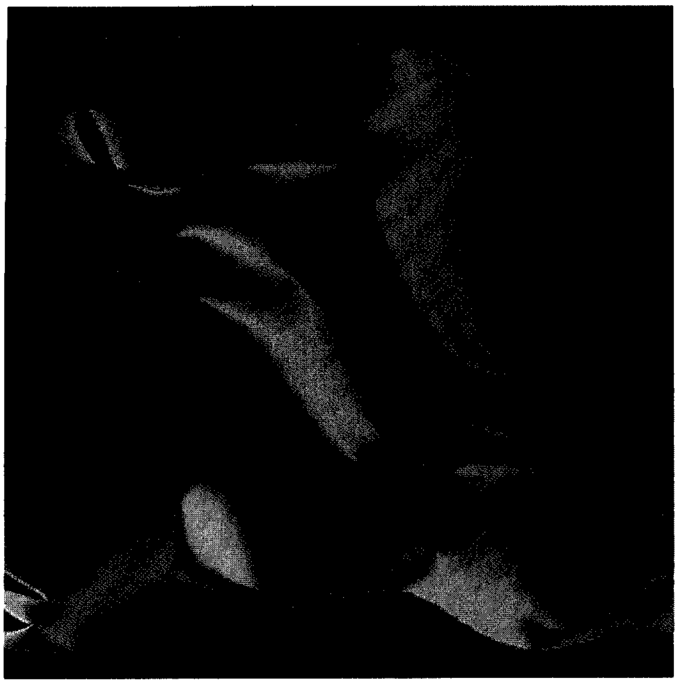
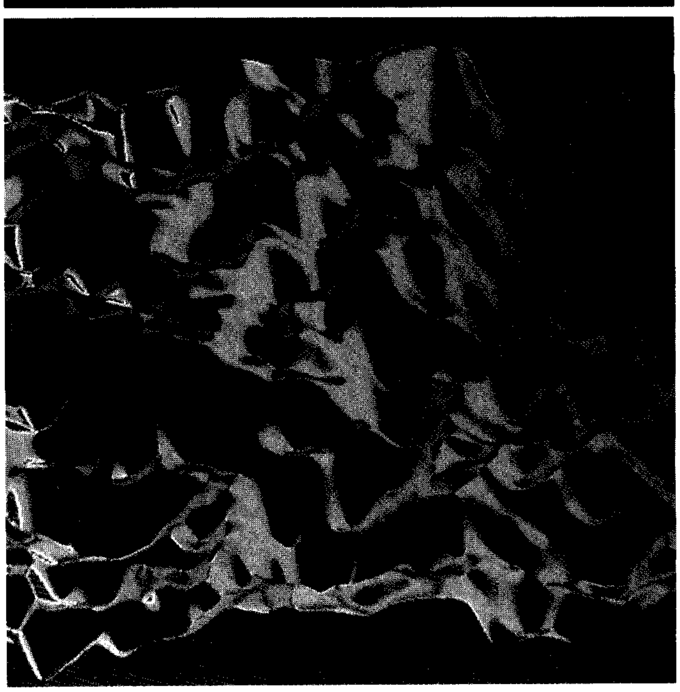
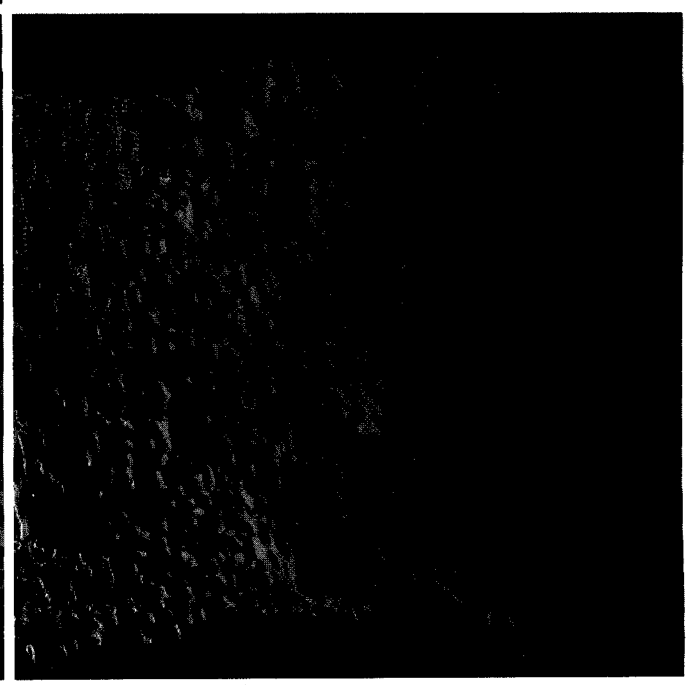
SPRING MEETING 1991

Program and Abstracts







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