

P71B-0465 0830h POSTER

Viscosity and Density of Fe-Rich Silicate Melts Relevant to Mars

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Observations from Mars missions have revealed that Mars has had a very active igneous history. While volcanism on Mars is thought to have occurred in the first half of the planets history, recent evidences suggest that Mars may, in fact, still be volcanically active. An improved understanding of the unique geological history and evolution of Mars relies on the development of models for the planets interior and hypotheses regarding the planets formation and evolution. This, in turn, requires a knowledge of the physico-chemical properties of Martian magmas. Of all the properties of interest, viscosity and molar volume are those that most tightly control the dynamics of magmas. Composition of Martian magma has been derived from the composition of the SNC Martian meteorites and it is generally accepted that Martian magma may contain up to 18 wt% of iron. Unfortunately existing models to calculate the physico-chemical properties of Martian magmas are insufficient in at least one important aspect: they are not calibrated for the high iron contents inferred in Martian magmas. In order to rectify this we are developing an experimental program to determine the physico-chemical properties of iron-rich silicate melts relevant to Mars, from which the partial molar properties of both iron components (FeO and Fe₂O₃) will be derived. A first step, compositions in simple iron-bearing systems have been studied. Variable amounts of iron (up to 30 wt%) have been added to the anorthite-diopside eutectic composition, a basalt analogue. The high-temperature viscosities and densities of these melts have been measured in air by concentric cylinder method and using the Pt-based double-bob Archimedeon method, respectively. These measurements suggest a decrease of the viscosity with increasing Fe-content and an increase of the density with increasing Fe-content. In addition, the oxidation state of iron in these samples as a function of temperature was investigated by wet chemistry methods. Preliminary results show that Fe₂O₃-content decreases with increasing temperature (i.e., about 10% within the temperature range investigated, namely between 1300 and 1600°C).

P71B-0466 0830h POSTER

Rayleigh-Taylor Instabilities as a Mechanism for Coronae Formation on Venus

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Coronae are Venusian quasi-circular volcano-tectonic features that range in size from 60km-1000km. They are believed to form over small-scale mantle upwellings. Previous models of corona formation can best match the observed topographic morphology when the upwellings cause the cold, dense lower lithosphere to delaminate, sinking into the mantle and deforming the surface. These complex evolutionary models can predict the general topography of most classes of coronae and can also account for most of the deformation observed around coronae. The size and depth at which these plumes might originate is unclear, however, and the relatively close spacing of coronae is surprising if these plumes originate from deep in the mantle. We here investigate an alternative causal mechanism for coronae based on the idea that gravitational instability of the dense mantle lithosphere could also explain the observed topography and gravity. In Rayleigh-Taylor instability, coupled downwelling and upwelling develops from an initial perturbation in lithospheric thickness. Recent analysis of gravity data suggests that deformation of the crustal layer may play an important role in causing surface topography for coronae and explaining volcano-tectonic deformation features. We examine the role of crustal thickness in forming specific corona morphologies using "basil", a 2D finite deformation program adapted to calculate viscous deformation assuming cylindrical axisymmetry. Instantaneous flow fields are integrated forward in time in order to compute the final strain field. Rayleigh-Taylor instability with imposed cylindrical axisymmetry produces either central depression surrounded by a positive topographic annulus (or vice-versa). If deformation is small we observe that linear growth rates q are the same

for either form of the instability. We find this rate to be maximum at wavenumber $k=2.5$ for rigid boundary models, but the wavelength of deformation lengthens to $k=0.32$ for free-slip boundaries. When a low density crust is added (crust viscosity = mantle viscosity), we observe that surface topography above a central downwelling evolves from an initial central depression to central uplift surrounded by a depressed annular region, and find that the growth rate is now maximum at $k=1.3$ for free-slip boundaries. Adding a low density crust reduces q for all k as the buoyant crustal layer inhibits the growth of the instability. Whether the surface is elevated or depressed depends on crustal buoyancy and crustal viscosity.

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The Role of the Crust and Elastic Lithosphere in the Formation and Evolution of Venusian Type 2 Coronae

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The population of over 500 coronae provide a useful means of probing the structure of the lithosphere on Venus. We examine the admittance signature for all the 37 Type 2 coronae (defined as having less than 50% complete fracture annuli) that are well resolved in the gravity data using both Cartesian and wavelet admittance approaches. We obtain a wide range of elastic thicknesses, from 10 to 85 km. Larger values are derived from bottom loading models, which have not been used in most prior studies of Venus. Estimates of crustal and elastic thicknesses obtained for Type 2 coronae span the range obtained for Venus globally. Neither the thickness of the elastic lithosphere nor the crust appear to control whether Type 1 coronae, Type 2 coronae, or volcanoes form over small scale mantle upwellings. Using the estimated lithospheric properties, loading signature, and geologic characteristics, we examine the factors controlling corona morphology, size, and fracture pattern (Type 1 versus Type 2). Elastic thickness has no correlation with diameter, and thus does not limit the location of coronae. The ratio of the crustal thickness to plume diameter does not control morphology as a function of size, as predicted by a spreading drop model. However, rim only coronae, which are predicted to form via isostatic rebound of crust thickened by delamination are clearly supported by a density interface. This interface could be the basalt-eclogite transition, which would favor delamination and might be more common in the plains. Lithospheric properties for Type 2 coronae vary with topographic morphology. The complex processes that form different morphologies preclude a simple increase in elastic thickness over time. Overall the stage of evolution and formation mechanism account for the majority of variability found in Type 2 corona morphology, and probably for Type 1 coronae as well. The role of a density interface and delamination of the lower lithosphere are likely more important in understanding the evolution of the Venusian lithosphere than variations in elastic thickness.

P71B-0468 0830h POSTER

The Effect of Small Scale Convection on the Uplift Rate of Beta Regio

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Recent evidence suggests that the Beta Regio equatorial highland, generally considered to be a plume-related structure, was emplaced over a relatively short

period of time in the recent Venus history (100 - 400 m.y.). Numerical simulations which use this evidence as a new constraint on geodynamic models show that it is difficult to satisfy simultaneously the constraint on the uplift rate and the constraints on gravity, topography and rheology.

One possible solution is that the effective viscosity contrast between the mantle and the lithosphere does not exceed about 10^4 . If our simple models do capture the basic dynamics of formation of Beta Regio, this value implies that the viscosity of the lithosphere is softer than olivine at subsolidus temperatures and that the Venusian lithosphere may not be much stronger than the terrestrial one.

We investigate another possible interpretation of these results - the effect of small-scale convection which can be developed in the plume or in some other type of upwelling. This can significantly accelerate the uplift rates of Beta Regio and satisfy the timing constraints.

P71B-0469 0830h POSTER

Short-wavelength Contractual Structures in Venusian Fold Belts: Additional Constraints From New Models

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We have previously reported on the development of very short-wavelength (<1 km) contractual topography (VST) in Venusian crustal plateau fold belts, which show structures with wavelengths from ~100 m to >30 km [1, 2]. We simulated the initiation and growth of VST using finite-element models with uniform composition and elasto-visco-plastic rheology undergoing simultaneous cooling and shortening. The models were constrained by Magellan SAR imagery and motivated by the current plume hypothesis for crustal plateau origin [3, 4]. We determined that VST developed only in models with surface temperatures near 1000 K and elevated thermal gradients derived from a halfspace cooling model with initial uniform temperatures of 1200-1400 K. Model rheological profiles indicated a truly viscoplastic character, in which both creep and plastic mechanisms were significant at shallow depths. The resulting topography showed both very short-wavelength components and slightly longer-wavelength, low amplitude folds, as is common in Venusian crustal plateau fold belts.

New simulations with greater spatial extent and higher mesh resolution allow further exploration of the interplay between viscous and plastic processes during VST development. Wider models allow more detailed investigation of viscous folding on the 1-4 km scale. We also employ temperature-dependent thermal conductivity [5] to better represent the thermal behavior of the model crust. The additional insight and expanded parameter space provided by these new models allow us to place improved constraints on the early thermal and mechanical evolution of crustal plateaus.

[1] Ghent, R.R., R.J. Phillips, V.L. Hansen, and D.C. Nunes, Eos Trans. AGU, 83(19), Spring Meet. Suppl., Abstract P21A-05, 2002. [2] Ghent, R.R., R.J. Phillips, and V.L. Hansen, 2001, Eos Trans. AGU, 82(47), Spring Meet. Suppl., Abstract T41B-0865, 2001. [3] Hansen, V.L. and J.J. Willis, Icarus, 132, 321-343, 1998. [4] Phillips, R.J. and V.L. Hansen, Science, 279, p1492, 1998. [5] Hofmeister, A, Science, 283, p1699, 1999.

P71C MCC: Hall D Sunday 0830h Stable Isotopes and the Search for Life in the Solar System II Posters (joint with B, V)

Presiding: S J Mojzsis, University of Colorado

P71C-0470 0830h POSTER

Variable Carbon Isotopes in ALH84001 Carbonates

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The Martian meteorite ALH84001 contains a small amount of carbonate that was deposited from aqueous fluids on the Martian surface approximately 3.9 Ga. McKay et al. (1996) proposed evidence for the existence of life preserved within the carbonate grains. In order to determine the nature of the ancient Martian aqueous system we have combined previously collected oxygen isotopic data with new carbon isotopic measurements performed on the Cameca 6f ion microprobe at Arizona State University. Isotopic measurements were made at high mass resolution with a spot size of 10 microns. The measured carbon isotopic values range from 29.2‰ to 64.5‰ (PDB) with an average uncertainty of ±1.6‰ (1σ). These data agree very well with previous acid dissolution and stepped combustion experiments which range from a δ¹³C of +32‰ to +41‰. As observed with the oxygen isotopic data, the carbon isotopic composition is correlated with the chemical composition of the carbonates. This allows us to establish that the earliest (Ca-rich) carbonates had the lightest carbon isotopic composition while the latest forming (Mg-rich) carbonates had the heaviest carbon isotopic composition. The large range of carbon isotopic compositions measured in this study cannot be explained by previously proposed models. Temperature change or a Rayleigh distillation process caused by progressive carbonate precipitation are insufficient to create the observed carbon isotopic compositions. Furthermore, processes such as evaporation or photosynthesis will not produce large carbon isotopic variations due to rapid isotopic equilibration with the atmosphere. We propose two possible models for the formation of the ALH84001 carbonates consistent with the isotopic data collected thus far. Carbonates could have formed from an evolving system where the carbon and oxygen isotopic composition of the carbonates reflects a mixing between magmatic hydrothermal fluids and fluids in equilibrium with an isotopically heavy atmosphere. Alternatively, carbon enrichment could have occurred as a portion of the carbon dioxide is reduced through abiotic Fischer-Tropsch synthesis or biologically mediated methanogenesis. In this scenario, cooling of the system over time would be necessary to create observed oxygen isotopic values.

P71C-0471 0830h POSTER

An instrument for elemental and isotopic characterization of extra-terrestrial materials

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Samples returned from the Genesis and Stardust missions of NASA's Discovery Program require quantitative analysis at sensitivities unobtainable with present instruments. This has driven development of a new generation of instruments for laser-post-ionization secondary neutral mass spectrometry (laser-SNMS). Construction of a prototype time-of-flight (TOF) SNMS instrument has been completed recently at Argonne National Laboratory (ANL) and testing began in August 2002. This instrument is optimized for laser post-ionization of sputtered neutrals and is capable of locating and analyzing individual sub-micrometer interstellar particles on a sample stage for Stardust or determining elemental concentrations in shallow implants at ultra-trace levels for Genesis. Post-ionization can be accomplished with a variety of laser sources. These include high repetition rate tunable Ti-sapphire lasers for ultra-trace analysis of a single element and two vacuum ultraviolet (VUV) light sources for simultaneous ionization of most atomic and molecular species in the sample. The two VUV lasers are an F2 laser with a fixed wavelength of 157 nm and the self-amplified spontaneous emission free-electron laser (SASE FEL) capable of generating tunable VUV at wavelengths down to 60 nm. Fundamental physical theory of ion sputtering forms the scientific basis of the

approach used to design the instrument. An ion optics design for the instrument was perfected through extensive three-dimensional computer simulations using SIMION software. Realistic sets of photo-ions were calculated using formalisms derived from sputtering theory. Their trajectories in various instrument designs were then traced by SIMION. Finally, results of the simulations were processed to estimate instrument capabilities including resolution and useful yield. This same approach proved accurate and quantitative during tests of an existing TOF SNMS instrument demonstrating the reliability of the simulation method. The completed prototype instrument and results of recent tests will be presented. This work is supported by the U. S. Department of Energy, BES-Materials Sciences, under Contract W-31-109-ENG-38 and in part by a contract from NASA's Office of Space Science's Cosmochemistry Program.

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Oxygenation of Earth's atmosphere and its impact on the evolution of nitrogen-based metabolisms

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The evolution of metabolic pathways is closely linked to the evolution of the redox state of the terrestrial atmosphere. Nitrogen has been an essential biological element since the emergence of life when reduced nitrogen compounds (e.g. ammonia) were utilized in the prebiotic synthesis of proteins and nucleic acids. The nitrogen isotopic composition of sediments has been used to trace the origin of sedimentary organic matter in the rock record. Nitrogen is therefore suitable as a biosignature to trace the emergence of life on Earth or other planetary bodies as well as to follow the subsequent evolution of the biosphere in response to global redox changes. Evidence is strong that biological nitrogen fixation evolved very early in the history of life. The Last Common Ancestor (LCA) on Earth was most likely capable of nitrogen fixation as seen from the phylogenetic distribution of nitrogen-fixing organisms in both the domains of Bacteria and Archaea. Phylogenetic trees plotted with nitrogen-fixing gene (*Nif*) sequences from lineages of Bacteria and Archaea suggest that the *Nif* genes originated in a common ancestor of the two domains. Other phylogenetic analyses have also demonstrated that the paralogous duplication of the *nifDK* and *nifEN* operons, central to nitrogen fixation, predated the divergence of Archaea from Bacteria and therefore occurred prior to the emergence of the LCA. Although the same may be true for denitrification, this metabolic pathway probably did not become dominant until atmospheric pO₂ increased between ~2.4 to 1.9 Ga during the Great Oxygenation Event (GOE). Recent work has shown a general depletion in ¹⁵N content of Archean (pre-2.5 Ga) relative to Phanerozoic (<540 Ma) kerogens. Studies have shown that the distribution of the δ¹⁵N values in kerogens shift from negative values in the Early Archean (from -6 to +6‰ with an average near 0‰) to approximately contemporary positive values (from +2 to +10‰ with an average at +6‰) by the Early Proterozoic. In the anoxic Archean atmosphere, the nitrogen cycle must have been different and the instability of oxidized nitrogen species such as NO₃⁻ under low pO₂ must have limited its availability. Therefore nitrogen fixation probably was the dominant nitrogen-based metabolic pathway during the Archean until the rise of oxygen in the atmosphere in the Early Proterozoic, which resulted in more favorable conditions for denitrification to become the dominant nitrogen-based metabolism. Stable isotopic ratios can be used to detect denitrification (which positively fractionates δ¹⁵N) and nitrogen fixation (which negatively fractionates δ¹⁵N) in K⁺-containing minerals such as biotite and muscovite. In an effort to characterize the transition from the essentially anoxic Archean atmosphere to the modern oxidizing atmosphere, we are investigating sedimentary rocks spanning 2.4 to 1.9 Ga from Rovaniemi, Finland. Structural NH₄⁺ in minerals is characterized by μFTIR spectroscopy. Our new μFTIR measurements of Early Proterozoic metasediments spanning the 2.4 - 1.9 Ga time interval (and focused on the well-represented 2.2 - 1.9 Ga time interval from Rovaniemi) provide a high-resolution record of ammonium content during the GOE as a prelude to future detailed δ¹⁵N measurements by laser mass spectrometry. This work traces the evolution of nitrogen fixation in the biosphere, its response to changes in global redox and provides a tool for the investigation of biosignatures in samples returned from other ancient planetary surfaces.

P71C-0473 0830h POSTER

Isotopic Fractionation in Magnetite-Catalyzed Hydrothermal Carbon Dioxide Reduction Processes

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The occurrence of volatile hydrocarbon species in mid-ocean ridge vent fluids, suggests an inorganic (abiogenic) origin. Since isotopic composition is used as an effective tool for identifying the origin and mechanism of hydrocarbon formation, determining isotopic fractionation during inorganic hydrocarbon formation in hydrothermal experiments is of importance.

An experiment involving carbon dioxide reduction at 400°C, 500bar was carried out in hydrothermal solution equipment. Magnetite (5g, powder), a common product of subsurface metamorphism, was used as a catalyst. Formic acid was used as carbon precursor, as it instantly decomposes to CO₂ and H₂ at elevated temperatures and pressures. The concentration of formic acid in the starting solution (0.5M NaCl + 0.001M HCl) was 189.11 μmol. To monitor reaction progress in solution, separate fluid samples were collected over 1070 hours of reaction, and analyzed for chemical and isotopic species.

Dissolved CO₂, CO, CH₄ and H₂ were observed in aqueous fluid. No formate ion (HCOO⁻) was detected by ion chromatography. The total amount of carbon in solution, however, was always less than that in the fluid at the start of the experiment. At the end of the experiment, 35% of the initial carbon was lost. This suggests formation of other C-bearing species in solution and/or attached to magnetite surfaces. To better understand this, we performed isotopic measurements of dissolved carbon species. The carbon isotopic composition of starting formic acid, is 29.81‰ (V-PDB). The δ¹³C values of CO₂ range from 29.39 to 29.56‰, which are close to that of the starting formic acid. The δ¹³C values of CH₄ and CO are lower than that of starting formic acid, ranging from 35.61 to 39.05‰ and 46.14 to 47.78‰, respectively. During the experiment, the variations of δ¹³C values of CO₂, CH₄, and CO were relatively small.

Data suggest that CO₂ and CO achieved chemical equilibrium, while the amount of CH₄ was much less than theoretical prediction. An additional experiment, using ¹³C-spiked formic acid as carbon source, showed that about 85% of CH₄ was from a carbon phase other than the starting formic acid. The ¹³C/¹²C isotope fractionation between CO₂ and CO, 1000lnα (CO₂-CO), was approximate 17.9±0.7‰, which is smaller than an equilibrium value at 400°C (23‰), suggesting that the entire system was not in isotopic equilibrium.

Surface compositional analysis was conducted using X-ray Photoelectron Spectroscopy (XPS) on magnetite before and after reaction. The concentration of carbon increased by a factor of two following reaction. The carbon spectra from reacted and unreacted magnetite revealed similar functional groups with C-C, C-H, C-O, and O-C=O bonds, however, hydrocarbon compounds containing those functional groups may not be the same. The isotopic analysis showed that the carbon on the magnetite surface has δ¹³C values (-28.8±2.0‰) similar to that of formic acid. The carbon on the magnetite surface, only accounted for the half of lost carbon, suggesting the existence of aqueous hydrocarbons.

A complex mechanism, other than a simple kinetic chain reaction, is implied for magnetite-catalyzed hydrothermal carbon dioxide reduction processes. The detection of long chain, branched and/or aromatic hydrocarbons in aqueous products, is the key to understanding the overall reaction mechanism.

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Apatite-Graphite in Quartz-Pyroxene Rock From Akilia Island; Primary Biogenic Origin Questioned by Oxygen Isotope Evidence.

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Recent field and geochemical research (1) has questioned the claim for the earliest traces of life on Earth (2) in a banded quartz-pyroxene dominated rock from Akilia Island, southern West Greenland. This rock, once considered a banded iron formation (BIF), has now been interpreted as a highly deformed ultramafic igneous rock that has undergone pervasive silica addition. We present oxygen isotope analysis by laser fluorination/mass spectrometry on quartz in a suite of samples from the banded rock on Akilia, as well as similar rocks on Ingnessuurt Island (ca. 10 km south of Akilia). All studied rock samples show $\delta^{18}\text{O}$ values consistently around $+12\text{‰}$ relative to SMOW, which is significantly lower than $\delta^{18}\text{O}$ values of quartz from BIFs of the related amphibolite-facies Isua Supracrustal Belt, ca. 150 km northeast of Akilia. Instead, the data fall in the $\delta^{18}\text{O}$ range of granites and pegmatites. Typical low-grade metamorphic BIFs have quartz $\delta^{18}\text{O}$ of ca. $+20\text{‰}$ and magnetite $\delta^{18}\text{O}$ of ca. $+3\text{‰}$. If one assumes closed-system conditions, isotope mass balance shows that the observed low values for quartz can only be obtained by isotope exchange between quartz and magnetite during metamorphism if an original BIF consisted of at least 50-80 wt % magnetite. This is not consistent with the observed mineralogy; magnetite is a minor mineral phase in the Akilia quartz-pyroxene rock, and some of the layers in the succession are nearly pure quartzites. It is possible, however, that open-system isotope exchange occurred between quartz of an original chert/BIF and a low $\delta^{18}\text{O}$ metamorphic fluid that equilibrated with surrounding igneous rocks. In order to explain the observed low $\delta^{18}\text{O}$ values, a pervasive fluid infiltration and high fluid/rock ratio is required, for a sufficiently long time to allow complete recrystallization of the original quartz grains. Quartz from our Akilia samples does not show any variation in $\delta^{18}\text{O}$, suggesting that if it was ever part of a chert/BIF, then pervasive fluid infiltration would have been required for the entire outcrop. Such fluids would dissolve graphite during recrystallization if not carbon-saturated, and would exchange $\delta^{13}\text{C}$ if carbon saturated. Either way the preservation of carbonaceous inclusions in apatite crystals, that were previously interpreted as biogenic in origin, appears highly unlikely. It could be argued that we have sampled only those parts of the outcrop that were most intensely infiltrated with silica, and our $\delta^{18}\text{O}$ values would simply reflect metasomatic quartz, not the original chert/BIF. However, we obtained $\delta^{18}\text{O}$ values from the exact same location in which the isotopically light carbon was discovered. We conclude that the observed mineralogy and quartz $\delta^{18}\text{O}$ do not favor a BIF protolith. The apatite-graphite associations in the Akilia quartz-pyroxene rock must have formed during or after the last main metamorphic event, and thus are at least younger than ca. 2800 Ma. The graphite inclusions may be metasomatic in origin or may be derived from the introduction of organic carbon during metamorphism. (1) Fedo, C. M., Whitehouse, M. (2002) Science, 296, 1448-1452. (2) Mojzsis, S. J., et al. (1996) Nature, 384, 55-59.

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Graphite as a Biomarker in Rocks of the 3.8 Ga Isua Supracrustal Belt

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Recent petrographic and isotopic studies of graphite and apatite in supracrustal rocks from the 3.8 Ga Isua belt (ISB) in southern West Greenland [1, 2] have shown inconsistencies in interpreting traces of life in the earliest terrestrial sediment record. Isotopically light graphitic carbon, signature of a biogenic origin, has been previously reported from the carbonate-rich Isua rocks [3, 4] that at the time were recognized as sedimentary deposits. However, these carbonate-rich rocks, that provided the basis for original biogenic interpretations, have been shown to have a metasomatic

origin [5] not sedimentary as previously believed. This protolith reinterpretation has highlighted the need for assessment of graphite genesis and related isotopic systematics when using graphite as an ancient biomarker. We have, for this purpose, studied graphite in a suite of samples from the ISB including metacarbonates, turbidites, cherts and banded iron formations (BIFs).

Graphite is relatively abundant (0.1-2 wt. %) in metacarbonate samples, while the abundances of reduced carbon in metasedimentary BIFs and metacherts are below 100 ppm. Petrographic analyses show that graphite in metacarbonates typically associates with Fe-bearing carbonate and magnetite. This mineral association indicates graphite formation in Isua metacarbonates by thermal-metamorphic reduction of carbonate ion, in which the carbonate ion is reduced to form graphite and ferrous iron is oxidized to form magnetite. Carbon isotopic compositions of graphite ($\delta^{13}\text{C}$ ca. -2 per mil) and associated Fe-carbonate ($\delta^{13}\text{C}$ ca. -6 per mil) indicate isotopic equilibrium between these two phases at ca. 500 C, consistent with the metamorphic history of the ISB. Stepped-combustion experiments undertaken on Isua BIFs and metacherts reveal that these sediments contain virtually no graphite, and the small amount of reduced carbon found there represents recent organic contamination. Our stepped-combustion-mass-spectrometry data demonstrate that previous isotopic results on graphite deficient Isua rocks obtained by single step combustion are unreliable.

The proposed biogenic significance of graphite occurring as inclusions in apatite [4] in Isua rocks is not supported by our findings because such graphite-apatite association can only be found in biologically irrelevant metacarbonate rocks. The isotopic systematics of the epigenetic processes responsible for formation of isotopically light graphite enclosed in apatite crystals [4] will be discussed, integrating new ion microprobe isotope data on graphite in apatite and other mineral phases occurring in Isua metacarbonates.

References: [1] van Zuilen, M., Lepland, A. & Arrhenius, G., 2002. Reassessing the evidence for the earliest traces of life. Nature 418: 627-630. [2] Lepland, A., Arrhenius, G. & Cornell, D. in press. Apatite in early Archean Isua supracrustal rocks, southern West Greenland: its origin, association with graphite and potential as a biomarker. Precamb. Res. [3] Schidlowski, M., 1988. A 3,800-million-year isotopic record of life from carbon in sedimentary rocks. Nature 333: 313-318. [4] Mojzsis, S.J., Arrhenius, G., McKeegan, K.D., Harrison, T.M., Nutman, A.P. and Friend, C.R.L., 1996. Evidence for life on Earth before 3800 million years ago. Nature 384: 55-59. [5] Rosing, M.T., Rose, N.M., Bridgwater, D. and Thomsen, H.S., 1996. Earliest part of Earth's stratigraphic record: a reappraisal of the >3.7 Ga Isua (Greenland) supracrustal sequence. Geol. 24: 43-46.

P72A MCC: Hall D Sunday 1330h

Closing the Loop: Remote Analysis of Terrestrial and Planetary Surfaces II Posters (joint with V)

Presiding: L K Fenton, California

Institute of Technology; S W Ruff, Arizona State University

P72A-0476 1330h POSTER

Reduction of Spectral Contrast Between Laboratory and Remote Spectral Observations

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A significant challenge in "Closing the Loop" is the apparent reduction in spectral contrast observed in remotely acquired data compared to laboratory data. Laboratory measurements of many geologic materials (minerals, rocks, soils) show well defined absorption or emission features linked to the fundamental chemistry and structure of the constituents, forming the basis of remote material identification. High spectral resolution observations of natural surfaces exhibit diagnostic absorption features permitting material identification. However, the strength of the absorption features is attenuated relative to laboratory measurements. While this does not affect the identification of materials which have well defined, strong absorptions, it can affect identification of materials that exhibit weak absorptions. Furthermore, models or analytical approaches to quantify the amount of material present will under estimate the true amounts due to this reduction in spectral contrast. A central question is what are the causes of the reduction in spectral contrast and can they be accommodated? Here I assess three possible causes: particle size, texture, and unaccounted for components. Many

laboratory measurements are of well characterized materials of relatively large particle size. Natural surfaces contain a wide range of particle sizes. Theory predicts and many studies have shown that contrast is reduced for small particle sizes. Also, where a range of particle sizes exists, the small particle sizes influence the measured signal greater than their mass fraction in the system. Texture (solid vs. particulate, rough vs. smooth) is well known to affect spectral contrast. This is particularly important for thermal emission measurements where cavities behave as small blackbodies, reducing spectral contrast. Smooth surfaces for vis-near infrared wavelengths have much reduced contrast while contrast is increased at thermal emission wavelengths. Unaccounted for constituents probably play the largest role in reducing spectral contrast. Natural surface contain a number of weathering products which are poorly known, and equally poorly crystalline. The lunar example provides guidance for this where the lunar soils show weakened contrast relative to rocks from which they were derived. Detailed detective work revealed that this was due to agglutinates, free iron metal, and very fine grained shocked plagioclase. An assessment of the relative importance of these spectral reduction processes will be presented and possible effects on the goal of "Closing the Loop" will be discussed.

P72A-0477 1330h POSTER

Application of the machine learning method in an inverse scattering problem

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In the past few years and in the next decade, several ground penetrating radars have been or will be used to explore geological composition of subsurface layers, for example, with the aim to discover water or ice subsurface reservoirs. This paper is focused on the fundamental physical and mathematical theory behind these measurements and numerical analysis of a gradient inverse scattering method for the determination of the geometrical and dielectrical properties of the subsurface layers from received radar signal backscattered by the studied media.

We consider a model of an ellipse-shaped seam surrounded by several layers with different conductivity and a numerically generated backscattered signal (eventually with imposed artificial noise). We discuss several convergence methods (Newton's method, gradient and conjugate gradient methods, Levenberg-Marquardt method, false position method, simulated annealing and threshold accepting) used for the inverse analysis of the backscattered signal. To improve accuracy and efficiency of these methods we use machine learning method. Its procedures decision trees and support vector machines are analyzed with respect to their ability to recover seam's properties from the signal without additional information about the backscattering process.

P72A-0478 1330h POSTER

Development of Rule-Based Autonomous Spectral Analysis Techniques for Planetary Surfaces: Preliminary Results Using Lab Spectra

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Many different regression schemes have been used for autonomous identification of minerals from reflectance and emittance spectra. Most existing analysis procedures focus on direct examination of individual spectra or ad hoc procedures to identify specific types of minerals. These procedures are constrained by limitations of the spectral library used as a training set and are inadequate to deal with the enormous volume of data from current and planned missions. One promising alternative to regression schemes is 'expert systems' or rule-based systems, which is one of the oldest AI technologies. A simple rule-based system consists of three components: a list of facts, a set of rules, and a 'production rule interpreter'. The rule-based approach has several advantages over other classification schemes, including the ability to take advantage of the knowledge of human experts, simple problem diagnosis methods, and a trace facility to explain reasoning. Because of these advantages development of a rule-based system for autonomous spectral identification on planetary surfaces is underway.