

will present also data on Fe-Ni (7.5 at %) and preliminary data on magnesiowüstite to 100 GPa.

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## MR72A MCC: Hall C Sunday 1330h

### Applications of Neutron Scattering in Earth Sciences II Posters (*joint with V, DI*)

**Presiding:** M C Wilding, University of California, Davis

#### MR72A-1016 1330h POSTER

##### Dynamism or Disorder at High Pressures?

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Phase transitions in minerals at elevated temperatures typically involve dynamics as a natural consequence of the increase in thermal energy available to the system. Classic examples include quartz, cristobalite, and carbonates in which the high-temperature, high symmetry phase is dynamically disordered. This disorder has important thermodynamic consequences, including displacement and curvature of phase boundaries (e.g. calcite-aragonite). In other minerals such as clinopyroxenes and anorthite feldspar, the dynamic behaviour is restricted to the neighbourhood of the phase transition. The fundamental question is whether increasing pressure generally suppresses such dynamic behaviour (as in anorthite; Angel, 1988), or not. In the latter case it must be included in thermodynamic models of high-pressure phase equilibria and seismological modelling of the mantle; the potential dynamics and softening in stishovite may provide the critical observational constraint on the presence or otherwise of free silica in the lower mantle.

We have continued to use the lead phosphate as a prototype ferroelastic in which to understand dynamic behaviour, simply because its dynamics and transition behaviour is far better characterised than any mineral. Furthermore, the phase transition is at a pressure where experimental difficulties do not dominate the experimental results. Our previous neutron diffraction study (Angel et al., 2001) revealed that some disorder, either dynamic or static, is retained in the high-symmetry, high-pressure phase just above the phase transition. New neutron diffraction data on the pure material now suggests that this disorder slowly decreases with increasing pressure until at twice the transition pressure it is ordered. Further data for doped material provides insights into the nature of this disorder.

Angel (1988) *Amer. Mineral.* 73:1114. Angel et al (2001) *J PhysC* 13: 5353.

#### MR72A-1017 1330h POSTER

##### Neutron Diffraction Measurements of Changes in Strain Partitioning Between the Phases During Plastic Yielding in Two Phase Composites

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The rocks which make up the lithosphere are predominantly polymineralic aggregates with a range in composition and microstructure that is far too wide for it to be feasible to measure the mechanical properties of every rock-type individually. However, the number of volumetrically important rock-forming minerals is small, and although the range in microstructures is very large, the number of mechanically significant microstructural variables is not. Consequently, in seeking a description of the mechanical properties of such materials, it makes sense to formulate them as a weighted sum of the properties of the constituent mineral phases (as determined independently), in which the weighting is expressed as some function of the significant microstructural variables. For the experimentalist seeking to characterize the mechanical properties of polymineralic materials in this way, it is necessary to be able to determine the contribution which each mineral phase makes to the whole rock properties during the deformation, since it is this which specifies how the properties of each phase should be weighted. Unfortunately, conventional rock deformation experiments are restricted to measuring whole rock properties. The contribution which each phase makes to those properties can only be determined by examining the microstructure of the run products after the experiment, and then only when the strains are sufficiently large for the microstructural changes to be quantifiable. However, by performing the deformation experiments in a neutron beam-line and determining the lattice parameters of the constituent minerals as a function of load, then the contribution which each phase makes to the whole rock properties can be determined not only during the test, but also at very small strains.

A series of room temperature, uniaxial deformation experiments of this kind have been performed on synthetic garnet+halite and calcite+halite samples within the neutron beam-line at the ISIS neutron spallation source, Rutherford Appleton Laboratory, U.K., specifically with a view to examining how the strain partitioning between the phases changes as they undergo plastic yielding. The elastic strain partitioning between the phases prior to plastic yielding falls within bounds specified by the Hashin-Shtrikman analysis of the elastic properties of composite materials. There is no change in this elastic strain partitioning (and hence in the stress partitioning) when the weaker phase (halite in both cases) starts to yield. However, once the second phase also begins to yield (as it did in the calcite+halite experiments), the elastic strain partitioning evolves rapidly such that the stronger phase experiences more elastic strain, that is, more stress, than it would otherwise have done. The technique permits the progress of this load transfer phenomenon to be quantified accurately at bulk strains of less than 1%, and work is in progress to examine how it varies as the spatial distribution of the two phases in the aggregate is changed.

#### MR72A-1018 1330h POSTER

##### Synthesis and characterization using neutron diffraction of the first examples of high-pressure stabilized A- and B-site ordered perovskites

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The perovskite (ABX<sub>3</sub>) structure type is of primary importance technologically as well as in the context of the structure and properties of the deep earth. The transport properties of perovskites are known to be affected by the tilt schemes adopted and by the ordering that might occur on the A- and B-sites. The stability of perovskites depends the relative sizes of A-, B- and X-ions; too small an A cation tends to favor structures where both A and B sites are six-coordinated (pyroxene and ilmenite structure types). The application of pressure, however, can compress the A-X bond distance to a greater degree than the B-X bond distance resulting in an extension of the perovskite stability field into that of the corundum or ilmenite structure type. Although several examples of A-site and B-site ordered materials are known, including those reported in the CaTiO<sub>3</sub>-FeTiO<sub>3</sub> [1] and CaTiO<sub>3</sub>-CaSiO<sub>3</sub> [2] systems respectively, no materials where both ordering

schemes exist together are known. Using bond valence approaches we have predicted the stability of a number of ordered compositions, such as CaCu<sub>3</sub>Ga<sub>2</sub>M<sub>2</sub>O<sub>12</sub> (M=Sb,Nd,Ta,Cr) and synthesized these at around 12 GPa and 1200°C. These materials possess ordering in both the large dodecahedral (A) site and the smaller octahedral (B) sites as demonstrated with diffraction experiments on the D20 beamline at the ILL.

[1] Leinenweber et al. (1995) *Phys. Chem. Minerals* 22, 251 [2] Leinenweber and Parise (1997) *Am. Mineral.*, 82, 475 \*Support for this research provided by NSF and ACS-PRF grants

#### MR72A-1019 1330h POSTER

##### Strategy for Locating Potential Sites for Hydrogen in Minerals

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Neutron diffraction is ideally suited for determining structural positions of hydrogen in minerals and usually the sample is deuterated in order to reduce the incoherent scattering from the hydrogen. In many cases, however, difficulties in location of hydrogen in minerals by neutron diffraction may arise because the there may be too little hydrogen in the sample to detect, the sample cannot be deuterated, there may be deterioration in the quality of diffraction data collected in pressure cells, etc. We propose a strategy that will aid in both the determination of potential docking sites of hydrogen and in the determination of the crystallographic orientation of O-H bonds. The strategy is based on determining the Laplacian of the electron density,  $-\nabla^2\rho(r)$ , of the mineral. As demonstrated by Bader et al. (1984), a mapping of the Laplacian of the electron density distribution yields a series of concentric shells centered at the nucleus of each atom defining where the electron density distribution,  $\rho$ , is alternately locally concentrated and locally depleted, a distribution that reflects the shell structure of the atom. The region where the distribution is positive is called the valence-shell charge concentration (VSCC) of the atom (Bader, 1990). When two atoms combine and a bond is formed, the VSCC of each atom is distorted to one degree or another with the concomitant formation of maxima and minima in the VSCC of each atom. The maxima define domains where  $\rho$  is locally concentrated and the minima define domains where  $\rho$  is locally depleted. It has been found that the number, the location and the relative sizes of the maxima provide a faithful representation of the bonded and non-bonded electron pairs of the Lewis model. The non-bonded electron pairs correspond with sites of potential electrophilic attack. Gibbs et al. (2002) has extended this approach to minerals and predicted potential sites for hydrogen in coesite. The theoretical results agree very well with Koch-Mueller et al.'s (2001) infrared spectroscopic study of H-doped coesite. We present further results here for other high-pressure silicates, including stishovite, periclase, wadsleyite, ringwoodite, akimotoite, and MgSiO<sub>3</sub> perovskite, and compare the results with available experimental data. In general, the correspondence between the theoretical predictions and experimental data is good. We propose that the combined theoretical and experimental approach provides a powerful tool for understanding the role of hydrogen in minerals.

#### MR72A-1020 1330h POSTER

##### Hydrogen Storage in Clathrate Hydrate

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Hydrogen and water are by far the most abundant gas and ice molecules in the solar system, but the mechanism of condensation and retention of hydrogen is not well understood. Direct condensation of pure H<sub>2</sub> requires temperatures < 3 K, far below those of dense,

molecular clouds (10-40 K). We discovered a new crystalline hydrogen clathrate at 180-220 MPa and 240-280 K that contains H<sub>2</sub> to H<sub>2</sub>O molar ratio of 1:2. The new clathrate was successfully quenched to ambient pressure (0.1 MPa) at liquid nitrogen T (77 K), thus demonstrating a great potential for effective hydrogen storage. The new hydrogen clathrate was confirmed by visual observation, Raman spectroscopy, and x-ray diffraction, but neutron diffraction is essential for providing unequivocal determination of hydrogen content and hydrogen positions in the crystal structures. At LANSCE, we have conducted a high-pressure neutron diffraction experiment with an aluminum cell which was half-filled by D<sub>2</sub>O. The deuterium gas was compressed into the chamber to fill the remaining space to the desired pressure. The cell was cooled to the temperature range of 280-80 K at high pressures, and powder neutron diffraction of the hydrogen clathrates were collected in-situ. Rietveld analysis of the diffraction pattern at 180 MPa and 220 K indicates that the new compound crystallizes in a face-centered-cubic unit cell with a = 17.0830.018, in excellent agreement with the archetypal sII clathrate (space group Fd3m). In other clathrates, normally each cage is filled by a single guest molecule (Villard's Rule). In the present hydrogen clathrate, the cages are occupied by clusters of multiple hydrogen molecules to accommodate the large amount of hydrogen. Although hydrogen is a main component in the composition of the gas-giant planets of the outer solar system, the surfaces of their icy satellites show very little hydrogen. The discovery of the low-T, high-P clathrate implies that depending on formation conditions, a significant amount of hydrogen could be stored in solid clathrates hidden in the interiors of the icy satellites.

#### MR72A-1021 1330h POSTER

##### Transformation Behaviour of Cumingtonite: a Neutron Diffraction Study

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Neutron powder diffraction patterns at the HRPD line of neutron spallation facility, ISIS, at the Rutherford Appleton Laboratory can be collected as a function of temperature with exceptionally high quality. This gives the opportunity for full Rietveld refinement of crystal structures and, hence, permits detailed insights to be obtained into structural evolution as a function of temperature. In the present study, this approach has been used to characterise geometrical aspects of and spontaneous strain associated with the *P21/m* to *C2/m* phase transition which occurs with increasing temperature in the amphibole mineral, cumingtonite.

The cumingtonite structure consists of double chains of SiO<sub>4</sub> tetrahedra parallel to the c-axis and linked laterally by Mg and Fe cations which occupy four crystallographically distinct sites M1, M2, M3 and M4. The phase transition which occurs in Mg-rich cumingtonites involves, primarily, distortion of the tetrahedral chains.

Two series of experiments were carried out in the temperature interval 4-570 K, using a natural sample with composition close to Mg<sub>4.6</sub>Fe<sub>2.4</sub>Si<sub>8</sub>O<sub>22</sub>(OH)<sub>2</sub>. This temperature range includes the phase transition itself and order parameter saturation effects at low temperatures. Eleven diffraction patterns were collected at about 40 K steps for 10 hours in order to obtain structural parameters and isotropic temperature factors from full Rietveld refinements. The largest atomic displacements obtained are, as expected, due to rotations of the SiO<sub>4</sub> tetrahedra in the amphibole double chains. Chains that are related by symmetry in the *C2/m* space group become distinct in the *P21/m* structure with a consequent change in the coordination of the cations at the M4 sites. This gives rise to a significant decrease of its average bond length due to the phase transition. The evolution of the unit-cell parameters as a function of temperature was obtained by refinements of diffraction patterns collected every 5 K for twenty minutes. The spontaneous strains obtained from the lattice parameters are found to vary in a manner consistent with a classical second order transition, including order parameter saturation.

#### MR72A-1022 1330h POSTER

##### In-situ Single-Crystal Neutron Diffraction on Hydrogen Related High-Pressure Compounds at High-Pressure

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The hydrogen bonding at high densities is of great interest to Earth sciences, condensed matter physics, planetary astronomy, and energy application.

Using the large size diamond anvil cell (DAC) and recent developed moissanite anvil cell (MAC) [1], we will now be able to conduct high-quality in-situ neutron-diffraction measurements on single crystals at high pressure. This is a unique development of great promise that will open up a wide exciting and completely new area of ultrahigh-pressure research. We have started the neutron diffraction studies on the crystal structures, particularly the hydrogen positions and bond lengths, of the novel solids: D<sub>2</sub>(D<sub>2</sub>O)<sub>6</sub>, DKDP and the methane hydrate CH<sub>4</sub>-H<sub>2</sub>O s-II phase at high-pressures. The results shall reveal the first ever-detailed structural information on such solids, and the hydrogen molecule, under such high-pressure conditions.

Two new phases (sII and sH) of methane hydrates were recently discovered and their unit cell parameters were determined by single-crystal X-ray diffraction, but the crystal structures have not been determined. A single-crystal of the methane hydrate sII phase with a volume of 1.8mm<sup>3</sup> with the excess H<sub>2</sub>O fluid has been grown in a MAC. A series single crystal diffraction peaks have been identified from both X-ray (in X-17C, BNL) and neutron diffraction (in SCD, LANSCE) measurements recently.

Without actual determinations of the hydrogen positions, even the most basic crystallographic information is still uncertain. The in-situ single-crystal neutron diffraction provide a unique way to resolve these novel structures, unequivocally. They will also provide key answers to the behaviors of hydrogen at the extreme pressure conditions.

[1] Xu, J. and H.K. Mao, Science 290, 783, 2000.

URL: <http://www.gl.ciw.edu>

#### MR72A-1023 1330h POSTER

##### Inelastic Neutron Scattering Experiments in Polycrystalline Fayalite

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Transition metals have an important influence on many properties of mantle minerals including their crystalline structure, vibrational modes, and elastic wave velocities; magnetism and thermal excitation of d electrons add important contributions to thermodynamic properties such as the heat capacity. In order to better understand the role of transition metals, we have studied the most abundant Fe-bearing species in the upper mantle, fayalite.

We performed inelastic neutron scattering measurements on polycrystalline fayalite using the LRMECS time of flight spectrometer at IPNS. Experiments were carried out for temperatures from 10 K - 70 K, spanning the paramagnetic, antiferromagnetically ordered, and spin canted phases. Incident energies ranged from 6 meV - 150 meV, allowing us to probe low lying magnetic excitations as well as the multiphonon continuum. At high temperatures, we observed quasielastic magnetic scattering which collapsed to lower energies and the antiferromagnetic zone center below the 65 K Neel temperature. This quasielastic critical scattering is strongly suppressed in the spin canted state,

transforming into a triplet of crystal field excitations at 3.4 meV, 5.9 meV, and 11.5 meV. All three excitations harden and become more intense with reduced temperature, suggesting that a dramatic reduction of crystal symmetry accompanies the spin canting transition. Substantial nonmagnetic scattering is also observed. The phonon density of state is derived and from it the vibrational contribution to the heat capacity, which we compare with existing experimental measurements to mantle temperatures.

#### MR72A-1024 1330h POSTER

##### Applications of Neutron Diffraction Measurements in the Characterization of the Mechanical Properties of Polycrystalline Geological Materials

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Conventional deformation experiments on polycrystalline materials are restricted to measurements of whole sample properties. This is a significant limitation for problems where it is important to know how the deformation is accommodated at the grain scale in order to interpret the experimental results and compare them with theoretical treatments. Such problems include (a) characterizing the properties of elastically anisotropic materials, where it is helpful to know the elastic strain in different lattice directions of the constituent minerals, and how this varies with microstructural variables such as the lattice preferred orientation of those minerals; (b) characterizing the mechanical properties of polymineralic materials in terms of the properties of their constituent minerals, where it is helpful to know the contribution which each mineral phase makes to the whole rock properties during deformation and how this varies with microstructural variables such as the spatial distribution of those phases; (c) calibrating stress-induced crystallographic transformations (e.g., mechanical twinning) where it is important to monitor closely the initiation and progress of the transformation as a function of applied stress.

By performing deformation experiments in-situ within neutron beam-lines and collecting neutron diffraction patterns at different applied loads, the lattice parameters of all the constituent minerals in the sample may be determined as a function of load. All the requisite information required to address the three problems above may then be obtained. The value of such an approach is much diminished if in obtaining the data, compromises have to be made in the quality of the mechanical measurements. This is particularly so if the diffraction data have to be collected either from small samples or from near surface parts of the sample because the interpretation of the mechanical data in such circumstances is notoriously difficult. In this respect, the penetrating nature of neutrons offers significant advantages over X-rays by permitting the interior of samples of the same size as used in conventional rock deformation experiments to be examined.

An experimental procedure for carrying out such experiments has been developed at the ISIS neutron spallation source, Rutherford Appleton Laboratory, U.K., and has been applied successfully to both synthetic and natural samples containing a wide range of rock-forming minerals. The validity of the technique is demonstrated using results from uniaxial deformation experiments performed on olivine + magnesio-wustite samples, and current progress in using it to address each of the three problems outlined above is described.

#### MR72A-1025 1330h POSTER

##### Evidence of differences in structure in forsterite- and enstatite-composition liquids

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Understanding the structure of magnesium silicate liquids is important for interpreting the behavior of liquids produced by melting processes in the Earth and Lunar mantles. Glasses produced from MgO-SiO<sub>2</sub> liquids ranging in composition from forsterite to enstatite have been studied by combined neutron and X-ray diffraction to constrain their structure and related transport and thermodynamic properties.

Neutron diffraction measurements were made on the Glass and Amorphous Materials Diffractometer at the Intense Pulsed Neutron Source, Argonne National Laboratory (ANL). The collected data yield real space pair correlation functions which show the coordination environments for the main structural units in these glasses.

The neutron diffraction data are dominated by the scattering from oxygen so complementary high energy X-ray diffraction data was collected at the 11-ID-C beamline at the Advanced Photon Source at ANL. The X-ray and neutron diffraction data can be combined to eliminate the contribution of Si-O correlations to the pair correlation function and serve to highlight the changes in Mg-O coordination which occur as the composition changes from forsterite to enstatite.

The combined data show abrupt changes in liquid structure close to forsterite composition. This change involves an increase in the Mg-O coordination number and a distortion of the Mg-O unit in forsterite liquids. Such structural changes imply a large change in configurational entropy over a small compositional range. Similar changes in structure are to be expected for the more silica-rich liquids as pressure is increased.

## MR72B MCC: Hall C Sunday 1330h

### Elasticity and Constitution of the Earth's Interior III Posters (joint with G, GP, P, S, T, V, DI)

**Presiding:** D E Smylie, York University; A M Hofmeister, Washington University

#### MR72B-1026 1330h POSTER

##### Analysis of Non-Equispaced VLBI Nutation Measurements

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VLBI nutation measurements offer a unique opportunity to evaluate very small relative motions of the Earth's axis of rotation. This, in turn, can allow us to deduce properties of the Earth's deep interior. However, since VLBI nutation measurements can only be taken when the radio sources being observed are visible, the data is inherently non-equispaced. One of the fundamental problems posed in spectral analysis is the approach one should take when dealing with unevenly spaced sampling - the conventional Discrete Fourier Transform and the Fast Fourier Transform Algorithm for its computation, for example, strictly require a constant interval between successive data points.

It is shown that a Discrete Fourier Transform can be obtained directly from a non-equispaced record by minimizing an objective function which weights the error energy terms in inverse proportion to the square of their standard deviations. The conditional equations have a coefficient matrix of Toeplitz form, and can be solved by any of a variety of linear algebra routines, including the Levinson algorithm. By its nature the fitting matrix can be highly ill-conditioned. This problem can be overcome by re-evaluating the result after setting the reciprocal of the smallest singular values in the fitting matrix to zero using the Singular Value Decomposition technique.

The sampling in the non-equispaced case is modelled by multiplication of the record in the time domain by a Dirac comb with non-equispaced teeth. The effect of this sampling in the frequency domain is to convolve the Fourier Transform of the comb with the true frequency spectrum. Correction of the effect of non-equispaced sampling can be accomplished by convolving the computed spectrum with the frequency domain inverse of the Fourier Transform of the sampling comb. Using synthetic non-equispaced time series the results are shown to compare highly favorably with the traditional approach to non-equispaced data, a polynomial interpolation onto an evenly spaced time grid.

The forgoing methods are used to provide a spectral analysis of a 16 year long VLBI nutation residual sequence in the search for the Retrograde Free Core Nutation and the numerically predicted Prograde Free Core Nutation. The results are then used to obtain a reappraisal of the viscosity of the outer core at the core-mantle boundary by determining the Q factor of the Free Core Nutation resonance.

#### MR72B-1027 1330h POSTER

##### Viscosity of Fe-FeS Liquids at High Pressure

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We present results of high P, T viscosity measurements on Fe-FeS liquids up to 6GPa and 2050K based on synchrotron experiments carried out at the Advanced Photon Source. Radiography was used to image, in-situ, the velocity of a composite probe sphere, consisting of a Pt inner core and a ruby mantle, rising through the sample melt. Viscosity was calculated with a modified form of Stokes' equation using the terminal velocity of the probe sphere. Measurements on pure Fe and on Fe-8.5wt% S liquids show that viscosity is constant along the pressure dependent melting boundary - consistent with a prediction based on semi-empirical formalism. Using the viscosity value along the melting boundary of Fe-8.5wt% S of  $1.6 \times 10^{-2}$  Pa s as the viscosity at the inner core boundary we calculate a new viscosity profile for Earth's outer core.

#### MR72B-1028 1330h POSTER

##### The Upper Mantle: Misunderstood or Just Complicated?

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The advent of space-based geodesy has revealed solid Earth deformation acting on timescales in-between those classically found through seismology and studies of glacial isostatic adjustment (GIA). Maxwell viscoelastic models of the mantle are typically employed to explain long-period Earth response to forcings such as surface load changes and fault rupture, yet the range of well-determined values for upper mantle viscosity now spans several orders of magnitude. Despite the relative accessibility and numerous studies of the upper mantle, a generalized understanding of its response to forcings remains elusive. We present here a study of extreme, ongoing uplift in southern Alaska that requires an upper mantle viscosity of  $3.5 \times 10^{19}$  Pa s.

Using campaign style GPS techniques, we have measured uplift over an area of  $2 \times 10^5$  km<sup>2</sup> with a peak rate of 35 mm yr<sup>-1</sup>. Elastic response to present day surface load changes (melting glaciers) is insufficient to account for these observations. The Little Ice Age, lasting from AD 1200 to 1900, witnessed the largest glacial expansion in southern Alaska since the late Pleistocene and resulted in total surface loading on the order of  $8 \times 10^{15}$  kg. Rapid melting over the past century has removed roughly all of this surface load. We have modeled the response to this cycle, and find that the changes in loading over the last 1000 yrs can explain the magnitude and pattern of the extreme present day

uplift rates, but only when invoking an upper mantle viscosity that is 10-15 times smaller than indicated by classic studies of GIA associated with the Last Glacial Maximum. The range of viscosities that allows our model to match the observed uplift rates is very narrow, suggesting that our study has precisely determined this anomalous upper mantle viscosity.

Our results are roughly in the middle of the range found in other studies that have also tightly constrained upper mantle viscosity. Recent studies have found values as low as  $3.8 \times 10^{17}$  Pa s from postseismic deformation in southern California, and as high as  $0.5 - 1.0 \times 10^{21}$  Pa s from GIA in Fennoscandia. Such a wide range of values is typically explained by inferred lateral variations in the upper mantle, but a trend is building that appears to correlate modeled upper mantle viscosity with the timescale of the forcing involved. Is this an indication that we are overly manipulating the Maxwell viscoelastic model to fit all observations, or is the upper mantle truly such a widely varying region?

#### MR72B-1029 1330h POSTER

##### Geodetic Constraints on Mantle Q at Periods from a Fortnight to 18.6 Years

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Seismic observations have provided numerous constraints on the earth's spherically-averaged mantle anelasticity at periods of tens of minutes and shorter. Meanwhile, post-glacial rebound and other geodynamic studies provide information at periods of a few thousand years and longer. However, constraints at intermediate periods are scarce. Such constraints could be useful in trying to connect the seismic anelastic models with the longer-period visco-elastic behavior.

Here we will describe constraints on anelasticity in this intermediate range of periods as obtained from earth tide and earth rotation observations. We discuss results from: (1) VLBI observations of the monthly and fortnightly tidal variations in rotation rate; (2) satellite laser ranging observations of the 18.6-year tidal variations in the earth's gravitational field; and (3) astrometric and geodetic observations of the 14-month Chandler Wobble period and damping. We find that these observations are consistent with a nearly frequency-independent mantle Q stretching from seismic periods all the way out to the 14-month Chandler Wobble period; but that Q appears to decrease significantly between 14-months and 18.6-years.

#### MR72B-1030 1330h POSTER

##### Earth's Heat Flux and Links to Chemistry

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The global heat budget (or power, Q<sub>tot</sub>) and its change with time are needed for models of planetary evolution. The latest Q<sub>tot</sub> of 44 TW is 2.3 times radiogenic power provided by various chondritic (CI) models. To account for this difference, additional heat sources, processes, and various chemical models have been proposed. Most of the discrepancy originates in methods of estimating Q<sub>tot</sub>. Estimates of the continental flux since 1965 are consistent, and if scaled to represent the whole Earth provide 31-32 TW for Q<sub>tot</sub>, even though the number of heat flux measurements has increased 10-fold. In contrast, post-1965 estimates of the oceanic flux have markedly increased and have become increasingly disparate from the growing database. We develop two independent methods, based on minimal assumptions, to ascertain Earth's mean oceanic heat flux. One model uses mid-cell heat flux to derive oceanic power; the other depicts the oceanic crust as a conveyor belt. The results are congruent, insensitive to uncertainties in the dataset, and indicate that oceanic and continental heat fluxes are equivalent, giving Q<sub>tot</sub> as 311 TW. Various observations coupled with recent time-dependent geodynamic models (Van den Berg and Yuen, EPSL, 2002; Van den Berg et al., PEPI, 2002), suggest that heat production is radioactive and steady-state at present. A graphical method is devised to ascertain proportions of K, U, and Th from Q<sub>tot</sub> and the mass of the mantle. If Earth's bulk silicate composition is like that of enstatite chondrites (EH), radiogenic elements supply all the heat, whereas C1 models require that primordial heat dominates mantle flux. EH, but not C1, meteorites provide sufficient iron for