that the age of the characteristic remanent magnetizations (ChRMs) in Devonian and Mississippian carbonates is primarily related to Laramide orogenesis, with some degree of variability apparent. Certain reservoirs or diagenetic phases have ChRMs of either latest Cretaceous or Tertiary age, have depleted oxygen isotopic signatures indicative of major recrystallization and / or fluid flow, have enriched strontium isotopic signatures, and have relatively large grain size e.g. Keg River Rainbow A reservoir, Wabamun Limestone mesodolomite, Mount Head Waterton dolomite, and the Sulphur Point Rainbow South saddle dolomite. In other reservoirs or diagenetic phases, the ChRM age is more variable (early Jurassic to mid Cretaceous), and the oxygen isotope values are less depleted or show a trend away from postulated sea water values, suggestive of partial rather than complete recrystallization e.g. Turner Valley Moose Reservoir, and Rainbow South fine and medium crystalline dolomites. Finally, specific diagenetic phases from three reservoirs show residual primary (syndepositional) magnetization along with a Cretaceous overprint and isotopic values consistent with postulated Mississippian or Devonian sea water values e.g. Waterton anhydrite, Rainbow South limestone, and Debolt Dunvegan fine crystalline dolomite. From the above results, we suggest that the rock permeability may significantly influence the observed ChRM age. Lithology and facies strongly affect permeability, and the more permeable phases are more likely to have been totally remagnetized. The influx of external basin-derived diagenetic fluids is dependent on permeability, and is evident in the resetting of oxygen and strontium isotopic values. Where primary isotopic values are preserved, there is often evidence for a syndepositional magnetization. As well, the degree of recrystallization - perhaps corresponding with burial depth and fluid type - of the carbonate phases is a strong influence on the observed ChRM: the more recrystallization, the more likely remagnetization. Thus, in the WCSB, the observed ChRM reflects the interplay of the above factors under local reservoir conditions. However, we cannot eliminate the possibility that the latest Cretaceous / early Tertiary ChRMs are due to tectonically-induced fluid flow through the basin.

GP31B-02 0830h POSTER

Preliminary Paleomagnetic Results From Late Cretaceous Volcanic Rocks of Northern Ellesmere Island, Canada

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We report new paleomagnetic results from Late Cretaceous volcanic rocks found on northwestern Ellesmere Island (present-day latitude of 81-82^o N). These rocks, which are preserved in relatively small fault-bounded basins, appear to be younger than the widespread ~95 Ma volcanic rocks of the Strand Fiord Formation, which have yielded paleomagnetic data that indicate latitudinal coherency with cratonal North America (Tarduno et al., 2002). Standard field-drilled samples were collected and all samples were oriented with a Sun compass (due to the high diurnal variation of the field at the sampling site). Initial results of detailed alternating field (5 mT steps to 80 mT) and thermal demagnetization (25 ^{o}C temperature steps, 50-650 ^{o}C) experiments confirm that these rocks are younger than the Strand Fiord volcanics (which formed during the Cretaceous Normal Polarity Superchron); the flows form a stratigraphic section exposed near Audhild Bay that yield reversed polarity characteristic remanent magnetizations, corresponding to chron 33r (or a more recent reversed polarity chron). Further paleomagnetic and rock magnetic data data from these rocks will be presented, as well as the implications of these results for magmatism in the Amerasian basin.

GP31B-03 0830h POSTER

U-Pb Age and Preliminary Paleomagnetism of a Melville Bugt Diabase Dyke, West Greenland, and Implications for Mid-Proterozoic Laurentia-Baltica Reconstructions

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The NW to WNW trending, mildly-alkaline Melville Bugt (MB) dyke swarm represents an enormous volume of fresh, undeformed, olivine-bearing gabbro emplaced over a minimum of 1000 km of strike length across Archean and Paleoproterozoic crust during mid-Proterozoic time. The swarm includes numerous, very large dykes, individually up to at least 150m thick. One dyke that extends for 400 km [1,2] was sampled on the south coast of Nuussuaq, east of Disko Island. Here, the dyke is a 70m wide, near-vertical, medium- to coarse-grained, olivine diabase with well-defined chilled margins. This dyke previously yielded a Rb-Sr WR age of 1645±35 Ma [1] suggesting a unique occurrence of extension-related magmatism in the cratonic interior of NE Laurentia at this time. Abundant, prismatic baddeleyite recovered from the dyke are less than 1% discordant and yield a precise U-Pb age of 1629±1 Ma, interpreted as a more robust estimate of the magmatic crystallization age. Seven paleomagnetic samples from the dated dyke, a satellite dyke and baked host rocks are stably magnetized with a mean direction of D=12°, I=34° (α_{95}=13°) and corresponding virtual geomagnetic pole (VGP) at 38°N, 115°E (dm=15°, dp=9°). This VGP does not average out secular variation and has not been established as primary. The MB remanence is distinct from potential overprints due to nearby West Greenland Tertiary volcanism, and the metamorphic grade of the dyke is low. If the VGP for the MB dyke is primary, then it can be compared with primary Baltica paleopoles of similar age to assess Laurentia-Baltica reconstruction at 1630 Ma. The result derived thereby differs from published reconstructions based on tightly constrained data at 1270-1265 Ma from both cratons. This suggests that Laurentia and Baltica did not drift as a unit throughout the period 1630-1267 Ma, or that the MB VGP is not primary. Further sampling of other MB dykes is necessary to average out secular variation, and to carry out a baked contact test to establish whether the MB remanence is primary. [1] *Kalsbeek and Taylor (1986) Contrib. Min. Pet., 93, 439-448;* [2] *Nielsen (1990) Mafic Dykes and Emplacement Mechanisms, 497-505.*

GP33A CC: 220 C-E Wednesday 1330h

Comparing Magnetic Field Generation in the Earth and Planets Posters *(joint with G, P, T, V)*

Presiding: **M Heimpel,** University of Alberta**; J Aurnou,** University of California, Los Angeles

GP33A-01 1330h INVITED POSTER

Uranus' and Neptune's Unusual Magnetic Fields: a Result of Their Convective Region Geometry

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In an effort to model the Earth's magnetic field, current numerical dynamo models have produced fields dominated by an axial dipole. In these models, the dynamo is usually generated by convection in a thick, electrically conducting fluid shell surrounding a solid conducting inner core. The Voyager II observations of Uranus and Neptune revealed that these planets have non-dipolar, non-axisymmetric magnetic fields, in sharp contrast to the axially dipolar fields of Earth, Jupiter and Saturn. Determining why Uranus and Neptune possess a different field morphology is crucial for the study of these planets' interiors, as well as for understanding the dynamo process in all planetary bodies. Uranus' and Neptune's magnetic fields are most likely generated in their ionically conducting 'ice' shells. Thermal evolution models for Uranus and Neptune (Podolak et al. 1991, Hubbard et al. 1995) suggest that interior portions of these ice shells may be compositionally stably stratified and therefore unable to convect. This suggests that Uranus and Neptune may possess a different convective region geometry from the other planets: their dynamos may be generated in a thin convecting shell surrounding a stably-stratified fluid interior. We have implemented this geometry in the Kuang and Bloxham 3-D numerical dynamo model and found the resulting magnetic fields contain significant non-dipolar, non-axisymmetric structure, similar to those of Uranus and Neptune. Here we examine the dynamical processes causing this field morphology in our numerical models. We discuss the interactions between the convectively stable and unstable shells, and between the velocity and magnetic fields. We also examine the partitioning of energy into the various components of the field (axi- and nonaxisymmetric, toroidal and poloidal) and compare these characteristics to numerical dynamo models operating in thin shells surrounding solid inner cores.

GP33A-02 1330h INVITED POSTER

Compositional Dynamo in Mars and the Moon

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Recent planetary missions to Mars have shown that there once was a very energetic dynamo acting in its liquid core and that this dynamo is now extinct. Two options concerning the timing of this dynamo are highly debated, either early or delayed. The early dynamo has the advantage of being readily explained by thermal convection, that stops when the heat flow across the core mantle boundary drops below that conducted down the adiabatic temperature gradient. The delayed dynamo is more difficult to explain in this framework, since it requires a non monotonic heat flow history. However, such a timing is required to explain lunar magnetism by dynamo action operating between 4 and 3 Ga in its core. Here we explore the possibility of a dynamo sustained by compositional convection, which is known to operate more efficiently than thermal convection in the Earth core. Compositional convection is triggered by the onset of crystallisation of an inner core if the composition of the core is on the iron rich side of the eutectic. The gradual growth of the inner core leads to a change of composition of the outer core, until the eutectic is reached, shutting down compositional convection. Using all available data on the phase diagram of iron alloys, in the range of pressure relevant to cores of Mars and the moon, we determine the conditions that make possible this scenario.

GP

GP33A-03 1330h INVITED POSTER

Earth-Based Measurements of Mercury's Forced Librations in Longitude

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As Mercury follows its eccentric orbit (e ~0.206) with near-zero obliquity, it experiences periodically reversing torques due to the gravitational influence of the Sun on the asymmetric figure of planet. The torques affect the spin angular momentum and cause small deviations of the spin frequency from its resonant value of 3/2 times the mean orbital frequency. The resulting oscillations in longitude are called forced librations because the forcing and rotational response occur with a period dictated by the orbital motion (P ~88 days). The measurement of the forced librations can provide important information about the state and size of the core of Mercury, as demonstrated by Peale (1976). In order to determine the libration amplitude, we implemented a new Earth-based radar technique to measure planetary spins based on a description by Holin (1988,1992). Since May 2002, we have accumulated about a dozen measurements of the spin rate with a fractional uncertainty of 1 part in 10^5. Because the spin rate deviations due to the librations are predicted to be of order 2 arcseconds per day for a solid planet, corresponding to 1 part in 10^4 of the spin rate, our measurements can be used to measure the librational response of the planet. A libration amplitude much larger than that expected for a solid planet would indicate that the mantle is decoupled from the core and would suggest a liquid outer core. This situation would strengthen the possibility of a dynamo in a thin shell at Mercury.

GP33A-04 1330h POSTER

Axial and Equatorial Dipoles in Dynamo Simulations and Implications for Planetary Magnetic Fields

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We present numerical simulations of a self-consistent dynamo model in a rotating spherical shell. Besides solutions where a magnetic dipole aligned with the rotation axis dominates, we also find dipoles in the equatorial plane. A region of the parameter space exists where the two geometries compete, the axial dipole being subcritical and the equatorial dipole supercritical. The equatorial magnetic field is incompatible with a convection flow mainly made of vortices aligned with the rotation axis, and disrupts this flow at low magnetic energy. As a result the equatorial dipole dynamo saturates at a much lower magnetic field amplitude than the axial dynamo. This argument should pertain in planetary dynamos that are governed by strong rotational constraints. It provides an explanation for the comparatively low Elsasser number inferred for Uranus and Neptune.

GP33A-05 1330h POSTER

Planetary Dynamos Controlled by Rotating Parametric Instability

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The existence of rotating parametric instability (RPI) in Earth's fluid core has been interpreted from sequences of paleointensity data from ocean sediments. An RPI can be produced by straining of fluid streamlines in the core from both the semi-diurnal tide and precession of the mantle. Evidence of a relationship between strain in Earth's core and observed growth rate of an RPI, has led to to renewed interest in externally driven planetary dynamos. Reported here is the relationship between planetary magnetic field strength and tidal work done thus providing evidence for RPI in planetary cores.

GP33A-06 1330h POSTER

Magnetic Probing of Core Geodynamics

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To better understand geomagnetic theory and observation, we can use spatial magnetic spectra for the main field and secular variation to test core dynamical hypotheses against seismology. The hypotheses lead to theoretical spectra which are fitted to observational spectra. Each fit yields an estimate of the radius of Earth's core and uncertainty. If this agrees with the seismologic value, then the hypotheses pass the test. A new way to obtain theoretical spectra extends the hydromagnetic scale analysis of Benton [1992; GAFD] to scale-variant field and flow [Voorhies, 2004; JGR-SE, in press]. For narrow scale flow and a dynamically weak field by the top of Earth's core, this yields a generalized Stevenson-McLeod spectrum for the core-source field [Voorhies, Sabaka and Purucker, 2002; JGR-P], and a secular variation spectrum modulated by a cubic polynomial in spherical harmonic degree n. The former passes the tests. The latter passes many tests, but does not describe rapid dipole decline and quadrupole rebound; some tests suggest it is a bit hard, or rich in narrow scale change. In a core geodynamo, motion of the fluid conductor does work against the Lorentz force. This converts kinetic into magnetic energy which, in turn, is lost to heat via Ohmic dissipation. In the analysis at length-scale 1/k, if one presumes kinetic energy is converted in either eddy-overturning or magnetic free-decay time-scales, then Kolmogorov or other spectra in conflict with observational spectra can result. Instead, the rate work is done roughly balances the dissipation rate, which is consistent with small scale flow. The conversion time-scale depends on dynamical constraints. These are summarized by the magneto-geostrophic vertical vorticity balance by the top of the core, which includes anisotropic effects of rotation, the magnetic field, and the core-mantle boundary. The resulting theoretical spectra for the core-source field and its SV are far more compatible with observation. The conversion time-scale of order 120 years is pseudo-scale-invariant. Magnetic spectra of other planets may differ; however, if a transition to non-conducting fluid hydrogen in Jupiter acts as barrier to vertical flow, as well as current, then the shape of the jovi-magnetic spectrum could be remarkably Earth-like.

GP33A-07 1330h POSTER

Varying the core radius ratio in dynamo models: Effect of the initial seed field.

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The onset of dynamo action is studied as a function of the radius ratio and the initial seed magnetic field in self-sustaining 3D spherical numerical dynamo models. Two different initial seed magnetic fields are used; a weak and a relatively strong field. The radius ratio $\chi = r_o/r_i$, where r_i and r_o are the inner and outer core radii, respectively, covers the range $0.1 < \chi < 0.75$. Dynamo onset is characterized using the ratio of the Rayleigh number at the onset of dynamo action and the critical Rayleigh number for convection $Ra_d = Ra'_d/Ra_c$. We find that Ra_d is a decreasing function of χ and also depends on whether the seed magnetic field is weak or strong. In addition the seed field dependence of Ra_d is a function of χ. In some cases the specification of the seed field places a strong constraint on the onset of dynamo action. The seed field dependence of Ra_d seems to be caused by the existence of two different types of dynamos. For strong magnetic field initial conditions at relatively low Ra, we obtain, in many cases, strongly dipolar dynamos that are not accessible with a weak initial magnetic field. Some dynamos initiated with weak seed fields have stable but very weak dipole fields. At higher Ra dynamos obtained using strong or weak seed field merge for long time integrations, in the sense that their features are similar. Thus, moderately supercritical dynamo action can vary strongly with the structure and strength of the magnetic field. We explore the implications of these results for planets with weak observed magnetic fields, such as Mercury, and for polarity reversals of the Geodynamo.

GP33A-08 1330h POSTER

Radius Ratio Effects on Rotating Convection and Dynamo Action

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We present the results of numerical simulations of thermally-driven rotating convection and dynamo action in spherical shells with varying radius ratios, $\chi = r_i/r_o$, where r_i and r_o are the inner and outer shell radii, respectively. We have determined the critical Rayleigh number, Ra_C, over the range $0.10 \le \chi \le 0.92$ and at Ekman numbers $Ek = 10^{-3}$, $3x10^{-4}$ and 10^{-4} for Prandtl number $Pr = 1.0$ in cases with mechanically rigid, isothermal boundary conditions. We find the following fit to our critical Rayleigh number determinations: $Ra_C Ek^{1.16} = 0.21/\chi^2 + 22.4[(1-\chi)/(1+\chi)]^{1/2}$. This fit shows good agreement with the analytical results of Jones, Soward and Mussa (2000). Dynamo calculations have been carried out at weakly supercritical Rayleigh numbers to determine if similar scaling laws can be found for dynamo action. In these calculations $0.10 \le \chi \le 0.75$, $Ek = 10^{-3}$ and 3×10^{-4}, $Pr = 1.0$, and the magnetic Prandtl number is fixed at $Pm = 5.0$. The boundary conditions are mechanically rigid and isothermal and a strong dipolar seed magnetic field initiates each calculation. The onset of dynamo action occurs at roughly 5-10 x Ra_C for $\chi \le 0.15$. However as χ increases, dynamo action onsets at Ra values increasingly closer to Ra_C. For Rayleigh numbers less than twice the value at which dynamo action onsets, columnar convection produces strong axially-aligned dipole dominant magnetic fields. In this weakly supercritical dynamo regime, the ratio of quadrupolar to dipolar Gauss coefficients g_2^0/g_1^0 are fairly insensitive to the value of the radius ratio. However, the octopole-dipole ratio g_3^0/g_1^0 does show a more substantial, although non-monotonic, variation with χ. These results suggest that it may prove difficult to estimate planetary core radius ratio values using satellite determinations of g_2^0/g_1^0.

GP33A-09 1330h POSTER

Instability Growth Rates for Earth's Fluid Core From Paleomagnetic Intensity Data.

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Streamlines of flow in Earth's fluid core, strained elliptically by tidal deformation and sheared by precession of the mantle, will produce rotational parametric instabilities (RPI) in the fluid core as long as dissipation is sufficiently small. By using paleomagnetic intensity data from sedimentary records as a proxy for fluid velocity in the core, we have estimated growths and decays of this instability over the past two million years. Since the contribution from decay appears in both the growth and decay parts of the record, its removal gives a sequence of what we have termed 'pure growths'. Estimates of pure growth, that appear to be consistent across different sites, are directly related to rotational modes that contribute to the instability. Since these modes are determined by core dimensions, analysis of paleointensity data can ultimately tell us the history of the core's development.

GP33B CC: 519 B Wednesday 1330h

Four Decades of Paleomagnetism in Canada II *(joint with T, V)*

Presiding: **M T Cioppa,** University of Windsor**; R Ernst,** Geological Survey of Canada

GP33B-01 1335h INVITED

The Reliability of Paleomagnetic Directions and Poles

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It is generally accepted that several criteria must be met before a paleomagnetic result is deemed reliable, meaning that a paleomagnetic direction faithfully represents the ancient geomagnetic field at the time the rock formed. A set of seven such criteria has often been used in paleopole compilations, resulting in a Q factor that equals the number of criteria satisfied. However, results with Q = 7 are very rare, and usually a minimum Q of 3 has been used as a threshold. In this presentation, we take this type of analysis one step further and examine whether one of the best datasets for any geological interval and any continent is sufficiently robust to believe that the very small cones of confidence are representative of the uncertainty associated with the results. This dataset is for extra-Alpine Europe for the interval 300 - 220 Ma and comprises more than 60 individual pole positions with Q greater than or equal to 3. We classified results according to characteristics that may produce a systematic bias in pole positions, including lithology (volcanics vs. sedimentary rocks), demagnetization code, and quality of age control. We found that Early Permian (280+10 Ma) mean poles based on different subsets can differ by more than 10 degrees, suggesting that a combination of (1) inclination shallowing in sediments, (2) unrecognized present-day field overprints that have not been adequately removed by demagnetization, and (3) underestimation of rock ages, may introduce a bias. All three causes, as well as possible octupole contributions to the total geomagnetic field, would conspire to yield more southerly paleolatitudes for Europe than warranted. This matters greatly for Pangea reconstructions based on paleomagnetic data. With the highest paleolatitude (23 degrees N at Oslo), a Pangea-A type fit is easily possible without any continental overlap, whereas the lowest (12 degrees N) produces a large Gondwana-Laurussia overlap in a Pangea-A type fit, which could lead to the conclusion that a Pangea-B type reconstruction is preferable for the Early Permian. Thus the uncertainty in paleolatitude (more than 10 degrees) far exceeds the small alpha-95 value about the mean pole.