

and images of the radiometric target to estimate dust-fall during the mission. These and other observations will characterize the atmospheric properties at the two landing sites.

P22B MCC: Hall D Tuesday 1330h Impact Cratering Posters

Presiding: J OKeefe, California
Institute of Technology

P22B-0403 1330h POSTER

Multielement geochemical investigations by SRXRF microprobe studies on tektite material: Evidence from the NE-Mexican Cretaceous/Tertiary record

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The K/T boundary is long known as one of a few mass extinctions in earth history. The impact of a big meteorite at the Chicxulub on the northern Yucatan peninsula in Mexico is discussed to have triggered the faunal mass extinction and the rapid change of the palaeoenvironmental conditions near the K/T boundary. Tektite material, especially spherules are explained from many of the sections in correlation to the K/T-boundary event. This rare, glassy or altered material is extremely variable in its major element chemistry, morphology and stratigraphic position in K/T transitions worldwide. For the first time, we perform trace element analysis on tektites from the K/T boundary using synchrotron radiation XRF (SRXRF). Measurements were performed at the Hamburger Strahlungssynchrotronlabor HASYLAB at DESY (Hamburg, Germany) and at the ANKA (Karlsruhe, Germany) with polychromatic and monochromatic excitation, respectively collimating the beam to 15 m by capillary optics. Based on results from SRXRF microprobe determinations, these structures are to be interpreted as mixing of several melts with different chemical composition. The different components may represent melts from different sediment layers and possibly of basement material excavated by the Chicxulub impact. Igneous rocks with andesitic composition in cores at Chicxulub are considered to be impact melt rocks and are correlated mainly by the composition of major elements with the glass spherules found in the surrounding. Our investigations show that it is possible to trace elements with high sensitivity and a high spatial resolution. Some of the samples show clearly zonation and alteration parts, as well as carbonate inclusions, triggered by the Chicxulub impact event. In general, the results from the SRXRF show that the tektite material have different trace element patterns, formed by mixing of melts with different chemical composition derived from different sediment layers and possibly of basement material excavated by the Chicxulub impact. There is no evidence at the moment that there is a homogeneous origin in the sample material or distribution in the investigated sections. The enrichment of Ce in spherules from the Mesa-Juan Perez section indicates a possible origin from the Yucatan carbonate platform generated by the Chicxulub impact event near the K/T-boundary. Area scans from tektite material of the Bochil section show a clearly zonation in the inner part, dominated by Ba and Sr as well as an alteration margin dominated by secondary CaCO₃. Glassy material of the Beloc (Haiti) section is characterised by a homogeneous trace element distribution but shows characteristic differences between Ca-rich and Ca-poor glass. Moreover there is no similarity to material from other sections investigated. A clear differentiation between alteration rims, non-altered material and mixing of different source materials can be shown by space resolved trace element determination in m scale of schlieren structures and inclusions. (see also Schulte et al. this volume)

URL: http://www.uni-karlsruhe.de/~ipg/Prof_mit/Harting/harting.de.html

P22B-0404 1330h POSTER

A Geophysical Study of the Wanapitei Impact Crater

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It has been proposed that a 7 km diameter meteorite impact crater is located entirely within the 9 km Wanapitei Lake, Ontario (Canada). The lake is immediately bounded on its west side by the deformed East rim of the larger Sudbury impact structure. Evidence for the Wanapitei impact include a circular gravity low centered over the northern area of the lake, a concentric pattern of rivers and lakes in the region and features of shock metamorphism in samples of glacial drift found on the southern shores. These samples include boulders of suevite, coesite and glassy breccia. Two of these glassy samples were dated at 37 m.y. based on K/Ar methods, thus the possibility of any relation to the 1.8 billion year Sudbury structure was rejected. The purpose of the present marine seismic and magnetic study is to further constrain the crater's exact location and size. Prominent diabase dikes trending North-West through the region were used as markers indicative of an impact event, as brecciation of the crater floor will attenuate their magnetic anomaly. A ground survey was done to constrain the position and magnetic signature of the dikes passing through the central area of the lake where the crater is suggested to be located. Over 100 km of high frequency seismic data have been acquired over the lake in order to determine the thickness of unconsolidated sediments and map basement structures to better constrain inversion/depth estimates obtained from magnetic field data. Marine magnetics were able to map the late Precambrian dikes from the western shore to a distance of approximately 4-5 km inward. The marine trace resumes on the East side after a small gap over the >100 m depth portion of the lake. It is not known if this discontinuity is due to the fact that the dike's magnetic signature could not be detected with the shallow methods used here. Preliminary results of the survey therefore suggest that the crater is smaller than originally proposed (3-4 km²).

P22B-0405 1330h POSTER

A Sharp Rock-Magnetic Anomaly Characterizes the Cretaceous/Tertiary Boundary

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Cretaceous/Tertiary K/T boundary sections worldwide are characterized by the well-known geochemical anomaly, with high contents of iridium and other platinum group elements related to a large bolide impact. Here we show that the K/T boundary units in southern Mexico present sharp rock-magnetic anomalies. The impact site located in northwestern Yucatan peninsula has attracted attention to the crater and to K/T sections of the circum-Gulf of Mexico and the Caribbean. Results of rock-magnetic and stratigraphic studies of the Bochil and Guayal carbonate sections, located at about 540 and 600 km away from the Chicxulub crater center in southern Mexico are presented. The K/T boundary units present sharp 10 – 20 cm wide rock-magnetic anomalies, with high values of low-field susceptibility and intensities of natural remanent NRM, isothermal IRM and anhysteretic ARM magnetizations. In the Guayal section, low-field susceptibility increases an order of magnitude at the K/T boundary, with two smaller anomalies occurring above and below the boundary unit. NRM intensity increases some 6 times background with a small anomaly below the K/T unit. IRM intensity increases some 10 times background with a small anomaly above the K/T unit. The magnetic signal is associated with low-coercivity

minerals, likely magnetite or iron-rich titanomagnetite with single or pseudo-single domain behavior. Magnetic minerals reflect rapid cooling of high temperature melts generated by the Chicxulub bolide impact.

P22B-0406 1330h POSTER

Chicxulub Impact Simulation Demonstrates Virtually all Observed Crater Features using Shock Damaged Rock Model

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New hydrocode impact calculations of the formation of the Chicxulub structure describe the detailed formation of the overturned flap marking the rim of the transient crater, the broad central uplift with an annular depression of the Moho-outside the central region, the outward collapse of the central peak, and the formation of annular faults and rings outside the radius of the initial transient crater. The structure formed in about 5 minutes.

We use the Mohr-Coulomb-Anderson-Holmquist (MCAH) brittle damage model for rock fracture employing parameters for pristine and fractured rock measured in well understood laboratory experiments. We do not evoke other weakening mechanisms (e.g., acoustic fluidization).

The projectile and the Earth's crust (thickness = 33 km) was modeled with the equation of state of granite and the underlying mantle (depth > 33 km) with the equation of state of dunite. We varied the 20 km/s velocity impactor radius from 5.0 to 7.5 km. For the target rocks, we assume a MCAH rheology with an undamaged internal friction (μ_u) of 0.5 to 1.5, and shock and deformation-induced damaged internal friction (μ_d), of 0.1 to 0.5. The limiting von Mises strength was 2.4 GPa.

The size of the damage zone is a function of integrated strain to failure. The rock damage distribution which is calculated during the impact evolution is approximately hemispherical and has a maximum radius of approximately twice that of the 40 to 55 km radius of the transient crater cavity. We found that the damage distribution determines: 1) the transient cavity dimensions (e.g. depth of penetration), 2) Moho undulations, 3) ejecta lofting angles, 4) the occurrence of a central peak and the detailed dimensions, 5) the number and radii of terrace/slump faults, and 6) the radii and amplitude of final surface undulations (rings) extending outward of the circular faults.

Within an integrated computation, we calculate the projectile penetration through 200 km of atmosphere, the formation of a 50 km deep transient cavity, and the collapse of the transient cavity to form the final crater morphology. Upon impact, the projectile lines the transient cavity and produces an associated melt layer. During the transient cavity collapse, the melt flows near the centerline and forms a thin layer on top of the peak ring. The peak ring forms as a result of the collision of the down ward flowing transient central peak with the nearly vertically launched cavity flow. The radius of the overturned stratigraphy is a measure of the transient cavity size and thus the energy of impact. The terraced zone faulting is initiated during the over folding of the ejecta curtain and proceeds during the slumping of material in front of the ejecta curtain. The slumping is part of the transient cavity collapse flow field. An asymmetric ring fault is formed that terminates the faulting in the terrace zone and also extends downward to the Moho. This ring is often designated as the crater rim. We calculate this diameter to be 150 km. We find ~20 km of central uplift of material above the Moho, and small positive and negative undulations of the Moho near the centerline. Finally a ~200 km diameter exterior topographic high ring is formed which is the result of the secondary impact of ejecta deposited upon the region of damaged surface material.

P22B-0407 1330h POSTER

Chemical speciation in laser-desorption and impact-induced vapor in minerals

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Knowledge of the chemical species in vapors produced by hypervelocity impact on spacecraft impact detectors as well as planetary surfaces have applications ranging from determination of the composition of cosmic dust to the effects on atmospheres and climates of large impactors. Direct study of resulting atomic, molecular and ionic species is best accomplished via mass spectrometry. Pulsed laser desorption can be used to approximate small impacts on solid surfaces. We conducted pulsed laser desorption-ionization experiments using two different instruments: (1) a Caltech-built Time-of-Flight Mass Spectrometer (TOFMS) similar to that on board the Cassini spacecraft and (2) a commercial Matrix Assisted Laser Desorption Ionization TOFMS made by Applied Biosystems (Model, Voyager-DE Pro). Minerals included in this study were calcite, dolomite, gypsum, anhydrite, olivine, kamacite, brucite, serpentine, and pyrrhotite. We collected only positive ions. A nitrogen laser (337 nm wavelength, 4 μ sec pulse width, and 300 mJ) with power density ranging from 1.0×10^7 to 1.3×10^9 W/cm² induced vaporization and ionization. The results can be summarized as: (1) from kamacite and pyrrhotite, only $^{54}\text{Fe}^+$, $^{56}\text{Fe}^+$, $^{57}\text{Fe}^+$ (both kamacite and pyrrhotite) and $^{58}\text{Ni}^+$, $^{60}\text{Ni}^+$ (kamacite only) as well as contamination ions such as $^{23}\text{Na}^+$ and $^{39}\text{K}^+$, $^{41}\text{K}^+$ were observed; (2) Ca-containing minerals (calcite, dolomite, gypsum and anhydrite) produced vapors containing $^{40}\text{Ca}^+$ ions, and, at higher laser power, both $^{40}\text{Ca}^+$ as well as CaO^+ ions; (3) Mg-containing minerals (dolomite, olivine, brucite and serpentine) produced vapors containing MgO^+ ion; (4) for all hydrous minerals, neither H^+ nor H_3O^+ were observed in the vapor; (5) in the vapors of silicate minerals (olivine and serpentine), SiO^+ was observed only from serpentine but not from olivine.

P22C MCC: Hall D Tuesday 1330h Planetary Physics and Geophysics Posters (joint with S, DI, MR)

Presiding: N J Rappaport, Jet
Propulsion Laboratory

P22C-0408 1330h POSTER

The Effect of Pressure on Complex Chemical Equilibria at Low Temperatures.

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Several papers have recently suggested that decomposition of gas hydrates could have played an important role in the geologic history of Mars and Europa. Gas hydrates form in porous sediments under low temperatures and high pressures. The FREZCHEM model was developed to predict chemical equilibria over the temperature range from -70 to +25 °C at 1 atm pressure using the Pitzer equations, which are valid to high ionic strengths. As currently structured, the FREZCHEM model lacks a pressure dependence and gas hydrate chemistry. The objectives of this paper were to (1) add a pressure dependence to the FREZCHEM model as a prelude to incorporating gas hydrate chemistry, and (2) use the model to examine the controversial subject of ice compressibility.

Incorporation of pressure as a driver into the model necessitated a consideration of volumetric properties such as partial molal volumes (volume/mole) or its inverse, density (weight/volume). For the gas hydrate model, key variables and constants that were quantified as functions of pressure and temperature were solubility products, gas solubilities, activity coefficients, the density of aqueous solutions, and the activity of water.

As an example of how pressure affects equilibria, even at a modest pressure of 100 bars, the solubility of gases was increased by about 17%; at 1000 bars, there was about a 400% increase in gas solubility. We used our model and experimental measurements of the freezing points of ice as a function of pressure to estimate the compressibility of ice (Kice). Our estimates of Kice were significantly lower than the Bridgman estimates, but in relatively good agreement with other recent estimates.

P22C-0409 1330h POSTER

Predictable earthquakes?

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Summary: A world wide network has been continuously monitoring the secular change of the Earth's physical processes as recorded on the Earth like the geomagnetic field, the Earth's rotation, etc. The database, which has been collected by the observatories, gives us a chance to make a study of the temporal behaviour of the Earth's magnetic field and to understand the features of these and related phenomena. The long-term magnetic field data show a close qualitative relation both to the secular change of climate and to the variation in the sunspot cycle. On the other hand the fluctuations in the Earth's rotation also show a good correlation to the sunspot and climatic phenomena. This is a very important fact because the decade fluctuation in Earth's rotation depends on those streams in the outer core, which produce the long-term variation in the Earth's magnetic field. This result means that it may not be unrealistic to think of a rather strong interaction between the internal and external magnetic fields of the Earth, and the mechanical implications of this interaction. The outer reason(s) of both solar and the mentioned terrestrial physical processes is one of the possible theories, which is able to include and explain these observed facts. The calculated Earth's orbit, perpendicular to the ecliptic plane (so called Z-direction), and rather the 1st derivative in time of this orbital motion (Z-acceleration) is direct relation to the gravitational perturbations of the (primarily giant) planets. Therefore this time series gives us a chance to investigate the dynamical effects of the giant planets on the Earth. We ended up with quite accurate data sets both in the time series of the Earth's rotation (we used the so called dT-time series which is the measure of the cumulative discrepancy of Earth's rotation in time, and length of day [l.o.d.], which is the 1st derivative in time of dT, and the 1st derivative in time of l.o.d., which is related to the rotational acceleration) and global number of earthquake for this period from published literature which give us a great picture about the dynamical geophysical phenomena.

Methodology: The computing of linear correlation coefficients gives us a chance to quantitatively characterise the relation among the data series, if we suppose a linear dependence in the first step. The correlation coefficients among the Earth's rotational acceleration and Z-orbit acceleration (perpendicular to the ecliptic plane) and the global number of the earthquakes were compared. The results clearly demonstrate the common feature of both the Earth's rotation and Earth's Z-acceleration around the Sun and also between the Earth's rotational acceleration and the earthquake number. This fact might means a strong relation among these phenomena. The mentioned rather strong correlation ($r = 0.75$) and the 29 year period (Saturn's synodic period) was clearly shown in the counted cross correlation function, which gives the dynamical characteristic of correlation, of Earth's orbital (Z-direction) and rotational acceleration. This basic period (29 year) was also obvious in the earthquake number data sets with clear common features in time.

Conclusion: The Core, which involves the secular variation of the Earth's magnetic field, is the only sufficiently mobile part of the Earth with a sufficient mass to modify the rotation which probably effects on the global time distribution of the earthquakes. Therefore it might means that the secular variation of the earthquakes is inseparable from the changes in Earth's magnetic field, i.e. the interior process of the Earth's core belongs to the dynamical state of the solar system. Therefore if the described idea is real the global distribution of the earthquakes in time is predictable.

P22C-0410 1330h POSTER

Thermal Convection in a Fluid Layer Heated From Below and From Within Implication for Planetary Evolution

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Solid-state thermal convection in terrestrial planets interiors is generated by both volumetric heating (radiogenic elements, secular cooling) and heating from below (cooling of the metallic core). However, the relative importance of plumes emanating from both boundary layers and their interaction is still poorly understood. The aim of the present study is to propose a

precise scaling for heat transfer in this heating configuration. Our initial numerical experiments have examined an isoviscous fluid in a Cartesian geometry (both 2D and 3D), since this allows well resolved results to be obtained with modest-scale computation.

A relationship assuming that the top and bottom boundary layers are of equal thickness so that the ratio of temperature differences across them varies in a simple way with the fraction of heating from below produces a correct first order scaling. This leads to the prediction that the temperature of the well mixed interior does not vary with the fraction of heat supplied from below. However, in our numerical experiments, horizontally averaged temperature within the well mixed interior for a given amount of heat sources (basal plus internal) varies with the way heat is distributed between the bottom surface and the interior of the layer by an amount that can be significant on scales of interest for planetary evolution. In addition, systematic differences are observed between 2D and 3D numerical experiments : other variations appear according on the basal heating mode (either flux or temperature can be prescribed). This reflects the dynamics of the interaction of plumes with thermal boundary layers and with each other. We thus propose a more complete scaling based on the influence of a plume on both the boundary layer where it forms and the opposite boundary layer where it produces a stagnation point. This leads to a scaling which predicts that the two boundary layers are of different thickness and allows a more accurate description of temperature in the well mixed interior.

P22C-0411 1330h POSTER

The Dependence of Atmospheric Circulation and Heat Transport on the Planetary Rotation Rate

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Simplified models of planetary climate require a parameterization for the equator-to-pole transport of heat and its dependence on factors, including the planetary rotation rate. Various such parameterizations exist, including ones based on the theory of baroclinic eddy mixing, and on principles of global entropy generation. However, such parameterizations are difficult to test given the limited available observational opportunities. In this study, we use a numerical model to examine heat flux dependencies, as part of a wider study of circulation regime sensitivity to rotation rates and other parameters.

This study makes use of a simplified version of the Geophysical Fluid Dynamics Laboratory (GFDL) "Skyhi" General Circulation Model (GCM). All terrestrial hydrological processes have been stripped from the model, which in the form used here, is adapted from the Martian version of Skyhi. The atmosphere has the gas properties of CO₂, except that it has been made uncondensable. No aerosols or surface ices are allowed. The model surface is flat, and of uniform albedo and thermal inertia. For the simulations presented in this study, the diurnal, seasonal, and eccentricity cycles have been disabled (i.e. the surface and atmosphere receives constant, daily- and seasonally-averaged incident solar radiation). Radiative heating is treated with a band model for CO₂ gas in the thermal and near-infrared bands.

The use of a complex model to examine simplified theory of heat transport requires some justification since it is not necessarily clear that these models (GCM's) provide an accurate emulation of the real atmosphere (of any given planet). In this study, we have intentionally removed those aspects of GCM's that are of greatest concern. Especially for terrestrial GCM's, the hydrologic cycle is a major source of uncertainty due to radiative feedbacks, and cloud coupling to small-scale, convective mixing. For other planets, aerosols are important as radiatively and dynamical active species. Yet an additional cause of error, especially when testing global entropy principles, is the condensation of the atmosphere (as in the case of Mars). We have eliminated all of these concerns in the pure, non-condensable gas atmosphere of our simplified model. Our results will be compared with those of simplified theoretical predictions, and differences discussed.