[1]University of Wisconsin-Madison, Department of Materials Science and Engineering 1509 University Ave, Madison, WI 53706

[2]Brown University, Department of Geological Sciences, Providence, RI 02912

There are a wide variety of materials that exhibit behavior consistent with Hart's mechanical equation of state. For such materials, constant structure "hardness curves" can be generated using load relaxation experiments, which sweep out a spectrum of stress vs. strain rate at nearly constant strain. Hardness curves generated at different levels of work hardening scale with each other: that is, they can be translated in log-log space along lines of fixed slope so that they fit on top of each other. Despite the ubiquity of scaling among many varied materials, there has never been an experimental effort to establish a microscopic basis for it until now. And until now, there has never been a careful effort to establish the relationship between data generated from load relaxation and those obtained from creep tests. One benefit of such efforts would be to provide experimenters a tool for extending experimental techniques to lower strain rates - short duration load relaxation experiments can routinely achieve 10^{-8} s^{-1} and, with effort, 10^{-10} s^{-1}. Such efforts might also lead to a better understanding of power law creep itself, for which there is no universally accepted microscopic model. In this work we investigate mechanical equation of state in single crystal rock-salt at 673K and 973K deformed under compression in the [100] orientation. We find that different hardness states correspond to different average subgrain sizes and that subgrain size distributions obtained at different levels of stress are similar to each other, i.e., they have the same shape. We compare the experimental data with a model based on the partitioning of the crystal between dislocation glide in large subgrains and subgrain boundary migration in small ones; the distinction between "large" and "small" is based on strain rate. In the model, subgrain boundary migration is governed by the same kind of law that governs Nabarro-Herring creep (with subgrains substituting for grains), except that the numerical coefficient is much smaller in the case of subgrains owing to constraints between the migration of neighboring subgrain boundaries. Subgrain boundary migration is also responsible for dynamic recovery. The model is able to mimic all aspects of the data including load relaxation, transient creep, and steady state power law creep. Moreover, the model is able to account for a transition from power law creep at high temperature (973K) and low stress into power law breakdown at low temperature and high stress (673K) without resorting to additional mechanisms.

T41F-07 1200h

Grain Size Reduction and Deformation Mechanisms in Ultra-Fine-Grained Shear Zones From the Lherz Peridotite

Gill M. Pennock[1] (gpennock@geo.uu.nl)

Martyn R. Drury[1] (martynd@geo.uu.nl)

Hans G. Ave Lallemant[2] (ave@rice.edu)

[1]Department of Earth Sciences, Utrecht University, PO Box 80.021, Utrecht 3508TA, Netherlands

[2]Department of Geology and Geophysics,Rice University, PO Box 1892, Houston 77251-1892

We have used SEM and Electron backscattered diffraction to investigate the petrology, microstructure and lattice preferred orientation (LPO) of narrow (5-10 mm wide), high strain, ultramylonitic shear zones exposed in the Lherz peridotite body, N. Pyrenees, France. The wall rock is a protomylonite with a normal olivine LPO ([100] parallel to the stretching lineation). Fractures occur in the wall rock and terminate at the shear zone margin. There is a systematic step-like grain-size decrease (2 mm, 0.1 mm, 0.02 mm, 0.01 mm, 0.005 mm) at the margin of the shear zone. In the shear zone grains are elongated with a good alignment of grain boundaries. The mineral assemblage consists of olivine, pyroxene, spinel and amphibole clasts in a matrix of olivine, pyroxene, spinel, magnesite ($MgCO_3$). An olivine LPO occurs in the matrix similar to the type-B LPO reported by Jung and Karato(Science, 293,1460, 2001). The narrow ultramylonite zones may initially have formed as fractures that were subsequently infiltrated by CO_2 derived from adjacent limestones. If this hypothesis is correct then the initial grain-size reduction probably involved some cataclasis with shear zones forming during crustal emplacement of the peridotite. Microstructures and mineral assemblages indicate that recrystallization and the reaction (ol + CO_2 = opx + magnesite) have also contributed to grain size reduction. The decrease of matrix grain size into the shear zone may reflect increasing cataclastic strain, decreasing temperature during reaction or increasing stress during dynamic recrystallisation. The ultra-fine grain size and aligned grain boundaries suggest an important role for sliding along interfaces. Granular flow is the most likely deformation mechanism in such fine-grained rocks, unless deformation occurred at very high stress and strain rate. The presence of LPO in these ultra-fine grained shear zones is unexpected. The type-B LPO may be (a) a relict from early dislocation creep (b) produced by high stress-high strain rate dislocation creep or (c) could be characteristic of granular flow in aggregates with an elongated grain shapes.

T42A MCC: Level 1 Thursday 1330h

The Structure and Physical Properties of Grain Boundaries in Rocks III Posters *(joint with V)*

Presiding: **A Schubnel,** Lassonde Institute**; S Majumder,** University of Minnesota

T42A-0265 1330h POSTER

Mechanical compaction of Bleurswiller sandstone : elastic wave velocities and permeability evolution

Jerome Fortin[1] (fortin@geologie.ens.fr)

Alexandre Schubnel[1,2] (schubnel@geologie.ens.fr)

Yves Gueguen[1] (gueguen@geologie.ens.fr)

[1]Laboratoire de Geologie, ENS Paris, 24 rue Lhomond, Paris 75005, France

[2]Lassonde Institute, 170 College Street, Toronto, ON M5S 3E3, Canada

Field observations and laboratory experiments have recently documented in porous sandstones the development of compaction bands sub-perpendicular to the direction of maximum principal stress. These compaction bands have been preferentially observed in relatively homogeneous sandstones of high porosity, such as Bentheim sandstone studied by Wong et al. [2001] and Baud et al. [2003], but also in a heterogenous sandstone of high porosity, such as Diemelstadt sandstone Fortin et al. [2003]. Rock deformation, fluid transport, and acoustic velocity are coupled together. On one hand, Scott et al. [1993] showed that acoustic velocities across the brittle-ductile transition are clearly being affected. On the other hand the relation between permeability evolution and compaction of sandstone was demonstrated by Zhu et al [1999]. To understand better the complexity of damage resulting from compaction band formation and its effect on permeability, we performed series of experiments on Bleurswiller sandstone of porosity 25%. This vosgian sandstone is made of 50% quartz, 30% feldspars, and 20% of oxides and micas. Hydrostatic and conventional triaxial compression experiments were conducted at room temperature on saturated samples under drained conditions, with a constant pore pressure of 10 MPa. The samples were deformed in the range of confining pressure from 60 to 300 MPa Compressional wave velocities, shear waves velocity, and permeability have been measured during both hydrostatic and triaxial experiments.

T42A-0266 1330h POSTER

Reduction of ionic diffusivity in nanopore water of geomaterials

Tetsuro Hirono[1] (+81-46-867-9328; hirono@jamstec.go.jp)

Satoru Nakashima[2] (+81-3-5734-3544; satoru@geo.titech.ac.jp)

Chris J. Spiers[3] (+31-30-2534972; cspiers@geo.uu.nl)

[1]Japan Marine Science and Technology Center, Natsushima 2-15, Yokosuka 237-0061, Japan

[2]Tokyo Institute of Technology, Ookayama 2-12-1, Tokyo 152-8551, Japan

[3]Utrecht University, Budapestlaan 4, PO Box 80.02, Utrecht 3508 TA, Netherlands

Recent molecular dynamics simulations and spectroscopic approaches indicated that water molecules confined in nanometre scale has a constrained structure with shorter hydrogen bond distances. In order to verify a hypothesis that ionic diffusivity in rocks should be affected by the constrained molecule structure of water in nanopore, we measured the effective diffusion coefficients of iodine ion in undeformed rocks by through-diffusion experiments. We also studied the quantitative relationship between the diffusion coefficients and the pore structures. Most of effective diffusion coefficients (De) for rocks can be explained by the power law with effective porosity (p), while De values for the sample involving abundant nanopores were much lower than this relation. These could be resulted from that De depends not only on porosity and tortuosity (t) but also on ionic diffusion coefficient in nanopore water (Dn). By simultaneous equation of Dn and t with known De and porosity in two nanopore-type rocks, Dn and t can be deduced independently, leading the equation (De = 9.0 x 10^{-10} x p^3). This means that Dn is 9.0 x 10[− 10] m4^{24}/s. This Dn values is about two-times lower than the diffusivity in free pure water. This result can be applied for hydraulics, structural geology and new discipline of nano technology.

T42A-0267 1330h POSTER

An Experimental Study of Pressure Solution of Halite Under the Confocal Microscope

Zvi Karcz[1,3] (845 365 8463; zvi@LDEO.columbia.edu); Einat Aharonov[2] (einata@wicc.weizmann.ac.il); Deniz M Ertas[3] (deniz.ertas@exxonmobil.com); Robert J Johnston[3] (robert.j.johnston@exxonmobil.com); Richard S Polizzotti[3] (richard.s.polizzotti@exxonmobil.com); Christopher H Scholz[1] (scholz@LDEO.columbia.edu)

[1]Lamont-Doherty Earth Observatory and Department of Earth and Environmental Sciences, Columbia University , 61 Route 9W, Palisades, NY 10964, United States

[2]Department of Environmental Science and Energy Research, Weizmann Institute of Science , POB 26, Rehovot 76100, Israel

[3]Corporate Strategic Research, ExxonMobil Research and Engineering Company , 1545 Route 22 East , Annandale, NJ 08801, United States

We present an experimental study of pressure solution of halite under a confocal microscope designed to resolve conflicting results in previous experiments. Two pressure solution mechanisms, thin film diffusion and undercutting, were conceptually proposed (Weyl, 1959) and later experimentally shown to operate under similar conditions (Tada & Siever, 1986; Hickman & Evans 1992, 1995; Schutjens & Spiers, 1999). However, a transition between these mechanisms was never observed, and it is not clear what may induce it. Our experimental setup consists of a halite beveled indenter pressed against a flat quartz window. The contact is viewed in-situ through the window with the confocal microscope. We hypothesize that changing the angle of the bevel may change the relative magnitude of the driving forces, consequently inducing a transition in pressure solution mechanisms. The confocal microscope allows a 3D reconstruction of the microstructures at the contact.

T42A-0268 1330h POSTER

Mobility of Water Molecules on Brucite and Talc Surfaces by *Ab Initio* Potential Energy Surface and Molecular Dynamics Simulations

Hiroshi Sakuma[1,3] (81-3-5734-2617; hsaku@geo.titech.ac.jp)

Taku Tsuchiya[2] (takut@cems.umn.edu)

Katsuyuki Kawamura[1] (kats@geo.titech.ac.jp)

Kenshiro Otsuki[3] (otsuki@dges.tohoku.ac.jp)

[1]Department of Earth and Planetary Sciences, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro, Tokyo 1528551, Japan

[2]Department of Chemical Engineering and Materials Science (CEMS), University of Minnesota, 421 Washington Av. SE, Minneapolis, MN 55455, United States

[3]Institute of Geology and Paleontology, Graduate School of Science, Tohoku University, Aoba, Aramaki, Aoba, Sendai 9808578, Japan

The interaction between minerals and water molecules is a fundamentally important property that influences fluid distribution and migration in the earth's crust, and transportation of H_2O into the earth's mantle. In this work, we focused attention on the mobility of water molecules on the cleavage surfaces of brucite and talc, and performed the molecular dynamics simulations. Brucite is in most common as an alteration product of periclase in contact metamorphosed dolomites. It is also found as a low-temperature hydrothermal vein mineral in serpentinites and chlorite schists. Talc occurs most frequently as a product of metamorphism of hydrothermal alteration of ultramafic rocks and is an important phase in the oceanic crust. The first step in performing the simulations of mineral-water interfaces is to develop a reliable and consistent model for the interaction of water molecules with solid surfaces. Fundamental understanding of such interaction often requires physico-chemical knowledge at a molecular level, which is not easily obtained from experimental works, electronic state calculations provide remarkable information of the interactions between surface species and water molecules. The first-principles method based on the density functional theory is the most useful method in the present day. By using the first-principles method, we calculated the energy curves with respect to water configuration on brucite and talc surfaces and the *ab initio* model potentials were obtained by fitting the parameters to the calculated energy curves. Using this *ab initio* model potentials, molecular dynamics simulations of water thin film embedded between brucite and talc surfaces have been performed at various temperature-pressure conditions. The thicknesses of water thin film were employed from 0.5 to 2.0 nm. Since it is expected that physical properties of water would change with the distance from mineral surfaces, we analysed the mobility for each sliced layers having 0.25 nm thickness along with a normal axis for surface plane. The self-diffusion coefficient D_S and reorientation time τ_y^2 of water at each sliced layer were calculated. The τ_y^2 corresponds to τ_{NMR} measured by NMR experiments. The calculated D_S of nearest brucite and talc surfaces are 1.45 and 2.0 times and the τ_y^2 are 0.77 and 0.5 times as large as the bulk values at ambient condition, respectively. These anomalies are limited in monolayer nearest to brucite and talc surfaces and the water in the other layers are almost equal to bulk state. This rapid mobility of water on brucite and talc surfaces results from the weak interaction between water and surfaces. Thus rapid mobility of water might affect on the fluid migration in the earth.

T42A-0269 1330h POSTER

The Influence of Second Phases on Grain Boundaries of Mylonitic Microfabrics: Evidences From Natural Carbonate Mylonites

Andreas Ebert[1] (011-41-31-631-4832; ebert@geo.unibe.ch)

Marco Herwegh[1] (011-41-31-631-8764; herwegh@geo.unibe.ch)

Adrian Pfiffner[1] (pfiffner@geo.unibe.ch)

[1]Institute of Geological Sciences, Baltzerstr. 1-3, Bern 3012, Switzerland

Impure carbonate mylonites were sampled along basal thrusts of two Helvetic nappes in western Switzerland (Morcles and Doldenhorn nappe). The two nappes built up large-scale recumbent folds with intensively deformed and elongated inverted limbs. In both nappes the temperature rises towards the rear of each tectonic unit. Both type, mineralogy (sheet silicates, dolomite, quartz) and content of second phases vary within the samples. In this study we investigated the influence of volume fraction, grain size, shape, mineralogy of second phase minerals, and the temperature on the mylonitic microfabric. In all samples, calcite shows a steady state grain size, but the grain size varies as a function of (a) size and volume fraction of the second phase minerals and (b) temperature. (a) At constant temperature, two major microstructure controlling parameters can be distinguished: second phases in impure and dynamic recrystallization in pure mylonites. In impure calcite mylonites pinning and dragging of calcite grain boundaries by second phase minerals stabilize the calcite grain size (D_{cc}) after: D_{cc}=c* Z^m with Z=d_p/f_p (size d_p and volume fraction f_p of second phase minerals, modified after Zener in Smith, 1948). In this way the calcite grain size is inversely proportional to the second phase content. In contrast, the average calcite grain size is maintained constant by dynamic recrystallization via a balance of grain growth and grain size reducing mechanisms. Different lithologies with different second phase mineralogy from the same locality (constant temperature) show the same D_{cc}-Z trends, indicating that the shape of the second phases (elongated sheet silicates, blocky dolomite, spherical quartz) has no major influence on the calcite grain size. However, the elongation of calcite grains increases with decreasing Z, while in pure samples the elongation is constant. (b) With increasing temperature the steady state grain size D_{cc} of calcite increases, while the aforementioned D_{cc}-Z trends persist. Thus for both types of microstructure c is temperature dependent. In light of crystallographic preferred orientation, first investigations show a shift from random distribution to point maxima with increasing Z and temperature. This study shows that already small amounts of second phases can drastically influence the microstructure of mylonites and the associated deformation mechanisms. The aforementioned relation allows to take the influence of second phases on calcite grain size into account, which is an important requirement for rheological interpretations.

T42A-0270 1330h POSTER

A Close View Into the 3D Geometry of Grain-to-Grain Contacts and Surface Roughness in Sandstones Using Laser Scanning Confocal Microscopy

Beatriz Menendez[1] (+33 1 3425 4935; beatriz.menendez@geol.u-cergy.fr)

Christian David[1] (christian.david@geol.u-cergy.fr)

Laurent Louis[1] (+33 1 3425 4998; laurent.louis@geol.u-cergy.fr)

Angel Martinez Nistal[2] (angel@lupo.quimica.uniovi.es)

[1]UMR CNRS 7072 Univ. Cergy-Pontoise, Av.du Parc - Le Campus - Bat I, Cergy-Pontoise 95031, France

[2]Universidad de Oviedo, Servicio de Proceso de Imagenes, Oviedo 33006, Spain

Due to its sharp resolution (< 1 micron) and its ability in building 3D reconstructions from images scanned at various depths, laser scanning confocal microscopy (LSCM) is a powerful tool to render the three-dimensional geometry of microstructural features like pores, cracks and grains. This technique was used in particular to study the grain-to-grain contacts and grain surface topology at small scale in several sandstones. For that purpose, the rock samples to be studied were impregnated with a fluorescent dyed (Rhodamine B) resin in order to discriminate the void space from the grains. The next stage is then to make thin-sections with a thickness larger than usual (> 100 microns) that can be studied under LSCM. Three different sandstones have been studied: the Rothbach sandstone (Vosges mountains, Eastern France), the Bentheim sandstone (Germany) and the Darley Dale sandstone (UK). On each sample several three dimensional blocks have been investigated with size 228 by 152 microns and depths ranging from 35 to 100 microns. From each block, series of tens of parallel "virtual sections" have been recorded, separated by 1 or 2 microns in depth. We show on several examples the complex structure of grain-to-grain contacts which may be associated to the heterogeneity in cement distribution. In particular for the Rothbach sandstone, we found that the topology of the grain surfaces is dominated by the coating of clay particles which leads to a high surface roughness. Complementary SEM studies revealed that the clays are also present as cementing material between the grains. A thorough petrophysical study has shown that the anisotropy of P wave velocity in the Rothbach sandstone can be explained by an anisotropic distribution of cement: whereas this could not be confirmed from our LSCM and SEM analysis, we observed that the spatial distribution of contact lengths is anisotropic which explains qualitatively the spatial variability of P wave velocity. Finally we show examples of Hertzian cracks that initiated from the contact between grains in Darley Dale sandstone samples that experienced mechanical loading under triaxial conditions.

T42A-0271 1330h POSTER

On Grain Boundary Wetting During Deformation

Saswata Majumder[1] (612-626-0572; maju0003@umn.edu)

Perry H Leo[2] (phleo@aem.umn.edu)

David L Kohlstedt[1] (612-626-1544; dlkohl@umn.edu)

[1]University of Minnesota, Department of Geology and Geophysics, 310 Pillsbury Drive SE, Minneapolis, MN 55455, United States

[2]University of Minnesota, Department of Aerospace Engineering and Mechanics, 110 Union St. SE, Minneapolis, MN 55455, United States

We have developed a theoretical model of initiation of fluid segregation along grain boundaries in a solid fluid aggregate deforming under an applied shear stress. Prior to the application of stress, the fluid resides in triple grain junctions and partially wets all grain boundaries, but during deformation, the fluid may completely wet or dewet grain boundaries under tension or compression, respectively. The driving force for wetting or dewetting is provided by the normal stress at the tip of the fluid front along the grain boundary, solid-solid and solid-fluid interfacial energies and the fluid pressure at the tip of the fluid front. Kinetics of wetting or dewetting of grain boundaries under tension or compression, depends on the mobility parameter β, which is defined by the ratio of the rate of stress relaxation by grain boundary wetting to the rate of stress relaxation by grain boundary diffusion. The results from our numerical experiment indicate that, depending on the value of β, deformation can cause zero to complete wetting of the grain boundary under tensile normal stress. Based on the final wetting length along the grain boundary under tension and β, we divide the stress relaxation mechanism into the diffusive relaxation regime, the wetting regime, and the intermediate regime. In the wetting regime, most of the grain boundary fluid will segregate along the grain boundaries under tension and thus the geometry of the fluid distribution changes from a network of tubules along grain edges to a network of planar fluid films along those grain boundaries that are under tension during deformation.

T42A-0272 1330h POSTER

Connectivity of molten Fe alloy in mantle peridotite based on in situ electrical conductivity measurements

Takashi Yoshino[1]

Michael J Walter[1]

Tomoo Katsura[1]

[1]Institute for Study of the Earth's Interior, 827 Yamada, Misasa, Tottori 682-0193, Japan

The connectivity of molten Fe-S in peridotite has been experimentally investigated by means of in situ electrical conductivity measurements at high temperatures and 1GPa. Starting materials were powdered mixtures of peridotite KLB-1 with various amounts (0, 3, 6, 13, 19, 24 volume percent) of the 1 GPa eutectic composition in the Fe-FeS binary system. At temperatures above the eutectic point in the Fe-FeS system (1253K) and below the solidus of KLB1 (1473K), molten Fe-S in a solid silicate matrix interconnects when the volume fraction is over 5 percent. Conductivity-temperature paths indicate that in the presence of partial silicate melting the connectivity of molten Fe-S in a peridotite matrix is inhibited. Based on observations of retrieved samples, the percolation threshold of Fe-S melts in the presence of low to moderate degrees of silicate melt is estimated at approximately 13 volume percent. These results indicate that if the volume fraction of Fe-alloy in a planetesimal was initially greater than 5 percent, and if early heating by decay of radionuclides raised the temperature of the interior above the Fe-alloy melting point, initial metal segregation was controlled by permeable flow of molten iron alloy melt in a solid silicate matrix. These conditions were likely met by many terrestrial objects in the early nebula. Efficient removal of residual Fe-alloy (5 volume percent) from silicate requires high-degree melting of silicate so that metal can segregate as droplets. Giant impacts during the final stage of accretion of large planetary objects could supply the energy required for high-degrees of melting. Alternatively, if initial metal segregation were delayed until a planetery object grew to large size (approximately 1000 km in diameter), release of gravitational potential energy due to metal segregation could contribute enough heat to form a magma ocean.

T42A-0273 1330h POSTER

Compositional effect on the dihedral angle between olivine and Fe-S liquid up to 20 GPa: Possibility of percolative core formation

Hidenori Terasaki[1] (Hidenori.Terasaki@Uni-Bayreuth.de)

David C. Rubie[1] (Dave.Rubie@Uni-Bayreuth.de)

Daniel J. Frost[1] (Dan.Frost@Uni-Bayreuth.de)

Falko Langenhorst[1] (Falko.Langenhorst@Uni-Bayreuth.de)

[1]Bayerisches Geoinstitut, Universitaet Bayreuth, Universitaetsstrasse 30, Bayreuth 95440, Germany

The separation of liquid metal from a crystalline silicate mantle during planetary core formation could have only operated to completion if the liquid metal fraction formed an interconnected network. Interconnectivity depends on the dihedral angle between liquid metal and crystalline silicates at low melt fractions. Gaetani and Grove (1999) showed that liquid Fe-alloy can wet an olivine matrix at high O and S fugacities at ambient pressure. Therefore, it is important to understand the effects of the compositions of Fe alloy and the silicate phase on the dihedral angle behaviour systematically under high pressure conditions. The result is also applicable to core formation mechanisms on other terrestrial planets. For example, the Martian mantle is believed to be more Fe-rich and the Martian core more sulphur-rich compared to the Earth, which may have resulted in important differences in silicate-liquid metal dihedral angles during core formation. We have investigated the effects of the metallic and silicate phase compositions on the dihedral angle up to 20 GPa and 2200 K by varying the sulphur content of an Fe-S alloy (S = 22 $\sim$ 50 at.%) and the FeO content of a coexisting olivine assemblage (FeO = 0 $\sim$ 67 mol.%). Using a multianvil apparatus, experiments at high pressure and temperature were performed for 12 hours, which corresponds to the time scale for textural equilibration. Graphite was used as the capsule material. In the olivine stability field, texturally equilibrated dihedral angles decrease with increasing sulphur content and decrease dramatically with increasing

T

FeO content of olivine. Increasing the FeO content of olivine results in an increase in both the oxygen fugacity and oxygen solubility in the sulphide melt. Dihedral angles also decrease slightly with increasing temperature. The minimum value determined for the dihedral angle between iron-sulphide and olivine was 65°, which is still slightly higher than the critical angle for wetting of 60°. These results show that melting of the silicate is required to obtain complete metal-silicate separation and therefore support a magma ocean scenario during core formation.

T42A-0274 1330h POSTER

The role of interfaces in plastic flow of two-phase rocks

Xiaohui Xiao[1] (xhxiao@mit.edu)

Georg Dresen[2] (dre@gfz-potsdam.de)

Brian Evans[1] (brievans@MIT.EDU)

[1]EAPS, Massachusetts Institute of Technology, 77 Massachusetts Ave, Cambridge, MA 02139, United States

[2]GeoForschungsZentrum Potsdam, Telegraphenberg D424, Potsdam 14473, Germany

In polyphase materials, strain hardening is often related to the stress transfer from a weak phase to a stronger phase across an interphase boundary. Thus, interphase bonding may be an important aspect of composite deformation. Previous analytical and experimental approaches demonstrate that perfect bonding between rigid inclusions and matrix increases the internal stress in the inclusions substantially. Various models have been used to calculate the stresses within the two phases. Eshelby, estimated the internal stress arising from the misfit between the inclusion and the infinite isotropic matrix, by introducing the concepts of constrained strain (e^C) and equivalent transformation strain (e^T). Further extensions applicable at finite volume fraction of inclusion show that this model is useful for predicting a wide range of composite properties. In this study, we used the Eshelby-Mori-Tanaka (EMT) model (e.g., Eshelby, 1957; Mori and Tanaka, 1973; Murali and Weng, 1993) to describe the plastic flow of two-phase aggregates. The components of internal stresses in the matrix and inclusion are calculated by the EMT model. Based on the end-member flow laws, strain rates in each phase and the mean strain rate of the two-phase aggregates can then be calculated for both creep and constant-rate process. Using experimental data from the literature, we calculated the aggregate strength of anhydrite-halite, plagioclase-clinopyroxene, calcite-halite, calcite-quartz and anorthite-quartz mixtures.The model appears to overestimate the stress concentrations in inclusions and the bulk strengths when the strength contrast between the component phases is relatively high (anorthite-quartz and calcite-quartz aggregates). The agreements can be improved by relaxing stresses arising from misfit strain (e.g. by invoking interface sliding). Anorthite-quartz aggregates show less strengthening when high concentration of water-related defects are present. If these defects are present at grain boundaries, and if they weaken the interfacial bonding, the EMT model would be consistent with the relatively small strengthening observed in experiments. The calcite-quartz aggregates show less strengthening at high pore pressure (or low effective pressure), perhaps because high pore pressure allows the interface to relax stress transferring from weaker calcite matrix to the stronger quartz particles.

T42A-0275 1330h POSTER

Melt-Grown Grain Textures of Eutectic Mixtures of Water Ice with Magnesium- and Sodium-Sulfate Hydrates and Sulfuric-Acid Hydrate Using Cryogenic SEM (CSEM)

Christine McCarthy[1,3] ((503)313-1299; Christine_McCarthy@brown.edu)

Stephen Kirby[1] ((650)329-4847; skirby@usgs.gov)

William Durham[2] ((925)422-7046; durham1@llnl.gov)

Laura Stern[1] ((650)329-4811; lstern@usgs.gov)

[1]U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025, United States

[2]U.C. Lawrence Livermore National Laboratory, PO Box 808, Livermore, CA 94550, United States

[3]Brown University, Geoscience Dept., Providence, RI 02912, United States

Tectonic processes on Europa are influenced by the rheology of ice and icy compounds. The rheology of water ice alloyed with one or more hydrates at planetary conditions is not well known. We investigate grain size effects on ice rheology in Europan eutectic systems. Although much is known about the rheology of pure ice, the addition of other phases can potentially affect the grain textures and rheologies of polyphase mixtures. We make such alloys by cooling and crystallizing aqueous binaries of water with sodium-sulfate hydrate, magnesium-sulfate hydrate or sulfuric acid hydrate. Using a precision cryobath and seeded growth, we can make eutectic mixtures of ice with these hydrates by precisely controlled freezing of these solutions. This method of controlled growth with only small undercooling of the eutectics avoids the problem of rapid, uncontrolled growth that occurs when no seed material is used. A field-emission SEM fitted with a cryogenic prepping station and observation stage permits detailed SEM microscopy on fractured surfaces of these specimens without decomposition under the electron beam. We also use energy dispersive x-ray spectra to distinguish between the ice and sulfate-hydrate phases. We see reproducible eutectic grain textures developed using these methods and observe two types of grain morphologies made evident by differences in surface relief: (1) Large ice grains; (2) Fine eutectoid intergrowths associated with simultaneous growth of ice and hydrate. Grain sizes of the eutectic intergrowths range from approximately 5 to 50 microns, far smaller than developed during free growth of ice from the melt and apparently stable at temperatures near eutectic. We plan deformation tests on such samples to investigate the effects of these fine grain sizes on sample strengths compared to the strenths of cold-pressed mixtures of these same phases. This ongoing work is a first look at these important grain textures in chemical systems that are probably volumetrically important in Europa. Understanding the effects of these complex and intriguing intergrowths on rheology may enable prediction of the behavior of such material under stress and better explain morphological features on Europa's surface.

T42A-0276 1330h POSTER

Investigation Of The Transition To Nonlinear Acoustics In Driven Rods

Donatella Pasqualini[1] (505 667 0701; dondy@lanl.gov)

TenCate Jim[1] (tencate@lanl.gov)

Salman Habib[2] (habib@lanl.gov)

Katrin Heitmann[2] (heitmann@lanl.gov)

Paul Johnson[1] (paj@lanl.gov)

[1]Los Alamos National Laboratory Earth and Environmental Sciences, EES-11, MS D443, Los Alamos, NM 8745, United States

[2]Los Alamos National Laboratory Theretical Division, MS B285, Los Alamos, NM 8745, United States

We have investigated the response of rods of various materials as a function of the driving frequency and drive amplitude near resonance. For linear materials one expects no change in resonance frequency as a function of the drive amplitude, while classical (Landau) nonlinearity manifests itself as a softening (or hardening) in the resonance frequency proportional to the square of the driving amplitude. A softening in the resonance frequency directly proportional to the magnitude of the drive is known to exist in diverse materials, both damaged and undamaged. Our study of multiple materials, carried out over a broad range of internal strains, was aimed at unambiguously establishing the domains of internal strain where these different phenomena exist. As a function of internal strain, our results are consistent with an initial harmonic behavior, followed by the onset of classical nonlinearity, and finally by a frequency shift linearly proportional to the drive amplitude.

T42A-0277 1330h POSTER

α-β Inversion in Quartz From Low Frequency Electrical Impedance Spectroscopy

Nikolai Bagdassarov (+49(0)6879823376; nickbagd@geophysik.uni-frankfurt.de)

Nikolai Bagdassarov, Institut fuer Meteorologie und Geophysik, Universitaet Frankfurt, Feldbergstrasse 47, Frankfurt am Main 60323, Germany

The $\alpha - \beta$ phase transformation in polycristalline quartz has been studied in the pressure range from 0.5 to 2.5 GPa by the use of the low frequency electrical impedance spectroscopy in the range from 10^{-2} to 10^5 Hz. The electrical conductivity (dispersion) obtained at low frequencies (low frequency dispersion or LFD) is due to the grain boundary electric charge transport and electrode polarization. The temperature dependence of LFD exhibits a different slope on an Arrhenius plot $ln(\sigma_{LFD} \times T)$ vs. $1/T$ above and below T_c, where T is the absolute and T_c is the inversion temperature. The point where the slope changes, coincides with the T_c, i. e. the temperature point of α-β inversion in quartz. The obtained inversion temperature T_c from this method compares well with the previous measurements of T_c using DTA and laser interferometry. The LFD data in insulating materials with ionic conductivity due to impurities may be a useful method for characterization of structural displacive phase transitions in quartz-like structures, for example, berlinite $AlPO_4$ and $FePO_4$. The results of this study in SiO_2 demonstrated workability of the LFD method, and the experimentally determined slope of dT_c/dP in the range of from 0.5 to 2.5 GPa is $\sim$ 233.5°/GPa. The activation volume of the electrical conductivity in α phase is several times larger than in β phase indicating that in two phases differing proportion of ion types (alkalis and H^+) may be responsible for the overall electric charge transport along grain boundaries.

T42A-0278 1330h POSTER

Damage and elastic recovery of calcite-rich rocks deformed in the cataclastic regime

Alexandre Schubnel[1,2] (schubnel@geologie.ens.fr)

Jerome Fortin[2] (fortin@geologie.ens.fr)

Luigi Burlini[3] (lburlini@erdw.ethz.ch)

Yves Gueguen[2] (gueguen@geologie.ens.fr)

[1]Lassonde Institute, 170 College Street, Toronto, ON M5S E3E, Canada

[2]Laboratoire de Geologie, Ecole Normale Superieure de Paris, 24 rue Lhomond, Paris 75005, France

[3]ETH Zurich, Sonnegstrasse 5, 8092 Zürich, SWITZERLAND, Zurich 8092, Switzerland

Both compressional and shear wave velocities have been measured during hydrostatic and triaxial experiments in Carrara marble and Solnhofen limestone at room temperature. During brittle-ductile transition, competition between dilatant deformation mechanisms (crack opening and propagation) and compaction mechanisms (pore-collapse, phase transition, pressure-solution) takes place and inhibits microcrack propagation and coalescence. As a consequence, elastic anisotropy due to cracks is less sharp which is an expected result from fracture mechanics. During cataclastic dilatancy, elastic wave velocities decreased quasi-isotropically due to diffuse cracking in the rock. In such a deformation regime, during some deviatoric stress relaxation tests (i.e. blocking the piston movement, so that some of the elastic strain was converted into permanent deformation), we consistently observed a slight but yet non-negligible increase of elastic wave velocities. Elastic recovery was faster when grainsize was smaller and could be complete within a few days. In such conditions, absence of a dead band in the stress space indicates that calcite friction coefficient is very low (0.1-0.2). Microstructure analysis confirms that dilatancy is due to grain boundary sliding, wheras compaction is due to plastic pore collapse and twinning activity of calcite monominerals. Competition between dilatant and compaction mechanisms seems to depend on the presence of fluids and on the strain rate. This experimental result could have important consequences for fault mechanics and is in agreement with macroscopical mechanisms invoked by Rice [1992] to explain the low friction coefficient of certain major faults, such as San Andreas.

T42A-0279 1330h POSTER

Modeling constitutive behavior and compaction localization for high porosity sandstone

Eric R Grueschow[1] (219 548 3513; e-grueschow@northwestern.edu)

John W Rudnicki[1] (jwrudn@northwestern.edu)

[1]Northwestern University, Mechanical Engineering 2145 Sheridan Rd, Evanston, IL 60208, United States

The yield behavior of Castlegate sandstone (28 percent porosity) has been investigated with a variety of compressive loading paths. The initial yield surface was modeled as an ellipse quadrant with an intercept of 190 MPa along the pressure axis and 10 MPa along the differential stress axis. Unload loops during testing were used to model the decay of the shear modulus. Plastic strain behavior was fit using a separate hardening parameter along each axis and non-associated flow. Contrary to experiments, shear localization was predicted to precede compaction localization due to the small aspect ratio of the yield surface. With an aspect ratio nearer to unity, as suggested for a variety of sandstones by recent results from TF Wong et al, the model may predict compaction localization.

T42A-0280 1330h POSTER

Rheological Behaviour and Microstructures of Natural Gypsum Experimentally Deformed in Simple Shear

Valentina Barberini[1] (valentina.barberini@unimi.it)

Luigi Burlini[2] (luigi.burlini@erdw.ethz.ch)

Ernest H. Rutter[3] (e.rutter@man.ac.uk)

Monica Dapiaggi[1] (monica.dapiaggi@unimi.it)

[1]Dipartimento di Scienze della Terra "A. Desio", Universita' degli Studi di Milano, via Botticelli 23, Milano 20133, Italy

[2]ETH Geological Institute, Sonneggstrasse 5, Zuerich 8092, Switzerland

[3]Department of Earth Sciences, University of Manchester, Oxford Road, Manchester M13 9PL, United Kingdom

Gypsum is an important mineral of evaporitic rocks. Evaporites, interlayered within sedimentary sequences, play an important role in localizing the deformation especially in thrust tectonics (Apennines, Zagros, Gulf of Mexico, etc.) since are generally weaker than the other rocks; in some cases the deformation is accompanied by seismicity as in the Northern Apennines extensional systems. In order to determine the rheological and microstructural evolution of gypsum with strain, a set of experiments was performed on natural gypsum samples from Volterra (Tuscany, Italy). Experimental deformation tests were performed at confining pressures up to 300 MPa, at temperatures up to 130°C and at strain rates ranging between 6×10^{-4} and 5×10^{-6} s^{-1}. In order to reach high shear strain values, we deformed gypsum specimens using both the torsion technique in the Paterson apparatus at ETH Zurich (up to $\gamma = 5$) and the sawcut-type assembly at 35° in a Heard-type apparatus at Manchester University (up to $\gamma = 1.2$). All samples have been studied by optical microscopy, to investigate the evolution of the microstructure with strain, and by XRD analysis, to determine whether and to what extent gypsum dehydrated during deformation. In torsion, the shear stress increased with the strain rate and decreased with the temperature. In general a peak stress was reached at γ between 0.5 and 1 (at higher temperatures is reached sooner). After the peak, a various amount of weakening occurred, and mechanical 'steady state' conditions were never reached. Weakening was up to 30-40%. Most of the times the jacket failure ended prematurely the experiment. The microstructure evolved from a deformation microstructure, where grains changed shape according to the bulk strain imposed, into a recrystallization microstructure, where grains were more aequant. Grain boundary migration recrystallization was very effective in resetting the microstructure after γ of 1 or 2. In the samples deformed using saw-cut assembly, the shear stress increased together with confining pressure and strain rate; the temperature increase (up to 90°C) induced a slight decrease in the shear stress, whereas at 130°C the shear stress is higher because bassanite has formed. Regarding the gypsum-bassanite transition, we could observe that it is controlled by temperature and pressure but also by the strain rate and the applied differential stress.

T42A-0281 1330h POSTER

Physical Properties of the Interface between a Mineral Inclusion and the Host Mineral: Monazite Inclusions in Fluorapatite

Daniel E. Harlov[1] (+49 (331) 288-1456; dharlov@gfz-potsdam.de)

Richard Wirth[1] (+49 (331) 288-1371; wirth@gfz-potsdam.de)

Hans-Juergen Foerster[1,2] (+49 (331) 288-1242; forhj@gfz-potsdam.de)

[1]GeoForschungsZentrum, Section 4.1 Experimental Geochemistry and Mineral Physics Telegrafenberg, Potsdam D-14473, Germany

[2]Institute of Earth Sciences, University of Potsdam, Potsdam D-14415, Germany

The (Y+REE) chemistry of many metamorphic and igneous rocks is primarily controlled by phosphate-bearing accessory minerals such as fluorapatite and monazite. Studies of natural fluorapatite (Harlov and Foerster (2002) J Petrol 43, 801) as well as experimental investigations of chlorapatite (Harlov et al. (2002) Am Mineral 87, 245) and fluorapatite (Harlov et al. (2003) Am Mineral, 88, 1209) indicate that Th- and U-poor monazite, as inclusions in apatite, originate from the (Y+REE) budget available in the apatite as a product of mass transfer during fluid-triggered metasomatic alteration. Monazite inclusions form only in metasomatized regions of the apatite which have undergone fluid-induced dissolution-reprecipitation of the original apatite (Putnis (2002), Min Mag 66, 689) generally to an altered composition lower in (Y+REE+Na+Si). Dissolution-reprecipitation also results in a large increase in the micro-porosity throughout the metasomatized areas. The micro-pores provide natural nucleation sites for the growth of monazite inclusions via dissolution-precipitation as well as provide natural pathways for fluid movement and mass transfer throughout these metasomatized regions. TEM investigation of monazite inclusions in fluorapatite crystallized from late stage evolved magmas (Kiruna magnetite-apatite ore deposit, N. Sweden; Harlov et al. (2002) Chem Geol 191, 47) and in fluorapatite metamorphosed under granulite facies conditions in the presence of low H_2O activity fluids (Val Strona traverse, Ivrea-Verbano Zone, N. Italy; Harlov and Foerster (2002) J Petrol 43, 769), indicate that the interface between the monazite inclusion and the fluorapatite host tends to consist of either a 10-50 nm thick, continuous, amorphous layer surrounding the entire inclusion or a series of small, isolated voids, 10 - 20 nm in size, randomly scattered along the contact between the monazite inclusion and the surrounding host. These voids most likely represent fluid pathways. Chemically, the monazite inclusions are characterized by an enrichment in Cl along their rims in contact with the amorphous interface suggesting the presence of Cl-rich fluids. The composition of the amorphous layer consists of elements generally incompatible with the crystal chemistry of Th- and U-poor monazite. These include predominantly SiO_2 followed by MgO, FeO, CaO, and F; in essence all by-product elements not required by the monazite grains during metasomatically induced growth.

T42A-0282 1330h POSTER

The Impact of Olivine-Orthopyroxene Phase Boundaries on Mechanical Absorption: Inferences from Resonant Ultrasound Spectroscopy (RUS)

Jie Lan[1] (608-262-6799; jlan@students.wisc.edu)

Yun-Che Wang[1] (608-265-4498; yunchewang@students.wisc.edu)

Roderic S. Lakes[1] (608-265-8697; lakes@engr.wisc.edu)

Reid F. Cooper[2] (401-863-2160; reid_cooper@brown.edu)

[1]University of Wisconsin-Madison, Program in Mechanics and Materials, College of Engineering, Madison, WI 53606, United States

[2]Brown University, Department of Geological Sciences, Providence, RI 02912, United States

In polycrystalline aggregates having no lattice dislocations within the grains, mechanical absorption is effected by the motion of primary and secondary grain-(or phase-)boundary dislocations, which can be accommodated by chemical diffusion for high-enough temperatures and/or low-enough frequencies. We postulate that the absorption seen in most upper-mantle rock has its origin in such mechanisms. High-homologous-temperature mechanical-absorption experiments on metal aggregates suggest that solid-state phase boundaries are perhaps significantly more effective in absorbing mechanical energy than are grain boundaries [McMillan et al., 2003]. We are engaged in evaluating this effect in mantle aggregates. The experiments reported here examine the ambient-temperature, (shear) RUS response of very-fine-grained (grain size ~5 μm) aggregates of olivine and olivine plus orthopyroxene, with mechanical absorption characterized as a function of volumetric percentage of pyroxene (10, 15, 20 and 30 vol% opx). Aggregates were prepared via controlled-oxygen-activity, vacuum sintering of natural powders; mechanical data were collected on cubic specimens (~125 mm^3). Q_S^{-1} measured for the all-olivine aggregate was $4\mathrm{x}10^{-4}$. Addition of orthopyroxene demonstrated an approximately linear trend with volume percentage, with the 30 vol% opx specimens producing a $Q_S^{-1} = 1.6\mathrm{x}10^{-3}$. There was no discernable discontinuity in the data between 15 and 20 vol% opx, which is the volume-percentage range where pyroxene percolative connectivity is anticipated. K.M. McMillan et al., J. Mater. Sci., 38, 2747-2754 (2003).

T42A-0283 1330h POSTER

Anomalous Thermal Relaxation Induced by the Granular Composition of Berea Sandstone

TJ Ulrich[1] ((775) 784-1685; tju@unr.edu)

Katherine R McCall[1] (mccall@unr.edu)

Robert Guyer[2] (guyer@physics.umass.edu)

[1]University of Nevada, Reno, Dept. of Physics M.S. 220, Reno, NV 89557, United States

[2]University of Massachusetts, Amherst, Dept. of Physics, Amherst, MA 01003, United States

Berea sandstone is a well-studied material known to be nonlinearly elastic. For example, stress-strain measurements for stresses less than 30 MPa are repeatably hysteretic and display end-point memory. In an effort to understand the energy scales of the mechanisms causing nonlinear elasticity in Berea sandstone, we have studied the temperature dependence of sample resonances. Resonances are related to the elastic moduli of a sample, and thus indicate whether or not a sample is hardening or softening as a function of temperature. We find that for temperatures in the range 100 K – 330 K, sample resonance frequencies display significant hysteresis, and several unusual behaviors. Elastic softening is observed as temperature decreases, rather than the expected monotonic increase. In addition, while measurements are repeatable, they are rate dependent on a timescale much longer than the calculated timescale for temperature equilibrium across the sample. It is our hypothesis that this unusual elastic behavior and the slow onset of thermal equilibrium arises from the granular nature of the material. A series of time and temperature dependent experiments was designed and executed to investigate this hypothesis. We will discuss the results of these measurements and their implications for future research.

T42A-0284 1330h POSTER

Microstructural Evolution and Grain Boundary Structure During Static Recrystallization in Synthetic Polycrystals of Sodium Chloride Containing Saturated Brine

Janos Urai[1] (j.urai@ged.rwth-aachen.de)

Oliver Schenk[1] (o.schenk@ged.rwth-aachen.de)

[1]Geologie - Endogene Dynamik, RWTH Aachen, Lochnerstrasse 4-20, Aachen 52056, Germany

The effects of brine on recrystallization processes in halite are well known from nature and experiment. However, the detailed properties of the brine such as morphology, connectivity, diffusivity and their resulting influences on deformation mechanisms are still a matter of debate. This paper presents a microstructural study of dense, statically recrystallizing synthetic polycrystalline halite containing small amounts of brine. We used powders of two different grain size classes: <10 μm and 200-355 μm. The aggregates were compacted to brine-filled porosities less than about 2% and annealed at room temperature, without an external stress field. Coarse-grained samples undergo recrystallization manifested by the growth of large (up to 300 μm) strain-free grains into the deformed old grains. The new grains are frequently euhedral, with mobile grain boundaries moving at rates up to 6 nm/s. Their mobility is interpreted to be high due to the presence of water. Grain surfaces are smooth and the width of the water-rich zones is usually below the resolution of the SEM (less than 50 nm). The evolution of fine-grained samples starts with primary recrystallization and a reorganization of grain boundaries. After this stage which lasts a few hours, normal grain growth effectively stops, and no significant increase of grain size is observed even after several months. Microstructural observations indicate contact healing at the grain boundaries, with dihedral angles ranging between 20 and 110°. We interpret these boundaries to be fluid-free, with the brine residing in a network of triple junction tubes. This system of triple junctions is interconnected and associated with significant permeability. While grain growth is inhibited in the fine-grained samples, after a few hours of annealing exaggerated grain growth is commonly initiated. This is manifested by the growth of large, euhedral grains replacing the fine-grained matrix. These grains also grow with low-index facets and their boundaries are also interpreted to be mobile due to the existence of a water-rich phase.

T42A-0285 1330h POSTER

Grain-Scale Distribution of Aqueous Fluid in Wherlites

Tomohiro Ouchi[1] (81-22-217-7762; ouchitmh@ganko.tohoku.ac.jp)

Michihiko Nakamura[1] (81-22-217-7762; nakamm@mail.tains.tohoku.ac.jp)

[1]Inst. Mineral. Petrol. Econ. Geol., Graduate School of Science, TOHOKU Univ., Aobaku, Sendai 9808578, Japan

Aqueous fluid is one of the most important geological fluids in the Earth's upper mantle. The distribution of aqueous fluid affects not only to rheological properties and seismic attenuation, but also to material transport. Recently, many dihedral angles between minerals and fluids have been reported in order to evaluate connectivity of the fluids in rocks. Watson (1999) proposed the concept of lithologic partitioning of fluids. Grain size also affects the fluid distribution in rocks

T

(Wark & Watson, 2000). Fujii et al. (1986) pointed out that in the Ol - Opx - basalt system, the connectivity of melt through grain edges was interrupted by Opx grains whose dihedral angle with melt is larger than 60 degree. Processes that control the fluid distribution in multi-phase rocks, however, are not fully understood. In this paper, we report preferential distribution of pore-fluid in the phase-boundaries (PBs), which is caused by the fact that migration of grain boundary of the same phases (GBs) dragging the fluid ceases at PB. We have synthesized wherlites with various forsterite (Fo) / diopside (Di) ratios with 1 - 1.5 wt percent water at 1.2 GPa and 1200 deg.C for 3 days and a week. Preference of aqueous fluid for one phase relative to the other, due to the differences in relative mineral-fluid interfacial energies, was not expected, because dihedral angles of Fo-fluid and of Di-fluid are similar at the experimental conditions. Most of the fluid was distributed in the GBs as pore fluids and no fluid inclusion was observed. We classified the pore fluids into two types, those surrounded by GBs (A-type) and by PBs (B-type). Regardless of Fo/Di ratios, proportion of B-type was larger in 1 week runs than in 3 days runs. The 80-90 percent of pore fluids were B-type in the 1 week runs. This result can be explained by the difference in mobility between GB and PB: namely, the pore fluids are dragged by the GBs much more rapidly than the PBs. During grain-growth of multi-phase rocks, pore fluids dragged by the GBs bump against the other mineral surface. This result leads to the implication that the connectivity of fluid in multi-phase rocks would be strongly affected by properties of the triple junctions composed of two different mineral phases and fluid, i.e., dihedral angle, faceting, and spatial distribution.

T42B MCC: Level 1 Thursday 1330h

The Tectonics of Tibet and East Asia Posters

Presiding: **A Meltzer,** Lehigh University**; A L Ault,** Lehigh University

T42B-0286 1330h POSTER

Tectonic Evolution of South China Coastal Provinces Since the Mid-Mesozoic

Lung Sang Chan[1] ((852) 2859-8002; chanls@hkucc.hku.hk); Manuel F Pubellier[2] (33144322273; pubellier@geologie.ens.fr); Phach V Phung[3] ((84-4) 834 5402; pvphach@vista.gov.vn); Medhi Mechti[2] (33144322273; mechti@geologie.ens.fr); Kar F Leung[1] (9289 2705; leungkarfai@graduate.hku.hk); Frederic Ego[2] (33144322273; ego@geologie.ens.fr)

[1]Hong Kong University, Pokfulam, Hong Kong 00000, Hong Kong

[2]Ecole Normale Superieure, 23 Rue Lhomond, Paris, 75 F-75231, France

[3]Hanoi Inst. Oceanography, Nghia Do - Cau Giay, Hanoi 208D, Viet Nam

Structural analysis using satellite imageries and detailed field studies with fault-slip data inversions in critical areas in Guangxi and Guangdong Provinces and Hong Kong reveal a polyphase tectonic history in the southeastern margin of South China, which essentially resulted from the passive reaction of the region to relative motions of neigboring plates during various times. Northward subduction of the Paleo Kula-Pacific plate under South China during Middle Jurassic-Early Cretaceous (Yenshanian arc) created a volcanic arc-back-arc setting with left-lateral shear partitioning along ductile fault zones and occasional left-lateral pull apart basins. Subduction was blocked in the late Upper Cretaceous resulting in shortening of the back-arc region and, reactivation of older faults (e.g . Nanxiong B. in Guangdong & Mirs B. in Hong Kong), followed by orogen collapse with local detachment faulting and narrow molasse basins. The extensional setting continued during Eocene-Oligogene with rifting characterized by the formation of offshore basins and expansion of the continental shelves. The extension was accompanied by left-lateral transtensional basins along NW-trending faults transfer faults (Baise B. in Guangxi), probably influenced by the left-lateral motion of the Red River Fault. The area entered a period of relative tectonic quiescence during early Oligocene-mid Miocene when South China Sea formed, with little stratigraphic record preserved on land. Tectonic exhumation in the Red River region at around 20 m.y. produced NW-trending extensional structures in the region. Southerly extrusion of the Kunming Block in the western part and subduction process in the east during the mid-Miocene-Pliocene resulted in E-W extension in the region, and local N-S compression in southern Tonkin. The westward subduction of the Philippine Plate and the reversal to right-lateral motion on the Red River Fault since 5 m.y.b.p. resulted in right-lateral motion and formation of pull-apart basins along NE-trending faults in the region (e.g. Haifeng B. in Guangdong). [Support from HKU and PROCORE programme is gratefully acknowledged].

T42B-0287 1330h POSTER

A Lower Paleozoic Plate Tectonic Model for the North Qilian Mountains, NW China

Houng-Yi Yang[1] (886-6-2757575 ext. 65421; hyyang@mail.ncku.edu.tw); Chien-Yuan Tseng[1] (yuan1515@yahoo.com.tw); Guo-Chao Zuo[2]; Han-Quan Wu[3]; Zhiqin Xu[4]; Jingsui Yang[4]

[1]Department of Earth Sciences, National Cheng Kung University, 1 Ta-Hsueh Road, Tainan 70101, Taiwan

[2]Gansu Bureau of Geology and Mineral Resources, 206 Houngxing Road, Lanzhou 730000, China

[3]Xi'an Institute of Geology and Mineral Resources, 166 Youyi Road, Xi'an 710054, China

[4]Institute of Geology, Chinese Academy of Geological Sciences, 26 Baiwanzhuang Road, Beijing 100037, China

Abstract The north Qilian mountains are a strongly-lineated Caledonian fold belt. Their mountain ranges, major rivers, fold axes, fault lines, and the spatial distribution of major rock types are all more or less parallel to one another and trend in NWW-SEE direction. The Caledonian plate tectonic structures have still been well preserved despite modifications by the Indosinian and Himalayan crustal disturbances. The north Qilian mountains may be considered as a plate suture zone which sutured the Alashan craton and the central-south Qilian craton in the lower Paleozoic time. This suture zone consists of an active continental margin, a passive continental margin, and an intervening oceanic domain. The southern margin of the Alashan craton was an active continental margin in the lower Paleozoic time, on which continental margin arcs, forearc basin, forearc ridge, and accretionary prism were very well developed. The northern margin of the central-south Qilian craton was chiefly a passive continental margin, but might be active locally in the lower Paleozoic time. The intervening oceanic domain consists of oceanic island arcs, oceanic islands, oceanic ridges, major oceanic floor, and backarc basin ocean floor. A Paleo-Qilian ocean with well-developed oceanic islands and oceanic ridges is presumed to have existed during the late Proterozoic-early Cambrian period. It started to contract in the mid-Cambrian and a Mariana type subduction occurred to have formed an oceanic island arc and a backarc basin. The Andean type subduction followed in the late-Cambrian through the Silurian periods, during which the paleo-Qilian oceanic lithosphere obliquely subducted northward beneath the southern margin of the Alashan craton, converting it from passive to active, and produced continental margin arc, forearc basin, forearc ridge, and accretionary prism, accompanied by the abundant granitoid intrusions. During the same period of time, the northern margin of the central-south Qilian craton had remained largely as a passive continental margin, but the paleo-Qilian oceanic lithosphere might have also subducted southward locally probably in the middle section of the north Qilian mountains. The cessation of the northerly oblique subduction in the late Silurian-Devonian period resulted an arc-continent collision and formed a backarc basin in the eastern section, and also left behind a segment of mid-oceanic ridge, an oceanic island arc, the enclosed remnant ocean, and a backarc basin on the surface of the earth in the western section. In summary, the lower Paleozoic plate tectonic structures of the north Qilian mountains are characterized by the orderly-arranged, well preserved mid-oceanic ridges, oceanic island arcs, accretionary prism, continental margin arcs, and backarc basins, and by the occurrence of Mariana-type and Andean-type subductions, dipolar subduction, and continental reworking and reactivation.

T42B-0288 1330h POSTER

Geochemical and Geochronologic Constraints on the Tectonic Evolution of Southeastern Tibet

Amanda L Booth[1] (650-725-0045; mbooth@pangea.stanford.edu); Peter K Zeitler[2] (peter.zeitler@lehigh.edu); William S.F. Kidd[3] (wkidd@atmos.albany.edu); Joseph L Wooden[4] (jwooden@usgs.gov); Bruce Idleman[2] (bdi2@lehigh.edu); Liu Yuping[5] (cdlyuping@cgs.gov.cn); C. Page Chamberlain[1] (chamb@pangea.stanford.edu)

[1]Stanford University, Dept. of Geological & Environ. Sci., Stanford, CA 94305

[2]Lehigh University, 31 Williams Dr, Bethlehem, PA 18015-3188

[3]31 Williams Dr, ES 315, Albany, NY 12222-0001

[4]U.S. Geol Survey, 345 Middlefield Road, Menlo Park, CA 94025

[5]Chengdu Institute of Mines and Geology, 82 Beisanduan, Chengdu 610082, China

The eastern syntaxis of the Himalayas is expressed in the crust as a rotation of topographic, structural, and lithologic features from dominantly east-west to approximately north-south trends. The axis of rotation of geologic features is coincidental with the high topography of the Namche Barwa region, the exposure of granulite-grade metamorphic rocks, and a major bend in the Tsangpo River. Within the Namche Barwa and subjacent terranes are numerous granitoids that are associated with various events contributing to the tectonic development of southeastern Tibet. Our combined geochronologic and geochemical investigation of these granitoids provides insight into mechanisms of granite formation and helps to constrain the distribution of terranes, timing of assembly, and magmatic processes operative in each. U-Pb SHRIMP ages establish a complex tectonic history for southeastern Tibet, with the presence of at least five magmatic episodes: $\sim$250 Ma, $\sim$120 Ma, 40-70 Ma, 18-25 Ma, and 3-10 Ma. Two lines of evidence suggest that the Namche Barwa massif is a product of local feedbacks between tectonic and surficial processes: 1) exceptionally young zircon ages (2.8–9.5 Ma) for samples collected from the Tsangpo river gorge correspond to a period of rapid denudation; 2) granitoid geochemistry within the massif core reveals high Rb/Sr ratios (>1.4), suggesting a fluid-absent (decompression) melting regime dominates near the core of Namche Barwa.

URL: http://www.ees.lehigh.edu/groups/corners/corners.html

T42B-0289 1330h POSTER

Tectonic Evolution of Mirs Bay Basin in Guangdong, South China

Kar Fai Leung[1] (852-9289-2705; leungkf1@graduate.hku.hk)

Lung S Chan[1] (852-2859-8002; chanls@hkucc.hku.hk)

Manuel Pubellier[2] (33-01-4432-2273; pubellie@geologie.ens.fr)

[1]Dept. of Earth Sciences, The University of Hong Kong, Pokfulam Road, Hong Kong 000, Hong Kong

[2]Laboratoire de Geologie, Ecole Normale Superieure-CNRS, 24 rue Lhomond, Paris 75231, France

Comprehensive structural analysis based on extensive field mapping and LANDSAT TM imageries indicates that several coastal basins in Guangdong Province of South China, including Mirs Bay, Daya Bay and Honghai Bay, are Late Cretaceous pull-apart basins structurally controlled by the NE-trending Linhuashan Fault Zone (LHFZ). A detailed study of Mirs Bay reveals a series of NW-trending high-angle normal faults dipping eastward on the southwestern margin of the basin and a broad NNW-striking fault zone on the eastern margin. The overall basin geometry is comparable to one at the mature stage of a classical pull-apart basin. The basin intersects the 500 m-wide NE-striking Tolo Channel Fault Zone, which displays a positive flower structure probably formed during the oblique subduction of the Paleo-Kula Plate under South China. Detailed study reveals a right-lateral motion postdating an earlier ductile deformation with a sinistral sense of motion along the fault zone. A southward facing thrust sheet exposed at the southern margin of the basin probably represents a detachment that formed during the collapse of the volcanic arc. Analysis of satellite images shows that the two basins located east of Mirs Bay are comparable to ones in the transitional stage of the pull-apart basin model. These three left-stepping basins are evidence for the predominantly strike-slip nature of the LHFZ during the subduction event, which has probably experienced several changes in the sense of motion during the Late Cretaceous through Tertiary in response to changes in the geodynamic setting of the surrounding blocks. (Support from HKU and PROCORE programme is gratefully acknowledged.)

T42B-0290 1330h POSTER

Rising the Himalayan-Tibetan plateau: A 3-D finite element model

Youqing Yang[1] (573-882-4449; yangyo@missouri.edu)

Mian Liu[1] (573-882-3784; lium@missouri.edu)

[1]University of Missouri, 101 Geology, Columbia, MO 65211, United States

More than 2000 km of the Earth's crust has been telescoped by the continuous Indo-Asian collision in the past 50-70 million years. Some models suggest that